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AGROFORESTRY AND ENVIRONMENT

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CHAPTER 1

A BRIEF INTRODUCTION OF THE AGROFORESTRY AND AGRO-ECOLOGY

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ABSTRACT:

Agroforestry is also defined as a dynamic, ecologically based natural resource management system that diversifies and sustains production for increased social, economic, and environmental benefits for land users at all levels through the integration of trees on farms and in the agricultural landscape. Agroecology is the agricultural application of ecological ideas and principles. Agroecology encourages agricultural techniques that reduce emissions, recycle resources, and prioritize local supply chains in order to mitigate climate change.

KEYWORDS:

Agroforestry System, Alley Cropping, Agriculture System, Nitrogen Fixing, Soil Erosion.

INTRODUCTION

Agroforestry refers to a wide variety of land use strategies in which grassland or crops are mixed with trees and bushes. This intentional combination of agriculture and forestry has numerous benefits, including increased yields from staple food crops, improved farmer livelihoods through income generation, increased biodiversity, improved soil structure and health, reduced erosion, and carbon sequestration (Figure.1). Agroforestry practices are especially common in the tropics, particularly in subsistence smallholdings areas, with particular importance in Sub-Saharan Africa. However, due to its multiple benefits, such as nutrient cycle benefits and the potential for drought mitigation, it has been adopted in the United States and Europe [1].

Figure 1: Agroforestry: Diagram showing the overview of the agroforestry (Eco matcher).

Agroforestry is similar to intercropping in certain ways, but it may also entail considerably more complicated multi-strata agroforests with hundreds of species. Nitrogen-fixing plants, such as legumes, may also be used in agroforestry to restore soil nitrogen fertility. The nitrogen-fixing plants may be sown sequentially or concurrently. Taylor's Run farm in Australia uses agroforestry contour planting in conjunction with livestock grazing.

Scientific Foundation

According to Paul Wojtkowski, the theoretical foundation for agroforestry is ecology, sometimes known as agroecology. Agroecology encompasses a wide range of applications, including: improved nutrient and carbon cycling; soil water retention; biodiverse habitats; protection from pest, disease, and weed outbreaks; soil protection from water and wind erosion, and so on. Agroforestry is one of the three major agricultural land-use sciences. Agriculture and forestry are the other two.

There is currently insufficient evidence to identify the entire range of consequences and advantages that various agroforestry approaches may have. The indigenous practices that inspire and form the basis for agroforestry are frequently complex, involving a wide range of species. The most studied agroforestry practices involve a simple interaction between two components, such as simple configurations of hedges or trees integrated with a single crop. There is significant variation in agroforestry systems and the benefits they provide.

Benefits

Agroforestry systems may be more efficient than traditional agriculture and forest production approaches. They may give higher production, social, economic, and environmental advantages, as well as more variety in the ecological products and services delivered. It is important to highlight, however, that these benefits are contingent on effective farm management. This requires selecting the appropriate trees and trimming them on a regular basis, among other things [2].

Biodiversity

Agroforestry systems often have more biodiversity than traditional agriculture systems. In a given region, two or more interacting plant species provide a more complex environment that may sustain a greater range of animals. Agroforestry is beneficial to biodiversity for a variety of reasons. It offers a more diversified environment than a traditional agricultural system because the tree component generates biological niches for a broad variety of creatures both above and below ground. The diversity of life cycles and food chains begins an agro ecological succession that results in functioning agroecosystems that provide sustainability. The variety of tropical bats and birds, for example, may be equivalent to that of natural forests. Although agroforestry systems do not supply as many floristic species as forests and do not have the same canopy height, they can provide food and nesting opportunities. Another benefit to biodiversity is the preservation of fragile species' germplasm. Because agroforests lack natural clear spots, ecosystems are more consistent. Furthermore, agroforests may act as habitat corridors. Agroforestry may assist to maintain biodiversity while also benefiting other ecosystem services.

Plant and Soil Growth

Groundcover plants, such as naturally occurring grasses in agroforestry systems, may buffer depleted soil from erosion. When compared to short-cycle cropping systems, they help to stabilize the soil by increasing cover. Soil cover is an important role in avoiding erosion. Agroforestry may also provide cleaner water by reducing nutrient and soil surface runoff. Trees may assist minimize water runoff by limiting water flow and evaporation, allowing for improved soil infiltration Nutrient absorption can be higher in tree-cropped fields, reducing nutrient loss into streams.

Function in Sustainable Agriculture

Agroforestry systems may offer a variety of ecosystem services that can help maintain agriculture in the following ways. Agriculture product diversification, such as fuelwood, medicinal plants, and diverse crops, improves income security. Increased food security and nutrition through restoring soil fertility, crop diversification, and food crop resistance to environmental shocks. Land restoration is accomplished by decreasing soil erosion and controlling water availability. Crop cultivation and animal grazing are two examples of multifunctional site usage. Farm-grown fuelwood has reduced deforestation and strain on woods. Reduced chemical inputs, for example, as a result of enhanced fertilizer usage, greater insect resistance, and increased ground cover, which decreases weeds.

Growing space for therapeutic plants, for example, in areas where people have limited access to conventional medications Adopting agroforestry and sustainable production techniques, restoring the productivity of degraded agricultural areas, embracing healthier diets, and minimizing food loss and waste are all steps that need to be ramped up immediately, according to FAO's The State of the World's Forests 2020. Agribusinesses must satisfy their pledges to deforestation-free commodities chains, and enterprises that have not committed to zero-deforestation should do so[3].

Carbon sequestration is an essential ecosystem service. Agroforestry methods may enhance carbon stocks in soil and woody biomass. Trees in agroforestry systems, like trees in new forests, can recuperate part of the carbon lost when old forests are chopped down. They also sell extra meals and goods.

The rotation age and utilization of the resultant products are critical variables in determining how much carbon is stored. By supplying forest products, agroforests may alleviate strain on primary forests. Agroforestry approaches may help achieve a variety of environmental objectives, including: Reduction of odors, dust, Green space and visual appeal. Wildlife habitat enhancement or preservation.

Response to Climate Change

Agroforestry may considerably contribute to climate change mitigation while also providing adaptation benefits. A case study in Kenya found that agroforestry adoption enhanced carbon storage while also increasing livelihoods among small-scale farmers. In this scenario, preserving the variety of tree species, particularly land usage and farm size, is critical. In recent years, impoverished smallholder farmers have resorted to agroforestry to adapt to climate change. A survey of over 700 families in East Africa conducted by the CGIAR research program on Climate shift, Agriculture, and Food Security (CCAFS) indicated that at least 50% of those households had started planting trees, a shift from previous practices. In addition to their traditional crop, the trees were planted with fruit, tea, coffee, oil, fodder, and medicinal goods. Agroforestry, along with the adoption of better crop types and intercropping, was one of the most often used adaptation tactics.

Applications

In Zambia, research using Faidherbia albida revealed maximum maize yields of 4.0 tonnes per hectare when utilizing fertilizer and intercropping with these trees at densities ranging from 25 to 100 trees per hectare, compared to average maize yields of 1.1 tonnes per hectare in Zimbabwe. The Quesungual Slash and Mulch Agroforestry System (QSMAS) in Lempira Department, Honduras, is a well-studied example of an agroforestry hillside system. Historically, this area was utilized for slash-and-burn subsistence cultivation. The exposed soil was washed away by severe seasonal floods, leaving infertile barren soil exposed to the dry season. Farmed hillside sites had to be abandoned after a few years, and fresh woodland was burnt. The Food and Agriculture Organization of the United Nations (FAO) assisted in the implementation of a system that incorporates local knowledge and consists of the following steps: Thin and trim the secondary forest on the hillside, leaving individual valuable species, particularly nitrogen-fixing plants. They aid in soil erosion control, soil moisture retention, shade, and the addition of nitrogen-rich organic matter in the form of litter.

Rows of maize should be planted. This is an old-fashioned local crop. Plant beans and harvest from the dried plant. The maize stalks provide as an excellent support system for the climbing bean plants. Bean is a nitrogen-fixing plant, therefore it contributes to the introduction of additional nitrogen. During this season, pumpkins may be planted. The big leaves and horizontal growth of the plant give extra shade and moisture retention. It does not compete for sunlight with the beans since the latter grow vertically on the stalks. Rotate the crop every few seasons by grazing cattle, enabling grass to develop and contributing organic matter and nutrients (manure) to the soil. By grazing around the trees, the cattle hinder entire replanting. Crops are purposefully grown beneath tree canopies in a gloomy setting using shade treatments. Understory crops tolerate shade, while over story trees have rather open canopies. Coffee cultivated in the shade is an obvious example. This approach lowers weeding expenses while improving coffee quality and flavor. Woody perennials are used as a cover crop in crop-over-tree systems. Small shrubs or trees cut to near ground level are used for this. The goal is to improve soil nutrients and/or decrease soil erosion [4].

Crop strips alternate with rows of closely spaced tree or hedge species in alley cropping. Before sowing the crop, the trees are usually trimmed. To give nutrients, chopped foliage material, such as that from Alchornea cordifolia and Acioabarteri, is strewn over the crop area. In addition to providing nutrients, hedges act as windbreaks and help to prevent erosion. In tropical North and South America, many Inga species such as I. Edulis and I. Alley cropping has been done with oerstediana. Intercropping is beneficial in Africa, especially in terms of increasing maize yields in the Sub-Saharan area. The nitrogen-fixing tree species Sesbania sesban, Tephrosia vogelii, Gliricidiasepium, and Faidherbia albida are used. In one ten-year experiment in Malawi, maize/corn yields averaged 3.3 metric tons per hectare (1.5 short tons/acre) when the fertilizer tree Gliricidia (G. sepium) was used on land with no mineral fertilizer, compared to 1 metric ton per hectare (0.45 short tons/acre) in plots without fertilizer trees or mineral fertilizers. Alley cropping naturally controls weeds by providing mulch and shade.

Taungya is a Burmese-born system. Trees are tiny and widely spaced in the early phases of an orchard or tree plantation. Instead of expensive weeding, the unused area produces extra productivity and cash. More complicated taungyas grow numerous crops in between the trees. As the tree canopies increase and the quantity of sunshine reaching the ground decreases, the crops become more shade tolerant. Thinning may help to keep sunlight levels stable. Since time immemorial, itteri agroforestry methods have been employed in Tamil Nadu. They include the intentional management of multifunctional trees and shrubs planted in close proximity to herbaceous species. They are often found along village and country roads, minor valleys, and field borders. Bamboo-based agroforestry systems (Dendrocalamusstrictus + sesame-chickpea) have been researched for increasing production in central India's semi-arid tropics.

African agroforestry

The "Global Ever Greening Alliance" announced an initiative in 2019 to prevent climate change via agriculture. The goal is to remove carbon from the atmosphere. The regenerated area should sequester 20 billion tons of carbon per year by 2050. Although initially a tropical agronomy idea, the USDA identifies five temperate region agroforestry uses. Temperate climates may also benefit from alley cropping (shown above). Strip cropping is similar to alley cropping in that trees and crops alternate. The distinction is that the trees in alley cropping are in a single row. Area cropping involves planting trees or plants in a broad area. As with alley cropping, the goal might be to deliver nutrients to the crop in the form of leaves. Strip cropping allows trees to be solely productive, supplying fruits, nuts, and so on, while also sheltering neighboring crops from soil erosion and damaging winds.

Systems based on fauna

Trees may aid wildlife. The most prominent example is silvo pasture, which involves cattle, goats, or sheep grazing on grasses grown beneath trees. In warmer regions, the animals are less agitated and gain weight quicker when they graze in a cooler, shaded habitat. Tree or shrub leaves may also be used as feed. Other animals are supported by similar systems. Living and grazing in a forest habitat benefits deer and pigs, particularly when the tree forage sustains them. Trees provide shade for fish ponds in aqua forestry. In many circumstances, the fish consume tree leaves or fruit. Pigs and bulls are widely kept in Spain and Portugal, as seen by the dehesa or montado method of silviculture [5].

A living fence might consist of a dense hedge or fence wire stretched between live trees. In addition to limiting human and animal mobility, living fences provide habitat for insect-eating birds and, in the case of a border hedge, decrease soil erosion. Riparian buffers are strips of permanent vegetation found along or near active watercourses or in ditches where runoff collects. The goal is to protect dirt and fertilizers from polluting the water. Windbreaks lessen the velocity of the wind over and around crops. This boosts yields by reducing crop drying and/or avoiding crop toppling in heavy wind gusts.

Four-fifths of Swiss Hoch-stammobstgärten (traditional orchards with towering trees) have vanished since the 1950s. An agroforestry strategy with hochstamm trees and annual crops was trialled here. Walnut (Juglans regia) and cherry (Prunus avium) trees were examined. Forty to seventy trees per hectare were advised, with yields reducing somewhat as tree height and foliage increased. However, overall yield per area is proven to be up to 30% greater than in monoculture systems. Another set of tests involves growing Populus tremula for biofuel at 52 trees per hectare and with grazing pasture alternated every two to three years with maize or sorghum, wheat, strawberries, and fallowing between rows of modern short-pruned & grafted apple cultivars and apples, with bushes in the rows with tree.

Though the formal scientific study of agroforestry is relatively new, beginning in the twentieth century with ethnobotanical studies conducted by anthropologists, agroforestry has existed for centuries, practiced by local and/or indigenous communities that lived in close relationship with forest ecosystems. California's indigenous peoples burnt oak and other environments on a regular basis to keep a 'pyro diversity collection model' alive. This strategy resulted in increased tree health and environment in general.

Agroecology is a branch of ecology that examines ecological processes in agricultural production systems. Applying ecological ideas to agroecosystem management may lead to novel management techniques. A science, a movement, or an agricultural technique may all be referred to by the phrase. Agroecologists research a wide range of agroecosystems. Although some use the term especially for alternative agriculture, the area of agroecology is not related with any one form of farming, whether organic, regenerative, integrated, or industrial, intense or vast.

DISCUSSION

The OECD defines agroecology as "the study of the relationship between agricultural crops and the environment." Agroecology, according to Dalgaard et al., is the study of the interactions between plants, animals, people, and the environment within agricultural systems. Francis et al. utilize the term in the same manner, but believe it should be limited to food production. Agroecology is a comprehensive strategy to reconciling agriculture and local people with natural processes for the benefit of both nature and humans [6].

Agroecology is by definition interdisciplinary, including disciplines such as agronomy, ecology, environmental science, sociology, economics, history, and others. Agroecology employs various sciences to comprehend ecosystem elements such as soil properties and plant-insect interactions, as well as social sciences to comprehend the effects of farming practices on rural communities, economic barriers to developing new production methods, and cultural factors influencing farming practices. Productivity, stability, sustainability, and equitability are some of the system features of agroecosystems that have been examined. Agroecology does not have a fixed size; it may vary from a single gene to an entire population, or from a single field on a local farm to global systems.

Wojtkowski distinguishes natural ecosystem ecology from agroecology in that economics play no role in natural ecosystems, whereas in agroecology, which focuses on organisms within planned and managed environments, human activities, and thus economics, are the primary governing forces that ultimately control the field. In his 2002 book, Wojtkowski addresses the use of agroecology in agriculture, forestry, and agroforestry.

Varieties

In a 2003 conference report, Buttel outlines four types of agroecology. The primary variations he labels ecosystem agroecology, which he argues stems from Howard T. Odum's ecosystem ecology and focuses less on rural sociology, and agronomic agroecology, which he describes as being focused towards producing more sustainable agricultural knowledge and practices. Buttel's third long-standing variant is ecological political economy, which he characterizes as criticising agricultural politics and economics while emphasizing radical politics. Buttel names the smallest and most recent variety agro-population ecology, which he says is very similar to the first but is derived from ecology primarily based on more modern theories of population ecology such as population dynamics of constituent species and their relationships to climate and biogeochemistry, as well as the role of genetics.

Dalgaard et al. distinguish between two points of view: what they refer to as early "integrative" agroecology, such as the work of Henry Gleason or Frederic Clements. In the second iteration, Hecht is credited with coining the term "hard" agroecology, which they define as more reactive to environmental politics yet founded in quantifiable units and technology. They use the term "soft" agroecology to describe attempting to quantify agroecology in terms of "soft capital" such as culture or experience. People may use the word agroecology to refer to a science, movement, or practice. In the 1990s, using the term as a movement became increasingly prevalent, particularly in the Americas. Miguel Altieri, whom Buttel classifies as a "political" agroecologist, has written extensively in this regard. He has used agroecology in sustainable agriculture, alternative agriculture, and organic agriculture [7].

History Overview

The history of agroecology varies depending on whether you refer to it as a body of philosophy or a technique of practice, since many indigenous communities throughout the globe have historically utilized and continue to employ methods that we would today consider applying agroecology knowledge. Maori, Nahuatl, and many other indigenous peoples are examples. Prior to the colonization of the Americas, the Mexica people of Tenochtitlan utilized a method called chinampas, which is similar to the usage of composting in sustainable agriculture today. Agro ecological strategies such as nitrogen cycling and intercropping have been used for hundreds of years and by many different civilizations. Indigenous peoples are also a major number of individuals who use agro ecological methods and are participating in the drive to transition more farms to an agroecological paradigm.

Klages, according to Gliessman and Francis et al., was the first to combine agronomy and ecology with the study of crop ecology in 1928. This work is an investigation of the optimum places to cultivate crops. According to Wezel et al., the word agroecology was first used in 1928, with the publishing of the phrase by Basil Bensin. According to Dalgaard et al., the German zoologist Friederichs was the first to use the term in his book on the zoology of agriculture and forestry in 1930, followed by American crop physiologist Hansen in 1939, both using the term for the application of ecology inside agriculture. Tischler's 1965 book Agrarökologie was perhaps the first to use the term "agroecology." He investigated the many components (plants, animals, soils, and climate) and their interactions within an agroecosystem, as well as the influence of human agricultural management on these components.

Gliessman describes how, after WWII, ecologists focused more on experiments in the natural environment, while agronomists focused on cultivated systems in agriculture. However, in the 1970s, agronomists recognized the value of ecology, and ecologists began to use agricultural systems as study plots, and studies in agroecology grew more rapidly. In the 1970s, more books and articles employing the idea of agroecosystems and the term agroecology began to emerge. According to Dalgaard et al., it was probably Arthur Tansley's 1930s idea of "process ecology" that inspired Harper's 1974 concept of agroecosystems, which they consider the cornerstone of contemporary agroecology. Dalgaard et al. contend that Frederic Clements' research on ecology employing social sciences, community ecology, and a "landscape perspective" are agroecology, as are Henry Gleason's examinations of plant population ecology using several scientific disciplines. In the 1970s, ethnobotanist Efraim Hernandez X.'s study on traditional knowledge in Mexico inspired new agroecology teaching initiatives.

Works such as Silent Spring and The Limits to Growth raised public awareness of the environmental consequences of agricultural production, resulting in increased study into sustainability beginning in the 1980s. Montaldo employed the concept that the socioeconomic setting is crucial in his 1982 paper Agroecologia del Tropico Americano, arguing that this background cannot be isolated from agriculture when creating agricultural techniques. In 1985, Miguel Altieri investigated how farm consolidation and cropping methods affect insect populations, while Gliessman investigated how socioeconomic, technical, and ecological factors influenced producer choices of food production systems. Edens et al. examined the economics of systems, ecological implications, and agricultural ethics and values in Sustainable Agriculture and Integrated Farming Systems in 1995.

Several social movements have included agroecology into their overall organizational approach. Agroecology has been employed by groups such as La Via Campanian to achieve food sovereignty. Farmers have also used agroecology to counter global agricultural growth trends connected with the green revolution.

Agroecology is the application of ecological ideas to the construction, performance, and management of sustainable agroecosystems. Agro ecological methods in Latin America have a long history and vary by location, but they all have three primary approaches or levels: plot size, farm scale, and food system scale. Agroecology in Latin American nations may be utilized to provide ecological, economic, and social advantages to the people who practice it, as well as to preserve high biodiversity and provide refuges for flora and wildlife. Because of its vast breadth and adaptability, it is sometimes referred to as "a science, a movement, and a practice." The Ixcacao Mayan Belizean Chocolate firm grows and makes chocolate using Mayan traditions, overlooking a big shade cacao farm [2].

Gar produced two studies for the FAO in the early 2000s on employing an agro ecological strategy he coined "agrobiodiversity" to help farmers deal with the effects of AIDS in Africa's rural areas. The Shashe Declaration was released in 2011 during the first meeting of agroecology trainers in Zimbabwe. Through the Green Deal and the Farm to Fork Strategy, the European Commission encourages the adoption of sustainable methods such as precision agriculture, organic farming, agroecology, agroforestry, and tougher animal welfare regulations. There is substantial disagreement among academic research fields that specialize on agriculture or ecology, such as agronomy, veterinary science, environmental science, and others, over whether model of agriculture or agroecology should be promoted via policy. Different nations' agricultural ministries promote agroecology to differing degrees, with the UN being possibly its most vocal supporter [8], [9].

CONCLUSION

Agroecology is concerned with ecosystem-based techniques that may revitalize agricultural production systems while also improving human well-being, combating climate change, and protecting our living planet. Agroforestry methods make the most use of available land. Every section of the ground is thought to be ideal for growing valuable plants. The emphasis is on perennial, multipurpose crops that may be planted once and provide advantages for a long time. Agroforestry is practiced in both irrigated and rain fed conditions to produce food, fuel, fodder, timber, fertilizer, and fiber, as well as to contribute to food, nutritional, and ecological security, to sustain livelihoods, to alleviate poverty, and to promote productive and resilient cropping and farming environments.

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CHAPTER 2

A BELIEF DISCUSSION OF THE FOREST FARMING

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ABSTRACT:

Forest farming, along with alley cropping, riparian buffers, windbreaks, and silvo pasture, is one of the five main forms of agroforestry. It has been described as the purposeful integration of agricultural or cropping activities into forest systems, as well as the management of forestlands for purposes other than wood production. It is also known as the cultivation of high-value speciality crops beneath a forest cover and comprises operations like farming. Growing non-timber forest products, producing pine straw, growing trees, planting fodder grasses, grazing cattle, and producing farm tree crops and products such as honey, edible mushrooms, and medicinal plants are examples of these activities.

KEYWORDS:

Agroforestry System, Forest Farming, Forest Management, Medical Plant, Wood Production.

INTRODUCTION

Forest farming is the cultivation of high-value specialty crops under a forest canopy that has been purposely modified or maintained to offer shade and habitat that promotes growth and increases output levels.

Forest farming includes a variety of agricultural systems, ranging from introducing plants into the understory of a lumber stand to changing forest stands to improve the marketability and sustainability of existing plants. Forest farming is an agroforestry method distinguished by the "four I's": intentionality, integration, intensity, and interaction (Figure.1). Agroforestry is a kind of land management that mixes trees with crops, cattle, or both on the same piece of land. It focuses on enhancing landowner advantages while also preserving forest integrity and environmental health.

The approach entails planting non-timber forest products or specialty crops, some of which have considerable market value, such as ginseng or shiitake mushrooms. Plants, plant parts, fungus, and other biological elements gathered from inside and on the boundaries of natural, modified, or disturbed forests are classified as non-timber forest products (NTFPs). Ginseng, shiitake mushrooms, ornamental ferns, and pine straw are examples of crops. items are often classified as culinary, medical and nutritional supplements, floral or ornamental, or specialty wood-based items [1].

Figure 1: Forest farming: Diagram showing the overview of the forest farming (Goodnet.org).

History

Forest farming, while not necessarily called such, is done all over the globe. Humans have depended on fruits, nuts, seeds, sections of leaves, and pods from forest trees and plants to sustain themselves and their cattle for ages. Certain species have been chosen through time for cultivation near dwellings or animals to supply food or medication. Mulberry trees, for example, are often grown alongside pig quarters in the southern United States as a feedstock for pigs [2]. J. Russell Smith, Emeritus Professor of Economic Geography at Columbia University, wrote "Tree Crops - A Permanent Agriculture" in 1929, claiming that crop-yielding trees may be suitable alternatives for cereals in animal feeding programs while also preserving environmental health. Smith's article encouraged Toyohiko Kagawa, who started experimental farming beneath trees in Japan during the 1930s. Kagawa solved soil erosion issues via forest farming, or three-dimensional forestry, by convincing many of Japan's upland farmers to grow fodder trees to protect soil, produce food, and feed animals. He combined massive walnut tree plantings, gathered the nuts, fed them to the pigs, and then sold the pigs for profit [3].

When the walnut trees matured, they were sold for lumber, and additional trees were planted, creating a continual cycle of profitable cropping that supplied the tiny landowner with both short-term and long-term revenue. Because of the effectiveness of these studies, comparable research has been conducted in other nations. World War II hampered communication and halted forest farming progress. In the mid-1950s, studies in regions like southern Africa restarted. Kagawa was also an influence to Robert Hart, who pioneered temperate climate forest gardening in Shropshire, England, in the 1960s. Previously, animals were often considered a component of the forest agricultural system. They are now frequently omitted, and silvopastures are agroforestry systems that incorporate trees, forages, and animals. Forest farming is seen to offer significant promise for regenerating soils, replenishing ground water sources, regulating floods and droughts, and cultivating marginal regions because it combines the ecological stability of natural forests with profitable agricultural techniques. In addition to these advantages for re-establishing productive forests on marginal areas, forest farming, as explained in the techniques section, is a means to add financial value while protecting land that is presently forested. In recent years, there has been an increase in interest in locally produced and organic foods throughout the United States. Farmers' markets and community-supported agricultural small businesses have grown in popularity. These have also become NTFP distribution points. Many farmers want to diversify their crop offerings in order to remain competitive. Forest farming is becoming more popular as a viable land management practice, thanks to the growing number and quality of online resources that provide tutorials and educational information on how to create and maintain forest farms, forest gardens, cultivate specific crops such as shiitake mushrooms, and successfully market these items. The USDA National Agroforestry Center's publication section, the Center for Agroforestry at the University of Missouri, Cornell Cooperative Extension, the Non-Timber Forest Products website by The Virginia Tech Department of Wood Science and Forest Products, the USDA Forest Service Southern Research Station and the Top of the Ozarks RC&D in Missouri, and the collaborative Forest Farming community of practice on eXte are good places to look for research-based resources.

Principles

The ideas of forest farming provide an ecological approach to forest management. Forest resources are exploited wisely, while biodiversity and animal habitat are protected. Through purposeful modification to establish the ideal forest ecosystem, forest farms have the ability to restore ecological balance to fragmented second growth forests. In certain cases, existing forests are used to intentionally introduce species for botanicals, medicinal, food, or ornamental goods. What species will flourish is determined by the tree cover, soil type, water availability, land shape, and other site features. Understanding species/site interactions as well as site restrictions is required to use these resources for production demands while maintaining appropriate resources for the long-term health of the forest. Aside from environmental advantages, forest farming may raise the economic worth of forest property and give both short- and long-term benefits to landowners. Forest farming generates an economic return from intact forest ecosystems, although wood sales may continue to be an element of long-term management strategies [4].

Methods Forest

Farming methods may include: intensive, but careful, thinning of overstocked, suppressed tree stands; multiple integrated entries to achieve thinning while minimizing systemic shock; and interactive management to maintain a cross-section of healthy trees and shrubs of all ages and species. Physical disruption to the surrounding environment should be kept to a minimum. The following are forest farming practices detailed in the Training Manual provided by the University of Missouri's Center for Agroforestry.

Forest gardening is the most intense way of forest farming. In addition to reducing the overstore, this strategy entails clearing the understory of unwanted plants and other agronomic operations (tillage, fertilization, weeding, disease and pest control, and wildlife management). This approach often provides lower-valued products than other methods due to input levels. Forest gardens use the vertical levels of light availability and space beneath the forest canopy to produce many crops at once if needed.

Wild-simulated aims to preserve a natural growing habitat while enriching local NTFP populations to provide an ample renewable supply of the goods. Product look and quality will be comparable to those collected from the wild due to little disturbance and natural growth circumstances. Instead of tilling, practitioners often rake leaves to expose soil, spread seed straight into the ground, and then cover with leaves again. Because NTFPs grown using this approach closely resemble natural plants, they often attract a higher price than NTFPs produced using the forest gardening method. Forest tending entails altering tree crown density in order to regulate light levels in order to promote natural reproduction of desired NTFPs. Supplemental planting is not used in this low-intensity management strategy to promote populations of desirable NTFPs.

Wild crafting is the collection of naturally occurring NTFPs. It is not called forest farming since there is no human participation in the creation and upkeep of the plant. However, wild crafters often take precautions to safeguard NTFPs in order to ensure future harvests. Agroforestry occurs when forest thinning or other inputs are used to preserve or maintain plant populations that would otherwise die due to successional changes in the forest. The most significant distinction between forest farming and wild crafting is that forest farming creates NTFPS on purpose, whilst wild crafting seeks and collects from naturally growing NTFPs. For landowners, forest farming may be a modest economic opportunity that needs careful preparation, including a business and marketing strategy. Learning how to sell NTFPs via the Internet is one alternative, although it may result in increased delivery expenses. Landowners should think about all possible outlets for selling their goods, such as farmer's markets or restaurants that specialize on locally sourced food. A forest management plan including the landowner's goals, as well as a resource inventory, should be included in the development phase. Start-up costs should be considered since particular equipment may be required to harvest or process the product, while some crops need no upfront expenditure. Local incentives, as well as legislation and policies, for sustainable forest management should be investigated. The Convention on International commerce in Endangered Species of Wild Fauna and Flora (CITES) governs international commerce in certain plant and animal species (such as American ginseng and goldenseal). Regulated plants must be collected and records preserved in accordance with CITES laws and limits in order to be lawfully exported. Many states also have harvesting laws for certain native species, which may be found online. Another useful place to start for information is the Center for Biological Diversity's Medicinal Plants at Risk 2008 study in the United States [5], [6].

DISCUSSION

Forest farming, also known as agroforestry or tree-based farming, is a sustainable land management approach that combines agricultural or non-timber forest product production with forest management and conservation. It entails the deliberate integration of trees, crops, and animals in order to simulate natural forest ecosystems. The following are the main characteristics and components of forest farming: Depending on the precise ecological and economic aims, forest farming encompasses a varied variety of tree species, including both native and non-native trees. The tree species chosen may yield wood, fruits, nuts, medicinal goods, or other non-timber forest products (NTFPs).

Forest farming incorporates understory crops or plants under the canopy of the trees. These crops might be annuals, perennials, or a mix of the two. Shade-tolerant vegetables, herbs, medicinal plants, mushrooms, and berries are examples of understory crops. Understory crops are chosen depending on their compatibility with tree species and market demand for these goods. Livestock integration, such as chickens, pigs, or small ruminants, is common in forest agricultural systems. Livestock may help with nutrient cycling, weed control, and income diversification. They are often handled in such a manner that they may forage inside the forest or graze on surrounding pastures. Forest farming employs a variety of agroforestry methods to maximize resource use and production. Alley cropping (planting rows of trees with crops in between), silvo pasture (combining trees with livestock grazing), and multi strata agroforestry (building many layers of crops and trees) are some typical approaches. These activities help to improve ecosystem services including soil fertility, water retention, and biodiversity conservation[7].

Forest farming stresses sustainable management approaches in order to preserve the ecosystem's health and production. Techniques such as selective tree harvesting, controlled grazing, low pesticide usage, and the adoption of organic agricultural principles are examples of this. The goal of sustainable management is to strike a balance between economic rewards and the long-term ecological integrity of the forest system. Forest farming techniques provide various environmental advantages. Trees aid in the sequestration of carbon dioxide, the mitigation of climate change, and the reduction of soil erosion. They also contribute to biodiversity by providing habitat for a variety of animal species. Crop and animal integration within the forest may improve effective nutrient cycle and minimize the demand for synthetic fertilizers. Forest farming provides farmers with economic prospects through producing and selling wood, fruits, nuts, NTFPs, and agricultural items. Forest farming may give a more secure and resilient living by diversifying revenue sources. Furthermore, forest farming may offer jobs in remote regions and contribute to local economic growth. It is crucial to highlight that forest farming techniques varies based on the individual natural circumstances, cultural settings, and market needs of various places. Forest farming methods rely on careful planning, proper tree-crop combinations, continuing maintenance, and market access for the items produced.

Forest farming has several uses and may be performed in a variety of settings. Here are some examples of popular forest farming applications: Forest farming is often used in agroforestry systems, which combine trees with agricultural crops or animals. Agroforestry systems may be built in both rural and peri-urban regions and can give several advantages such as greater agricultural yields, better soil fertility, increased biodiversity, and diversification of income sources [8]. Forest farming is commonly utilized to produce non-timber forest products in a sustainable manner. These include medical herbs, fruits, nuts, mushrooms, fibers, essential oils, and decorative plants, among other useful plant-based resources. Forest farming enables these items to be grown and managed in a manner that assures their long-term availability while reducing environmental concerns. Forest farming may be used to aid with reforestation and ecological restoration initiatives. Forest farming may assist hasten the regeneration of degraded areas, enhance soil quality, minimize erosion, and offer animal habitat by combining tree planting with agricultural or horticultural activity. This technique both supports the ecological functioning of recovered regions and provides economic advantages.

Forest farming may be used for sustainable wood production, particularly in places where timber harvesting has traditionally resulted in deforestation and habitat loss. Forest farming may enable the sustainable management of forests for wood production while preserving ecosystem integrity by employing selective logging procedures and adding tree planting or spontaneous regeneration. Forest farming is often used in shade-grown agricultural systems, especially for crops that flourish in shadowed settings. Shade-grown coffee, cocoa, tea, spices, and some fruits are examples. Forest farming offers the essential shade for these crops by exploiting the existing forest canopy or adding shade trees, which may improve their quality, taste, and ecological sustainability [9], [10].

Forest farming helps to sequester carbon and mitigate climate change. Forest farming removes carbon dioxide from the atmosphere and stores it in biomass and soils through planting and maintaining trees, including agroforestry systems. This contributes to the reduction of greenhouse gas emissions and the fight against climate change. Forest farming may be an effective method of community and indigenous land management. It enables local people to use and manage forest resources in a sustainable manner, fostering food security, cultural preservation, and economic self-sufficiency. Forest farming approaches often correspond to traditional ecological knowledge and may aid in community-led conservation initiatives. These are just a few examples of how forest farming may be used in a variety of situations. Forest farming's particular use is determined by elements such as local natural circumstances, community requirements, market demand, and governmental frameworks.

CONCLUSION

The production of high-value crops beneath the shelter of a regulated tree canopy is known as forest farming. This is known as multi-story cropping in various regions of the globe, and when utilized on a small scale in the tropics, it is frequently referred to as home gardening. Without management, it is not merely recreational harvesting or wild harvesting of native understory wood land plants; management is an integral aspect of forest farming. This method of crop production makes deliberate use of both vertical space and the interplay of plants and microclimate. The intensity of forest farming production varies according on the producer's objectives, accessible markets, processing equipment, and location. Harvesting and scattering local seed; thinning out competing plants; additional site preparation for planting seeds, bulbs, or plant starts; soil amendments for pH or fertility; constructed raised planting beds; pest control; and even fencing to keep out animals and poachers are examples of management activities.

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CHAPTER 3

ROLE OF THE FOREST GARDENING IN AGROFORESTRY

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ABSTRACT:

Increased demand on the world's natural resources as a consequence of population expansion and economic pressure has resulted in unsustainable resource consumption and environmental instability. The unstable nature of the world climate, attributed to human activities, depletion of forest cover due to increased hunger for forest and non-forest products, has resulted in a slew of environmental issues such as land erosion, flooding, frequent and severe storms, and depletion of soil fertility, natural disasters, and seasonal changes of the world climate. These negative effects on the global ecosystem demanded immediate attention.

KEYWORDS:

Carbon Farming, Edible Forest, Food Forest, Forest Gardening, Perennial Vegetables, Trees Shrubs.

INTRODUCTION

Forest gardening is a low-maintenance, sustainable plant-based food production and agroforestry system based on woodland ecosystems, integrating fruit and nut trees, shrubs, herbs, vines, and perennial vegetables with direct human-use outputs. These may be intermixed to develop in a succession of layers to create a forest environment using companion planting. Forest gardening is an ancient way of obtaining food in tropical environments. After modifying the techniques and applying them to temperate settings, Robert Hart invented the phrase "forest gardening" in the 1980s (Figure.1) [1].

History

Hunter-gatherers may have altered forests since ancient times, for example, in Europe by Mesolithic people carrying favorite species like hazel with them. Forest gardens are perhaps the world's oldest and most resilient agroecosystem. They arose in ancient periods along jungle-clad river banks and in the drenched slopes of monsoon areas. Beneficial tree and vine species were found, conserved, and enhanced as families gradually improved their nearby environment, while unwanted species were destroyed. Superior foreign species were eventually chosen and included into the gardens. An archeologist from the Smithsonian reported First Nation settlements in Alaska with forest gardens replete with nuts, stone fruit, berries, and herbs in the 1930s. Forest gardens, also known as home gardens in Kerala, Nepal, Zambia, Zimbabwe, and Tanzania; Kandyan forest gardens in Sri Lanka; and huertos familiars, or "family orchards" in Mexico, are still popular in the tropics. These are also known as agroforests, and if the wood components are short-statured, they are referred to as shrub gardens. Forest gardens have been shown to be an important source of income and food security for local inhabitants. During the 1980s, Robert Hart adapted forest gardening to the temperate climate of the United Kingdom. Martin Crawford of the Agroforestry Research Trust and other permaculture lists such as Graham Bell, Patrick Whitefield, Dave Jacke, and Geoff Lawton further expanded on his beliefs.

In Temperate Regions

Hart started farming in Shropshire's Wenlock Edge with the purpose of producing a healthy and therapeutic environment for himself and his brother Lacon. Hart began as a fairly normal smallholder, but quickly learned that maintaining big annual vegetable beds, producing animals, and caring for an orchard were duties beyond their abilities. A tiny bed of perennial vegetables and herbs he planted, on the other hand, was taking care of itself with minimal assistance. Hart replaced his farm animals with plants after adopting a raw vegan diet for health and personal reasons. Fruit, nuts, and green leafy vegetables are the three major products of a forest garden. He developed a model forest garden on his property from a 0.12 acre (500 m2) orchard and planned to call his gardening approach ecological horticulture or eco cultivation. Hart eventually withdrew these titles after seeing that agroforestry and forest gardens were already being used to describe comparable systems in other regions of the globe. He was inspired by Toyohiko Kagawa's and James Sholto Douglas' forest farming methods, as well as the productivity of Keralan home gardens; as Hart put it, "From the standpoint of agroforestry, perhaps the world's most advanced country is the Indian state of Kerala, which boasts no fewer than three and a half million forest gardens... A study group discovered twenty-three young coconut palms, twelve cloves, fifty-six bananas, and forty-nine pineapples on a 0.12 hectare (0.30 acre) plot, with thirty pepper vines trained up its trees as an example of the extraordinary intensity of cultivation of some forest gardens. The smallholder also cultivated fodder for his house-cow [1]."

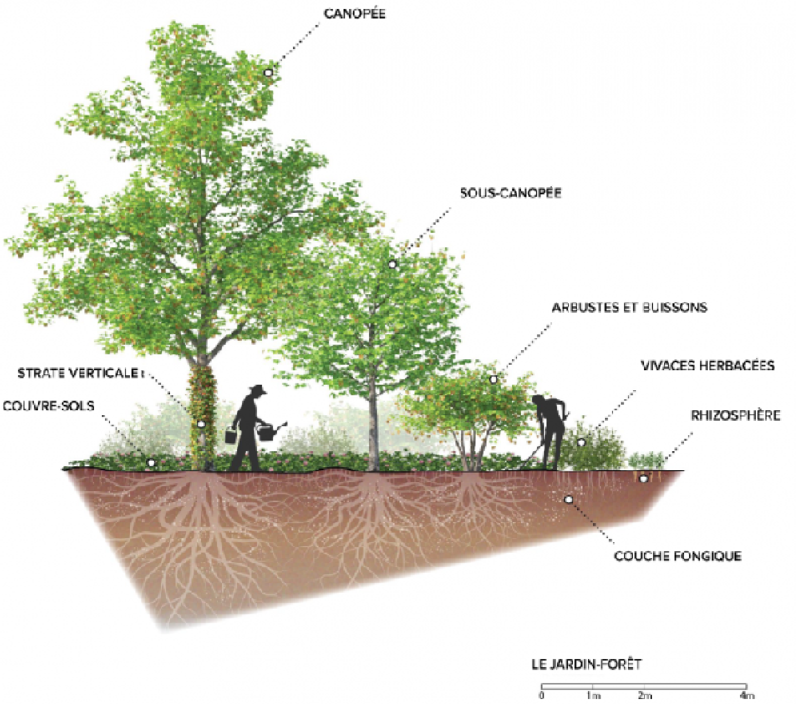

Figure 1: Forest gardening: Diagram showing the overview of the forest gardening (Reforest action).

System with Seven Layers

The woodland garden's seven tiers. Robert Hart pioneered a method based on his discovery that the natural forest may be separated into several levels. He employed intercropping to transform an existing modest apple and pear orchard into an edible polyculture landscape comprised of the following layers: The 'canopy layer' is made up of the original mature fruit trees. Smaller nut and fruit trees on dwarfing rootstocks form a "low-tree layer." Fruit bushes with a 'shrub layer,' such as currants and berries. Perennial vegetables and herbs form a 'herbaceous layer'. Plants farmed for their roots and tubers have a 'rhizosphere' or 'underground' dimension. 'Ground cover layer' of horizontally spreading food plants.

Vine and climber 'vertical layer'.

The plants he chose were an important part of the seven-layer structure. Most typical vegetable crops planted today, such as carrots, are sun-loving plants that are poorly suited to the shadier forest garden system. Hart like perennial crops that tolerated shade. Martin Crawford manages the Agroforestry Research Trust, which performs experimental forest gardening programs on a variety of plots in Devon, England. Crawford defines a forest garden as a low-maintenance method of producing food and other household goods in a sustainable manner. Ken Fern proposed that a broader choice of tasty shade tolerant plants be employed for a successful temperate forest garden. Fern founded the organization Plants for a Future to develop a plant database suited for such a system. In his book Plants for a Future, Fern used the phrase woodland gardening rather than forest gardening. Kathleen Janna way, creator of the Movement for Compassionate Living (MCL) with her husband Jack, authored Abundant Living in the Coming Age of the Tree in 1991, describing a sustainable vegan future. The MCL supports vegan organic gardening and forest gardening. It gave a £1,000 grant to the Bangor Forest Garden project in Gwynedd, North West Wales, in 2009. In 1985, Kevin Bradley in the United States named his property and nursery "Edible Forest" because it mixed trees with field crops. Today, his company and the book Edible Forest Gardens, published in 2005, have produced little "edible forests" all over the globe [2].

Permaculture

Near October 1990, Bill Mollison, the inventor of the term permaculture, paid a visit to Robert Hart's woodland garden near Wenlock Edge. Hart's seven-layer method is now a standard permaculture design feature. Many permaculture lists, like Graham Bell, Patrick Whitefield, Dave Jacke, Eric Toensmeier, and Geoff Lawton, advocate for forest gardens or food forests. Bell began working on his forest garden in 1991 and published The Permaculture Garden in 1995; Whitefield published How to Make a Forest Garden in 2002; Jacke and Toensmeier co-authored the two volume book set Edible Forest Gardens in 2005; and Lawton presented the film establishing a Food Forest in 2008.

In Tropical Regions

Forest gardens, also known as home gardens, are widespread in the tropics, where trees, crops, and cattle are all grown on the same plot of ground. The home garden is the most popular kind of land use in Kerala, south India, as well as in northeastern India, and it is also present in Indonesia. One recipe incorporates coconut, black pepper, chocolate, and pineapple. These gardens are great examples of polyculture since they preserve a lot of crop genetic variety and heritage species that aren't found in monocultures. The theological notion of the Garden of Eden has been loosely linked to forest gardens. According to the BBC's Unnatural Histories, the Amazon rainforest has been altered by humans for at least 11,000 years via activities such as forest gardening and terra preta. Numerous geoglyphs have been unearthed on deforested territory in the Amazon rainforest since the 1970s, adding to the evidence of pre-Columbian civilizations. Much of the Maya food supply was farmed in "orchard gardens" known as pet kot on the Yucatán Peninsula. The system gets its name from the low stone wall that surrounds the gardens (pet means 'circular' and kot means 'wall of loose stones').

Gardens are common in rural, periurban, and urban regions in many African nations, including Zambia, Zimbabwe, Ethiopia, and Tanzania, and they play an important role in achieving food security. The most well-known are the Chaga or Chagga gardens on the Tanzanian slopes of Mount Kilimanjaro. This is an illustration of an agroforestry system. Women are the primary players in home gardening in many nations, and food is mostly grown for sustenance. A classic style of forest garden in North Africa is oasis-layered gardening with palm trees, fruit trees, and vegetables. Plants some plants, like wild yam, function as both a root plant and a vine. Ground covers are low-growing edible 'forest garden' plants that help keep weeds at bay and make use of otherwise underutilized spaces. El Pilar, located on the Belize-Guatemala border, is a forest garden that showcases ancient Maya farming methods. A one-acre model forest garden named KänanK'aax (meaning 'well-tended garden' in Mayan) is being constructed at Cayo Santa Familia Primary School with funding from the National Geographic Society. The biggest known food forest on public property in the United States is thought to be the seven-acre Beacon Food Forest in Seattle, Washington. Other projects using forest gardens include those at the central Rocky Mountain Permaculture Institute in Basalt, Colorado, and the Montview Neighborhood Farm in Northampton, Massachusetts. The Boston Food Forest Coalition encourages community forest gardens [3].

For almost 30 years, Richard Walker has been creating and managing food forests in British Columbia, Canada. He created a three-acre food forest, which produced raw materials for a plant nursery and herbal company, as well as food for his family, when it was mature. In Ontario, the Living Centre has created a number of forest garden initiatives. Other than those sponsored by the Agroforestry Research Trust (ART), there are several forest garden initiatives in the United Kingdom, such as the Bangor Forest Garden in Gwynedd, northwest Wales. Martin Crawford of ART manages the Forest Garden Network, an informal network of individuals and organizations growing forest gardens.

Gisela Mir and Mark Biffen have been working on a small-scale edible forest garden (Verger in Catalan) in Cardedeu, a hamlet near Barcelona, Catalunya, since 2014. They were exposed to numerous edible forest garden initiatives in Wales and other areas of the UK throughout their earlier years of permaculture training. "...we want to learn and test what it means to have an orchard in an area with a Mediterranean climate: which species grow well here; how to manage limiting aspects, such as water; and, most importantly, what design implications there are due to the characteristics of our climate and our latitude." In April 2021, they published in Spanish the book Food forests and edible gardens (Bosques y jardines de alimentos), in which they draw on their early experimental advances and experiences, delving into the particularities of the Mediterranean climate through a book tailored to that climate and those species. It is one of the earliest non-English writings on the topic.

Carbon farming refers to a group of agricultural practices that try to trap atmospheric carbon in crop roots, wood, and leaves. The goal of carbon farming is to increase the rate at which carbon is sequestered into soil and plant material in order to create a net loss of carbon from the atmosphere. Increasing a soil's organic matter content can aid plant growth, increase total carbon content, improve soil water retention capacity, and reduce fertilizer use. Methods for lowering carbon emissions in agriculture may be divided into two categories: reducing and displacing emissions and increasing carbon sequestration. Reductions include enhancing agricultural efficiency (e.g., using more fuel-efficient equipment) and interfering with the natural carbon cycle. Forest management, in addition to agricultural activities, is a tool used in carbon farming. Carbon farming is often done by individual land owners who are given incentives to use and integrate methods that will sequester carbon through government policies. Carbon farming methods will typically have a cost, requiring farmers and land-owners to profit from the use of carbon farming. In part, soil carbon is thought to accumulate when decaying organic matter is physically mixed with soil. Small roots die and decay while the plant is alive, depositing carbon below the surface. More recently, the role of living plants has been emphasized, where carbon is released as plants grow. Deep soils contain around half of all soil carbon, with mineral-organic interactions stabilizing approximately 90% of this. At least 32 Natural Resource Conservation Service (NRCS) methods boost soil health and carbon sequestration while also providing key co-benefits such as higher water retention, hydrological function, biodiversity, and resilience. Farmers that use approved procedures may be eligible for government assistance. Not all carbon farming approaches have been recommended. Carbon farming may take into account associated concerns including groundwater and surface water damage [4].

Agriculture Techniques

Cropland soils are low in soil organic carbon (SOC) as compared to wild vegetation. When a soil is converted from natural or semi-natural land, such as forests, woodlands, grasslands, steppes, and savannas, the SOC content in the soil decreases by about 30-40%. The loss of carbon through agricultural practices can eventually lead to the loss of soil suitable for agriculture. Soil carbon either grows or diminishes as land use changes. This process is repeated until the soil finds a new equilibrium. Climate change may also effect deviations from this equilibrium. The decline can be offset by increasing carbon intake. This can be accomplished through a variety of strategies, such as leaving harvest residues on the field, using manure, or rotating perennial crops. Perennial crops have a larger below ground biomass fraction, which increases SOC content. Globally, soils are estimated to contain more than 8,580 giga tonnes of organic carbon, roughly ten times the amount in the atmosphere and much more than vegetation. Organic farming and earthworms may be able to more than offset the annual carbon surplus of 4 Gt/year.

Methods for lowering carbon emissions in agriculture may be divided into two categories: reducing and displacing emissions and increasing carbon sequestration. Reductions include enhancing agricultural efficiency (e.g., using more fuel-efficient equipment) and interfering with the natural carbon cycle. Effective approaches (such as eliminating stubble burning) may have a detrimental influence on other environmental problems (increased pesticide usage to combat weeds that are not killed by fire). As of 2016, carbon farming types covered hundreds of millions of hectares of the world's cropland, which totaled approximately 5 billion hectares (1.21010 acres).

By incorporating anaerobically burnt biochar into soil, roughly 50% of the carbon in the biomass is sequestered. If slash-and-burn is replaced with slash-and-char, up to 12% of anthropogenic carbon emissions from land use change (0.21 giga tonnes) may be offset yearly in soil. Agriculture and forestry waste might provide 0.16 giga tonnes each year. Through pyrolysis, bio-char may be created as a byproduct of biofuel production utilizing contemporary biomass, sequestering 30.6 kg for each gigajoule of energy produced. Soil-sequestered carbon may be simply and accurately quantified. Carbon farming reduces soil disturbance throughout the planting/growing/harvest cycle. Tillage is avoided by using seed drills or similar techniques. Livestock can trample and/or eat the remains of a harvested field. Reducing or stopping tilling increases topsoil carbon concentrations. Plowing splits soil aggregates and allows microorganisms to consume their organic compounds. Increased microbial activity liberates nutrients, initially increasing production. Following that, the loss of structure diminishes the soil's capacity to store water and resist erosion, lowering yield.

Grazing modifications for Livestock

Livestock, like other animals, is a net carbon producer. Ruminants such as cows and sheep emit not just CO_2, but also methane owing to the microorganisms that live in their digestive tract. Carbon may be sequestered in grassland soils via root exudates and manure. The paddocks may rest/recover between grazing periods if the herd is rotated between numerous paddocks on a regular basis (as frequently as daily). This pattern results in stable grasslands with plenty of fodder. Annual grasses have shorter roots and die when grazed. Rotational grazing causes annuals to be replaced by perennials with deeper roots that can recover following grazing. Allowing animals to roam across a big region for a lengthy period of time, on the other hand, may degrade grassland. Silvo pasture is the practice of grazing animals beneath tree cover, with trees spaced enough apart to provide adequate sunshine to grow the grass. For example, a farm in Mexico planted native trees over a paddock spanning 22 hectares (54 acres). This grew into a profitable organic dairy. The enterprise evolved into a subsistence farm, with money generated by consulting/training others rather than food production [5].

Mulch made of organic materials

Mulching is the process of covering the soil surrounding plants with a layer of wood chips or straw. Crop residue may also be left in situ to decay and infiltrate the soil. Compost sequesters carbon in a stable (difficult-to-access) form. Carbon farmers apply it to the soil surface without tilling. A 2013 research discovered that a single compost application enhanced grassland carbon storage by 25-70%. The continued sequestration was most likely caused by enhanced water retention and "fertilization" by compost decomposition. Both aspects contribute to greater productivity. Both studied locations revealed significant improvements in grassland productivity: a 78% increase in forage in a drier valley site and a 42% increase in a wetter coastal site. Another study discovered that grasslands treated with.5" of commercial compost began absorbing carbon at an annual rate of nearly 1.5 tons/acre and continued to do so in subsequent years, but this study had not been replicated as of 2018.

DISCUSSION

Forest gardening contributes significantly to agroforestry by blending forest ecosystem ideas and techniques into agricultural systems. It entails the deliberate design and maintenance of various and multi-layered perennial plants that resemble the structure and functions of a natural forest.

Forest gardening increases biodiversity by developing a complex and layered structure that offers habitat for a vast variety of plant and animal species. The numerous canopy layers, which include towering trees, shrubs, herbaceous plants, and ground coverings, provide niches for a variety of creatures, resulting in a more diverse and robust ecosystem. This encourages biodiversity conservation and aids in the restoration of ecological equilibrium.

Forest gardening improves nitrogen cycling and soil health by combining a diversity of plants with diverse nutrient needs and root architectures. Deep-rooted trees can access nutrients in deeper soil layers, but shallow-rooted plants can only access nutrients in the top layers. Leaf litter, fallen fruits, and organic detritus from the varied plants offer a steady supply of organic matter, improving soil fertility, structure, and moisture-holding ability. Forest gardens assist to moderate microclimates by providing shade, windbreaks, and moisture regulation. Tall tree canopy provides shade, lowering temperature extremes and sheltering understory plants from harsh heat or cold. Windbreaks, such as trees and bushes, reduce wind speed and prevent soil erosion. The thick vegetation also aids in moisture retention, lowering evaporation and promoting a more humid atmosphere [6].

By using vertical space and producing a diverse variety of food and non-edible goods, forest gardening fosters high productivity and crop diversity. Different plant species are chosen and organized in such a manner that the utilization of light, water, and nutrients is maximized, allowing for the development of a wide range of fruits, nuts, vegetables, herbs, medicinal plants, and other valuable goods. This broad crop mix lowers pests and illnesses, increases pollination, and produces a more balanced and healthy food supply. Forest gardening helps with water management by minimizing runoff, increasing infiltration, and limiting soil erosion. Rainfall is captured and slowed by the high plant cover, enabling water to permeate the soil, replenish groundwater, and limit surface runoff. The forest garden's layered structure also helps retain moisture, minimizing the need for irrigation and enhancing water-use efficiency. Forest gardening is very important for carbon sequestration and climate change mitigation. A forest garden system's blend of trees, shrubs, and perennial plants helps capture and store carbon dioxide from the atmosphere, helping to reduce greenhouse gas emissions. The long-lasting nature of many forest garden components provides long-term carbon storage in biomass and soil. Overall, forest gardening in agroforestry systems improves ecological sustainability, productivity, and resilience while also encouraging biodiversity conservation and mitigating climate change. It presents a paradigm for sustainable land use that blends forest ecosystem principles with agricultural methods, providing various advantages to both the environment and human well-being [7]–[9].

CONCLUSION

This study examines the relevance of agroforestry and several agroforestry strategies that might improve environmental sustainability. Agroforestry may help the nation break the cycle of deforestation, soil erosion, and other environmental issues. Agroforestry is the integration of agricultural and forestry methods into a farming system. As a land-use system, it meets the different demands of individual farmers in utilizing the natural resources surrounding them, something the conventional cropping system cannot. It entails combining trees and crops to boost the medicinal, environmental, and economic value of land while also providing much-needed profit and food security. Hence as a remedy to environmental difficulties, agroforestry methods such as living fence, home garden, shelterbelt, alley farming, taungya system, enhanced fallow, and agro silvopastoral are highly suggested.

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CHAPTER 4

SIGNIFICANCE OF THE AGRICULTURAL BIODIVERSITY IN AGROFORESTRY

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ABSTRACT:

The environmental benefits that agroforestry methods may offer, particularly their potential contribution to biodiversity conservation, have only lately gained traction among agroforestry and conservation specialists. This new perspective is compatible with the Convention on Biological Diversity's ecosystem approach to natural resource management. The contributions illustrate traditional agroforestry systems' significant potential to enhance biodiversity conservation, but also their limitations. These include the critical role of markets for tree products and a favorable policy environment for agroforestry land uses in maintaining high levels of biodiversity in agroforestry land use mosaics. The case studies imply that retaining variety in approaches to agroforestry system management, along with a pragmatic, non-dogmatic perspective of natural resource management, will give the most alternatives for adjusting to changing land use situations.

KEYWORDS:

Agriculture Biodiversity, Genetic Diversity, Food Agriculture, Situ Conservation, Wild Relatives.

INTRODUCTION

Agricultural biodiversity, often known as agrobiodiversity, is a subset of general biodiversity that is related to agriculture. It is defined as "the variety and variability of animals, plants, and microorganisms at the genetic, species, and ecosystem levels that sustain the ecosystem structures, functions, and processes in and around production systems, and that provide food and non-food agricultural products." It is managed by farmers, pastoralists, fishers, and forest dwellers, and it provides stability, adaptability, and resilience (Figure.1) [1].

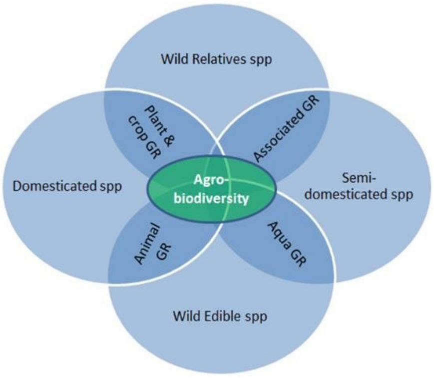

Figure 1: Agriculture biodiversity: Diagram showing the overview of the agriculture biodiversity (Research gate).

Etymology

It is unclear when or by whom the term agrobiodiversity was coined. The 1990 annual report of the International Board for Plant Genetic Resources (IBPGR, now Diversity International) is one of the earliest references to biodiversity in the context of agriculture, with most references dating from the late 1990s onward. While similar, different definitions are used by different bodies to describe biodiversity in relation to food production. The CGIAR tends to use agricultural biodiversity or agrobiodiversity, while the Food and Agriculture Organization of the United Nations (FAO) uses 'biodiversity for food and agriculture' and the Convention on Biological Diversity (CBD) uses the term 'agricultural diversity'. The CBD more or less (but not entirely) excludes marine aquatic organisms and forestry it.

Crop biodiversity

Crop diversity, also known as crop biodiversity, is the variety and variability of crops, plants used in agriculture, including their genetic and phenotypic characteristics; it is a subset of and a specific element of agricultural biodiversity. Genetic diversity within each crop and the number of species commonly grown have declined significantly over the last 50 years. Crop diversity loss threatens global food security because the world's human population depends on a decreasing number of varieties of a decreasing number of crop species. Crops are increasingly grown in monoculture, which means that if a single disease overcomes a variety's resistance, as in the historic Great Famine of Ireland, it may destroy an entire harvest, or, as in the case of the 'Gros Michel' banana, it may cause the commercial extinction of an entire variety [2].

Biodiversity of livestock

Animal genetic resources for food and agriculture (An GR), also known as farm animal genetic resources or livestock biodiversity, are genetic resources (i.e., actual or potential value genetic material) of avian and mammalian species used for food and agriculture. An GR is a subset of and a specific element of agricultural biodiversity. An GR can be embodied in live populations or in conserved genetic materials such as cryoconserved sperm or embryos. The diversity of animal genetic resources includes diversity at the species, breed, and within-breed level. There are currently 8,800 different breeds of birds and mammals within 38 species used for food and agriculture. Quinoa (Chenopodium quinoa) diversity approaching harvest, with quinoa farmer, in Cachilaya, Bolivia, Province La Paz. Genetic diversity refers to the variety and variability within and between species. It can refer to the naturally occurring genetic variability within and between populations of a species, for example wild relatives of food crops, or to the variability created by humans, for example farmer-developed traditional crop varieties called landraces, or commercially bred varieties of a crop (e.g. different apple varieties: Fuji, Golden Delicious, Golden Pippin, etc.). There is considerable genetic diversity within all food crop species, particularly in centres of origin, which are the geographical areas where species were originally developed. For example, the Andean region of Peru is a centre of origin for certain tuber species, and over 1,483 varieties of these species can be found there. Genetic diversity is important as different genes give rise to important traits, such as nutrient composition, hardiness to different environments, resistance to pests, or ample harvests. Genetic diversity is decreasing due to agricultural modernization, changing land use and climate change, among other factors. (It is even possible that breeding narrowly for the pest- and disease-resistance necessary to deal with climate change will, itself, reduce agrobiodiversity.) Genetic diversity is not static but is constantly evolving in response to changes in the environment and according to human intervention, whether farmers or breeders.

Species diversity

The number of species considered to contribute to food alone ranges from 5,538 to 75,000, depending on definitions. A conservative estimate is that approximately 6,000 species are commonly used for food. It also includes "associated biodiversity," which is defined as "the vast range of organisms that live in and around food and agricultural production systems, sustaining them and contributing to their output." Agriculture is defined as crop and livestock production, forestry, fisheries, and aquaculture. Aquatic diversity is an important component of agricultural biodiversity, and the conservation and sustainable use of local aquatic ecosystems, ponds, rivers, and coastal commons by artisanal fisher folk and smallholder farmers is critical to the survival of both humans and the environment. Because aquatic organisms, including fish, provide much of our food supply as well as supporting coastal peoples' income, it is critical that fisher folk and smallholder farmers have access to these resources.

Ecosystem diversity

The mosaic of ecosystem components delivers a variety of ecosystem benefits. Ecosystem diversity refers to the variety and variability of different components in a given geographical area (e.g., landscape, country). In the context of agrobiodiversity, ecosystem diversity refers to the diversity within and between agroecosystems: e.g., pastures, ponds and rivers, planted fields, hedges, trees, and so on [3].

Agrobiodiversity's contributions to food and agriculture

Ecosystem services are the services provided by well-functioning ecosystems (agroecosystems and also wild ecosystems such as forests or grasslands) to human wellbeing. They are usually clustered into four broader categories: provisioning (direct provision of goods such as food and water), supporting (the services that are required for agriculturist), and sustaining (the services that are required for agriculturist).

Provisioning

Agrobiodiversity's contribution to provisioning services is mainly for providing food and nutrition. Food biodiversity is "the diversity of plants, animals and other organisms used for food, covering the genetic resources within species, between species and provided by ecosystems." Historically at least 6,000 plant species and numerous animal species have been used as human food. This number is considered to be decreasing now, resulting in concerns about long-term diet diversity. Food biodiversity also covers subspecies or varieties of crops, for example the many forms of the Brassica oleracea species (cauliflowers, different broccolis, cabbages, Brussels sprouts, etc.). Many species which have been overlooked by mainstream research ('orphan' or 'neglected and underutilized' species) are rich in micronutrients and other healthful components. Also among different varieties of a species, there can be a wide variety of nutrient composition; for example some sweet potato varieties contain negligible levels of beta-carotene, which others can contain up to 23,100 mcg per 100g of raw, peeled sweet potatoes. Other provisioning services from agrobiodiversity are the provision of wood, fibre, fuel, water and medicinal resources. Sustainable food security is linked to improving the conservation, sustainable use and enhancement of the diversity of all genetic resources for food and agriculture, especially plant and animal genetic resources, in all types of production systems.

Supporting

Agrobiodiversity's contribution to supporting services is providing the biological or life support to production, emphasizing conservation, sustainable use and enhancement of the biological resources that support sustainable production systems. The main service is to maintain genetic diversity of crops and species, so that it is available to maintain adaptability to new and changing climate and weather conditions. Genetic diversity is the basis of crop and livestock improvement programmers, which breed new varieties of crops and livestock in response to consumer demand and farmers' needs. An important source of genetic diversity are crop wild relatives, wild plant species that are genetically related to cultivated crops. A second supporting service is to maintain the habitat of wild biodiversity, particularly associated biodiversity, for example pollinators and predators. Agrobiodiversity can support wild biodiversity through the use of field margins, riparian corridors, hedgerows and clumps of trees, which provide and connect habitats. A further supporting service is maintaining healthy soil biota. Agrobiodiversity contributes to regulatory services, which manage the natural processes required for a healthy agroecosystem, such as pollination, pest control, and carbon capture [4].

75% of the 115 major crop species grown globally rely on pollinators. Agrobiodiversity contributes to pollinator health by: (a) providing habitat for them to live and breed; (b) providing non-chemical biological pest control options (see below) so that insecticide use can be reduced and insect pollinators are not harmed; and (c) providing a symbiotic relationship of constant flower production, with crops flowering at different times

Pest Management

Agrobiodiversity contributes to pest control by: (a) providing a habitat for pests' natural enemies to live and breed in; and (b) providing wide genetic diversity, which means genes with resistance to any given pathogen or pest are more likely to exist, and the plant can evolve as pests and diseases evolve. Agrobiodiversity contributes to carbon capture when used as part of a package of agro ecological practices, such as providing cover crops that can be dug into the land as green manure, maintaining tree stands and hedgerows, and protecting soil integrity so that local microbes can continue to thrive. Farmers and breeders can use genetic diversity to breed varieties that are more tolerant to changing climate conditions, and which, when combined with practices like

Chhath puja celebrations using Traditional Fruit Species

Agrobiodiversity is central to cultural ecosystem services in the form of food biodiversity, which is central to local cuisines worldwide. Agrobiodiversity provides locally appreciated crops and species, and also unique varieties which have cultural significance. For example, ethnic traditional cultures influence the conservation of a wide diversity of rice varieties in China (e.g. red rice, sweet glutinous rices) developed by farmers over thousands of years and used in traditional cultures, rituals and customs. Another example are local food fairs, epitomized by the Slow Food movement, which celebrates local food varieties in order to add value to them, raise awareness about them and ultimately conserve and use them. In addition, some traditional cultures use agrobiodiversity in cultural rituals, e.g. many populations of fruit species (pomelo and mango) are maintained in rural communities specifically for use at the 'Chhath Puja' festival, celebrated in parts of India, Nepal and Mauritius. Home gardens are important as culturally constructed spaces where agrobiodiversity is conserved for a wide variety of social, aesthetic and cultural reasons. Genetic diversity is maintained by resource-poor farmers because of many non-monetary values, including culture and food [5].

Agrobiodiversity Loss

Agrobiodiversity is threatened by changing land use patterns (urbanization, deforestation), agricultural modernization (monocultures and abandonment of traditional, biodiversity-based practices), and Westernization of diets and their supply chains. It has been estimated that biodiversity as a whole is being lost at 100-1000 times the natural background rate. Agrobiodiversity loss causes genetic erosion, or the loss of genetic diversity, including the loss of individual genes and specific combinations of genes (or gene complexes) such as those found in locally adapted landraces or breeds. Genetic vulnerability occurs when there is little genetic diversity within a population of plants, making the population as a whole particularly vulnerable to disease, pests, or other factors. Reduced agrobiodiversity influences, and is influenced by, changes in human diets. Since the mid-1900s, human diets across the world have become more diverse in the consumption of major commodity staple crops, with a corollary decline in consumption of local or regionally important crops, and thus have become more homogeneous globally. The differences between the foods eaten in different countries decreased by 68% between 1961 and 2009. The modern 'global standard' diet contains an increasingly large percentage of a relatively small number of major staple commodity crops, which have increased substantially in the share of the total food energy (calories), protein, fat, and food weight that they provide to the world's human population, including wheat, rice, sugar, maize, soybean (by +284%), palm oil (by +173%), and sunflower (by +246%). Whereas nations used to consume greater proportions of locally or regionally important food biodiversity, wheat has become a staple in over 97% of countries, with the other global staples showing similar dominance worldwide. Other crops have declined sharply over the same period, including rye, yam, sweet potato (by -45%), cassava (by -38%), coconut, sorghum (by -52%) and millets (by -45%).

Conservation

Attempts to conserve or safeguard agrobiodiversity typically focus on the species or genetic level of agrobiodiversity. Conservation of genetic diversity and species diversity can be carried out ex situ, which means removing the materials from their growing site and looking after them elsewhere, or in situ, which means conserving the materials in their natural or cultivated site.

Ex situ conservation

Ex situ conservation is defined as the "conservation of components of biological diversity outside their natural habitats." Ex situ conservation is the conservation of genetic resources (species, varieties, cultivars, sub-species, landraces, and so on) for food and agriculture outside their natural habitat, in a managed environment such as botanical gardens, seedbanks, pollen banks, field gene banks, cryo banks, or herbaria. Ex situ conservation has some benefits for seed-bearing crops: 1) seed requires little space; 2) ex situ conservation can be implemented anywhere; 3) what is conserved is easily accessible for distribution, further use, research, and breeding; and 4) the costs for maintaining genetic diversity that has no immediate production or market value are minimal. Weaknesses of ex situ conservation include the following: 1) it is expensive to keep seeds and germplasm healthy in perpetual storage or in field collections; 2) coverage of the diversity of neglected and underutilized crops or crop wild relatives is currently very limited; gene banks have largely focused on the conservation of major staple crops, while non-staple crops and crop wild relatives are underrepresented; 3) there are species with 'recalcitrant' seeds, which means they cling to the plant [6].

Conservation in situ

In situ conservation means "the conservation of ecosystems and natural habitats and the maintenance and recovery of viable populations of species in their natural surroundings and, in the case of domesticated or cultivated species, in the surroundings where they have developed their distinctive properties". In situ conservation comprises both conservation of trees and crop wild relatives in situ in the wild, and conservation of landraces and neglected and underutilized species on farm in farmers' fields. Conserving agrobiodiversity in situ has the benefit that species can continue to evolve in response to natural and human pressures. In the case of crops, a large amount of diversity is retained in developing countries by smallholder farmers, particularly for many crops in their centers of domestication and diversity. There, farmers continue to grow landraces and maintain traditional knowledge and seed management practices in a process known as de facto conservation. Home gardens too are repositories of high levels of species diversity, and traditional landraces contain wide genetic diversity. For forest trees, in situ conservation is considered the most appropriate method since most tree seeds cannot be conserved ex situ, and because there are 60,000 tree species, each with multiple populations, so too many to identify and collect. A meta-analysis of studies comparing biodiversity found that, when compared to organic cropping systems, conventional systems had significantly lower species richness and abundance (30% greater richness and 50% greater abundance in organic systems, on average), though 16% of studies found a greater level of species richness in conventional systems. In situ conservation is relatively low cost for high levels of biodiversity, particularly crop wild relatives, neglected and underutilized species, landraces, trees, fish, and livestock; however, in situ conserved species and varieties may be vulnerable to climate change, land use changes, and market demand.

DISCUSSION

Biodiversity refers to the enormous variety of life on Earth. Greater and greater diversity arises when living creatures adapt to their surroundings and change through time. Scientists estimate that at least 8.7 million unique species of animals, plants, fungi, and other organisms, as well as countless varieties of bacteria, exist on Earth. Each of these species is adapted to play a specific role in its immediate environment, and this diversity ensures that ecosystems function properly and remain in balance. In agriculture, biodiversity benefits people as well: genetic variety in crops and cattle protects our food supply from disease and other hazards. Unfortunately, industrial agriculture values regularity and production above variety, relying on just a few plant and animal species. Treating crops and cattle as if they were assembly lines rather than distinct participants in a dynamic system endangers both wild species and has major consequences for our domesticated food source. Sustainable agriculture values biodiversity by limiting its influence on wild ecosystems and combining a diverse range of plant and animal species into complex on-farm ecosystems.

Biodiversity is what distinguishes each habitat on the planet. While we witness biodiversity in the stunning forms and hues of nature, it all begins with DNA. All living organisms have DNA, and that genetic code develops through time. Different genes are associated with various features of the organism. Many of these features are visible to the naked eye, while others, such as genes for stress and disease resistance, are less so. This genetic variety is critical for species survival in the face of ever-changing environmental circumstances [7].

Agriculture has relied on biodiversity from its inception. Humans harnessed and directed genetic variation long ago by domesticating food plants and animals. Even without knowing genetics, the early farmers accomplished this by selecting plants that produced big, edible seeds. Domesticated plants developed their own variants as they spread over the globe. Crops, like their wild counterparts, rely on genetic diversity for features that aid in disease resistance and productivity under stress. Genetic heterogeneity within crops also contributes to the wide range of meals we enjoy. Biodiversity in livestock is vital for the same reasons, and there are hundreds of heritage breeds of pigs, cattle, poultry, and other animals that are beautiful, one-of-a-kind, and uniquely suited to their habitats.

Maintaining biodiversity in the wild and in crops provides agricultural advantages. Farms are ecosystems, even if they are controlled by people. Plants, soil, and animals are all interdependent in terms of nutrients and habitat. Healthy soil bacteria in a working agro-ecosystem offer nutrients to plants, whose root systems keep the soil in place. Plants offer food and shelter for beneficial insects and birds, which pollinate them and help to control pests. Livestock may recycle agricultural waste and offer natural fertilizer to fields and pastures through manure. Agroecosystems rely on variety to maintain equilibrium, which modern agriculture disrupts. Agriculture depends on natural processes and living organisms to provide food, yet it often alters the environment. While farms may be managed in ways that minimize their impact on the environment, the concentration on production in industrial agriculture means that too many farms are disruptive to wild animals both close and distant. When industrialized agriculture alters or pollutes the environment, fragile species may lose their habitats and possibly go extinct, threatening biodiversity.

Agriculture takes up area, whether it's cultivating fruits and vegetables, cereals, or animals. Prime agriculture – property with rich soil and access to water — is a scarce resource. These same regions often sustain diverse natural ecosystems such as prairies and woods; turning these areas to farmland destroys much of the wild biodiversity. Unfortunately, agriculture's ever-expanding impact threatens to destroy these delicate and crucial natural regions. Intensification refers to the process of incorporating additional wild area into agriculture. Agricultural expansion is not a new phenomenon. Grassland ecosystems like the tallgrass prairie formerly spanned approximately 170 million acres in the United States and supported almost as many plant and animal species as tropical rainforests. Indigenous peoples helped maintain a rich, biodiverse environment where bison and other animals thrived through managed fires and other tactics. But as settlers pushed native peoples off their lands, this changed: the deep roots of grasses made the soil rich in organic matter, making it ideal for plowing into productive farmland. However, after 150 years of agricultural growth, tallgrass prairies have been reduced to 1% of their historic area, frequently retained in tiny strips between farms or along railroads. The disadvantages of industrial agriculture are not confined to habitat devastation due to its growing footprint: its dependence on heavy chemicals to generate massive stands of single crops has major ramifications for plant, animal, and microbe biodiversity.

Throughout the twentieth century, a number of advances enabled widespread agricultural intensification. Steel plows, hybrid crops, GMOs, chemical fertilizers, and pesticides were widely used, allowing farmers to produce more food per acre than ever before. Recently, the use of genetically engineered seeds has helped to boost yields even more. However, this productivity comes at a high cost. Wide fields of a single crop (known as monocultures) simplify farming and offer a continuous supply of feed to industrial farms, but they are biodiversity deserts. Monocultures need heavy chemical inputs, which diminish the number of wild species both on and off the farm. Pesticides and herbicides are intended to kill pests that destroy or compete with crops, but they may also affect plants and animals outside of agricultural areas. Herbicide overuse and intensive soil disturbance both have an impact on plant diversity on and around farms; researchers studying plant communities around intensively managed farms discovered that they had fewer species than their organic counterparts. Reductions in plant diversity can have an impact on the animals that rely on them; for example, the widespread adoption and increased use of the herbicide glyphosate in the United States has significantly reduced wild plant diversity in and around farms. While herbicides may disrupt food webs (and the creatures that live inside them), insecticides can directly damage other species. Pesticides such as neonicotinoids affect bees and other insects by restricting colony development and interfering with communication, decreasing their capacity to pollinate crops and other plants. Some pesticides are hazardous to fish, amphibians, and birds; agricultural pollution is the primary danger to many species worldwide [8].

Industrial agriculture also has a negative impact on soil biodiversity. When farmers plow up soil, they disrupt the ability of communities of insects and other invertebrates to recycle dead plants into the rich, stable organic carbon that makes soils fertile similarly, chemical use impairs the microorganisms involved in this process: scientists have found fewer species of beneficial bacteria and fungi in soils where chemical fertilizers and pesticides are used. As a result, these soils become less biodiverse. Such changes also contribute to climate change: soil stores more than 1.6 trillion tons of CO2 globally, but heavily disturbed soils with little biodiversity rapidly lose that carbon to streams and the atmosphere. Chemical usage may also have an influence on ecosystems located far from the farm. Nitrogen fertilizers, which aid plant development, may leach into rivers and produce excessive algae growth (known as an algal bloom), limiting light to the remainder of the water. When algae die, their breakdown consumes all of the available oxygen in the water, resulting in "dead zones," which are unsuitable for fish and other aquatic life. This process, known as eutrophication, may occur in both freshwater and saltwater. Excess manure from industrial farms contains similar nutrients and leads to eutrophication.

One of the most well-known examples of eutrophication is a 7,829 square mile dead zone in the Gulf of Mexico caused by fertilizers from farms across the Midwest draining into the Mississippi River. While some fish can find new habitat, these oxygen-free zones are fatal to animals that live on or in the seabed: these areas may have less than half the species as higher-oxygen sites. On a worldwide basis, industrial agriculture endangers biodiversity by contributing significantly to climate change. Agriculture-related emissions, mostly from chemical fertilizers and factory-farmed cattle, account for more than 20% of total greenhouse gas emissions each year. Climate change is one of the most significant threats to biodiversity, affecting even distant places where people have little influence. Warming temperatures have already been shown to affect the reproduction of migratory birds and other animals, and extreme weather cycles can completely alter the makeup of plant and soil communities. Overall, the pressures of a warming climate favor adaptable invasive species, which could annihilate millions of highly specialized plants, animals, and microorganisms. Climate change-related biodiversity loss, according to scientists predicting these changes, might constitute one of the greatest mass extinctions in Earth history [9]. While there are thousands of potentially edible plant species on the planet, the FAO estimates that 75 percent of the food on the planet currently comes from only plants and animals that we raise on a large scale. Many of these foods are popular due to their consistency and reliability, but they've displaced countless varieties of grains, fruits, vegetables, and livestock. Many of these crop kinds go extinct when they are no longer farmed because they are not found in nature. Domesticated crop and livestock biodiversity is essential because it guarantees a vast gene pool for qualities such as disease resistance; producing just a few species of plants makes our food supply susceptible to risks such as climate change and illness. Preserving wild relatives of crop plants, which are also threatened by industrial agriculture and other development, is important for the same reason: wild populations contain potentially useful genes that have been bred out of their cultivated relatives. There is also a human dimension to preserving biodiversity in crops and livestock, because they become unique foods that are essential to cultures, cuisines, and diets all over the world.

The widespread loss of biodiversity in agriculture is an example of genetic erosion, as defined by scientists. Genetic erosion can occur when entire species are lost: for example, when corn (a species native to Central America) was introduced into ancient North America, it began replacing a number of domesticated plants. Genetic erosion can also occur within species: of the 400,00 varieties of rice that once existed in India, only 30,000 remain today. This erosion occurs over time. Commercial breeding eventually restricted hundreds of local types, known as landraces, into a smaller number of varieties for most crops. In the twentieth century, the introduction of hybridized seeds and genetic manipulation expedited this trend. Control of the seed industry is held by a small number of companies, limiting farmers' options and driving down diversity even further: the four largest seed companies in the United States control 85 percent of the market, and most sales are of a few varieties of genetically modified corn and soy.

While current crop types provide stability and large yields, many rely on significant chemical usage to be productive and must be grown alone in a monoculture to get the greatest results. Crop monocultures were common during the Green Revolution: in the latter half of the twentieth century, modern varieties of wheat and rice — which propagated year after year — crowded out more diverse rotations of other crops, such as millets, legumes, and root crops. This transition helped provide food for a growing population, but it also completely displaced many crop varieties, and created an agricultural landscape dominated by chemical fertilizers. Monocultures may provide regularity to farmers and the food business, but also endanger food security. The majority of the world's banana output in the early twentieth century came from a single variety: the Gros Michel. A Panama Disease (a soil-dwelling fungus) epidemic in the 1950s almost wiped off the Gros Michel, which was particularly vulnerable to it. The Central American banana industry averted total catastrophe by switching to a different type, the Cavendish banana, which was immune to the fungus but smaller and less flavorful. The banana business was rescued by biodiversity 70 years ago, but the industry has made the same error again: the Cavendish banana now accounts for 99 percent of all banana exports. As another strain of Panama Disease that can attack the Cavendish Banana threatens to take over the industry, researchers are turning to other, less common banana varieties to try and breed more resistant crops. Apples, wheat, and other crops face similar disease threats, and neglected and rare varieties of these crops may hold the answer to their preservation [10].

Low biodiversity agricultural systems — both crop monocultures and industrial farms – promote climate change by diminishing soil carbon reserves and depending on greenhouse gas-intensive fertilizers. Climate change, in turn, presents dangers to agriculture: crops will need to adjust to drier, saltier soils and more frequent flooding, and animals will need to adapt to harsh weather conditions. These characteristics may be found in crop and animal types all throughout the globe, although many of them have been largely superseded by uniform kinds that are better suited to modern agriculture. Finally, adjusting agriculture to the difficulties of climate change will need protecting and drawing on the same pool of genetic resources that industrial breeding has slowly depleted over decades. Food is a defining component of culture, and every cuisine on the planet is dependent on distinct crops and animals. Unfortunately, many kinds are being displaced by commercially-bred crops, which are often imported from other nations. While new crops may be more productive in chemical-intensive monocultures, they tend to supplant culturally significant ones.

When local crop varieties disappear, food sovereignty a community's ability to access culturally appropriate food at a fair price is jeopardized. The replacement of local crop varieties with commercially bred imports increases farmers' reliance on chemical use and purchased seeds rather than saved ones. This eventually transfers money from small farmers all around the globe to giant agribusinesses. Many farmers are forced off their land as costs rise, even if they continue to grow traditional crops; the rush to cash in on lucrative new varieties drives up demand for farmland, rendering traditional farms unable to compete. This further limits their ability to grow culturally appropriate foods and contributes to the disappearance of biodiversity in crops and livestock.

Given that agriculture's growing footprint is responsible for so much habitat degradation, preventing wild areas from being converted to farmland is vital to biodiversity conservation. Farmers and scientists are producing food in a manner that leverages biodiversity to make the most of what nature gives by incorporating both old wisdom and modern research. This method is known as agroecology, and it is a key component of regenerative agriculture, which builds up natural resources such as healthy soil and water rather than depleting them.

While adopting agroecology is a revolutionary move away from industrial farming, it is not a new concept: these methods are often taken from Indigenous peoples throughout the globe, who have constructed sophisticated agro ecological systems that live in harmony with nature. Preserving and revitalizing these Indigenous practices may help make agriculture more sustainable across the globe while also preserving biodiversity. The fact that 80 percent of the world's biodiversity is kept on lands managed by indigenous people is testimony to the promise of agroecology.

Building a sustainable agroecosystem that is not dependent on chemicals is a fundamental component of regenerative agriculture. Harnessing biodiversity is critical to this, and adding a few extra species to large, mono cultured areas may provide significant advantages to both crops and animals. Creating productive agroecosystems entails, in the tradition of Indigenous peoples, picking plants that will benefit each other rather than depending on chemical inputs. Legumes, for example, like beans and lentils, contribute nitrogen to the soil, which other plants need to flourish. This has far-reaching implications: incorporating legumes into diverse fields not only provides crops with natural fertilizer, but it also avoids all of the greenhouse gas emissions associated with synthetic fertilizers, aiding in the fight against global warming. Other plants can provide valuable shade or support, similar to the classic "three sisters" system of Native American agriculture. Intercropping is the practice of combining plants in this manner, and it may assist reduce a farm's environmental imprint. Farmers can reap enormous benefits from growing crops in intercropped systems even without chemical inputs: experiments with corn, beans, wheat, bananas, and other crops have all shown that such systems can be more productive than their industrial counterparts while enhancing biodiversity on the farm and creating a varied, rich habitat for wildlife.

Agroforestry (also a traditional, Indigenous way of land management) is another strategy for creating biodiverse agroecosystems by incorporating woody plants within crops and pastures. This may include fruit and nut trees, as well as bushes chopped and gathered for biofuel. Tree roots also improve soil fertility by adding carbon and preventing erosion; compared to a traditional monoculture, some agroforestry systems see a 40% increase in yields of many crops. Models predict that existing agroforestry plantations will remove more than 2 billion tons of CO2 from the atmosphere over the next 50 years, and expanding these systems could be a valuable strategy in combating climate change.

Animals are often significant participants in agro ecological systems. Animals in an agro ecological system use less resources than feedlot animals because they consume crop wastes and other items that would otherwise go to waste. Animal dung is an effective natural fertilizer that promotes rich soil and high plant yield. Indigenous peoples around the world have used grazing livestock in this manner to manage grasslands to maximize productivity, and adopting these systems today can benefit biodiversity on wild grasslands. Careful grazing also boosts biodiversity on the farm: grazing animals can clear patches of grass and turn up soil with their hooves on well-managed pasture, creating an ideal environment for different plants to thrive.

Preserving genetic variation in livestock is essential for the same reasons that it is important to conserve diversity in crops: characteristics such as stress and heat tolerance are significant because they allow animals adapt to a broad range of environments outside of the controlled setting of a factory farm. Diverse livestock breeds also have distinct behaviors that contribute to a diverse agroecosystem; for example, various types of livestock have different grazing habits, and so an array of species and breeds may support great variety in a pasture. Adding animals to an agro ecological system may also provide farmers with an additional source of income, particularly in low-income regions; this financial boost is crucial to sustaining more sustainable farms.

Biodiverse agroecosystems also provide rich, low-chemical habitats for wild creatures. Birds, invertebrates, and other small animals are more common and varied in agroecosystems that include a variety of crops, according to biodiversity surveys in agriculture. Many of these species may give a broad range of advantages to crops. Diverse agroecosystems may reduce pests by up to 50% and double pollinator activity when compared to monocultures that exclude beneficial insects. One approach that harnesses natural biodiversity on the farm combines strips of native prairie plants into agricultural areas. This enriches the soil, attracts pollinators, and provides some hay for cattle. Farms with prairie strips may support three times more diversified insect and bird populations than farms without them, as well as witness huge reductions in fertilizer runoff and soil erosion, reducing their carbon footprint.

Creating groups of beneficial wild animals is an important component of integrated pest control, or IPM. Pesticides are only used as a last resort in integrated pest control, with positive connections between insects and plants serving as the first line of defense. Although it takes time and effort to build a functional and robust agroecosystem, these approaches generally see lower levels of damaging pests than conventional systems, where pesticides indiscriminately kill off beneficial insects along the way. As with other aspects of agroecology, using beneficial plants and insects to control pests is a core feature of indigenous agricultural practices around the world, and the push for sustainable agricultural development is putting this traditional, indigenous agricultural practice under pressure. It is critical to conserve the many variety of crops and animals under production, in addition to leveraging the advantages of species diversity to establish and sustain productive and healthy agroecosystems. This involves seed and gene banks, but it also need the involvement of farmers, gardeners, and eaters all across the world.

Indigenous people across the globe play an essential role in preserving agricultural biodiversity. Unfortunately, these genetic resources are often removed from the communities that have protected them and subsequently commercialized. Recognizing and paying these communities for their efforts is critical to preserving biodiversity. The Potato Park, for example, pays Andean farmers to catalog and develop biodiversity, and has doubled local incomes while expanding crop diversity.

Partnerships between indigenous groups, governments, and other organizations, such as the Native American Food Sovereignty Alliance, help to reintroduce preserved crop varieties while creating a platform for benefit. Other seed preservation programs harvest seeds and store them for a long time. Organizations such as the Crop Trust protect hundreds of crop types while investigating their genetic composition and documenting their cultural past. The Svalbard Global Seed Vault in Norway, one of the world's biggest seed banks, contains nearly a million samples from across the globe in cold storage. Smaller networks of seed banks are also important for preserving local landraces and variations.

Livestock preservation is also critical. It is possible to preserve sperm and egg cells from animals in the same way that seed banks for crops are preserved, and the FAO has already established regional gene banks for animals in Africa, Asia, and Latin America. These gene banks can be more difficult to maintain, as they require expensive equipment and consistent power, but preserving live animals in collections (and on farms) is another viable approach to livestock conservation. Organizations such as the Livestock Conservancy achieve this by connecting individuals who grow heritage breeds, teaching them how to manage them, and assisting them in maintaining a wide breeding pool in diverse areas. It is equally crucial to maintain agricultural and animal diversity on farms and in gardens. The Slow Food movement takes a "eat it to save it" approach to biodiversity: by promoting unique regional foods, chefs and activists create a new market for farmers who are encouraged to continue growing those crops. In addition to seed banks and large collections of living plants across the country, groups like the Seed Savers Exchange foster connections among individual gardeners who are preserving more than 25,000 heirloom vegetables and other crops.

CONCLUSION

Finally, biodiversity is critical in agriculture and is required for the long-term sustainability of our food systems. The richness and variability of plants, animals, and microbes within agricultural environments is referred to as agricultural biodiversity. Agriculture's biodiversity guarantees a diverse variety of genetic resources, including crop types and animal breeds. The development of robust and adaptive agricultural systems that can endure environmental changes, pests, and illnesses requires genetic diversity. It offers the foundation for agricultural development by enabling farmers to choose and breed plants and animals with desired characteristics.

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CHAPTER 5

A BRIEF OVERVIEW OF THE BIODIVERSITY AND CONSERVATION CONCEPT

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ABSTRACT:

Biodiversity is the totality of variety found at all levels of biological organization. Variety at the genetic, species, and ecological levels is very important, and conservation efforts attempt to maintain variety at all of these levels. The systems that sustain all life on Earth, including humans, rely on biodiversity. We cannot have healthy ecosystems that give us with the oxygen we breathe and the food we consume without a diverse variety of animals, plants, and microbes. People also respect nature in and of itself. The topic of biodiversity conservation was covered in this chapter.

KEYWORDS:

Animal Genetic, Climate Change, Genetic Diversity, Genetic Resource, Genetic Variety.

INTRODUCTION

Crop diversity, also known as crop biodiversity, refers to the variety and variability of crops and plants used in agriculture, as well as their genetic and phenotypic features; it is a subset of and a particular aspect of agricultural biodiversity. Over the past 50 years, genetic diversity within each crop and the number of species regularly farmed have both fallen dramatically. Agricultural variety decline endangers global food security since the world's human population is dependent on fewer agricultural kinds from fewer crop species. Crops are increasingly grown in monoculture, which means that if a single disease overcomes a variety's resistance, as in Ireland's historic Great Famine, it can destroy an entire harvest or, in the case of the 'Gros Michel' banana, it can cause the commercial extinction of an entire variety.

Livestock biodiversity

Animal genetic resources for food and agriculture (An GR), also known as farm animal genetic resources or livestock biodiversity, are genetic resources of avian and mammalian species utilized for food and agriculture. A GR is a subset of and a kind of agricultural biodiversity. An GR may be found in living populations or in genetically preserved materials such as cryopreserved sperm or embryos. The variety of animal genetic resources encompasses species, breed, and within-breed variation. There are now 8,800 distinct breeds of birds and animals belonging to 38 different species that are utilized for food and agriculture [1].

Levels

The term genetic diversity refers to the variety and variability that exists within and between species. It can refer to naturally occurring genetic variability within and between populations of a species, such as wild relatives of food crops, or to human-created variability, such as farmer-developed traditional crop varieties known as landraces, or commercially bred crop varieties (e.g., different apple varieties: Fuji, Golden Delicious, Golden Pippin, and so on). All food crop species have significant genetic variety, especially in centers of origin, which are geographical places where species were first formed. The Andean area of Peru, for example, is a center of origin for specific tuber species, with over 1,483 variants of these species identified there. Genetic diversity is important because different genes produce important traits such as nutrient composition, hardiness to different environments, pest resistance, or abundant harvests. Genetic diversity is decreasing as a result of agricultural modernization, changing land use, and climate change, among other factors. (It is even possible that breeding for pest and disease resistance in response to climate change will reduce agrobiodiversity.) Genetic diversity is not static, but is constantly evolving in response to environmental changes and human intervention, whether farmers or breeders [2].

Species Diversity

Depending on criteria, the number of species considered to contribute to food alone varies from 5,538 to 75,000. A conservative estimate is that roughly 6,000 species are routinely utilized for food. Agriculture is defined as crop and livestock production, forestry, fisheries, and aquaculture. It also includes "associated biodiversity," which is defined as "the vast range of organisms that live in and around food and agricultural production systems, sustaining them and contributing to their output." Aquatic variety is an essential component of agricultural biodiversity, and artisanal fisher folk and smallholder farmers' protection and sustainable use of local aquatic ecosystems, ponds, rivers, and coastal commons is crucial to the survival of both people and the environment (Figure.1). Because aquatic species, particularly fish, constitute a significant portion of our food supply while also sustaining the income of coastal peoples, it is vital that fisher folk and smallholder farmers have access to these resources.

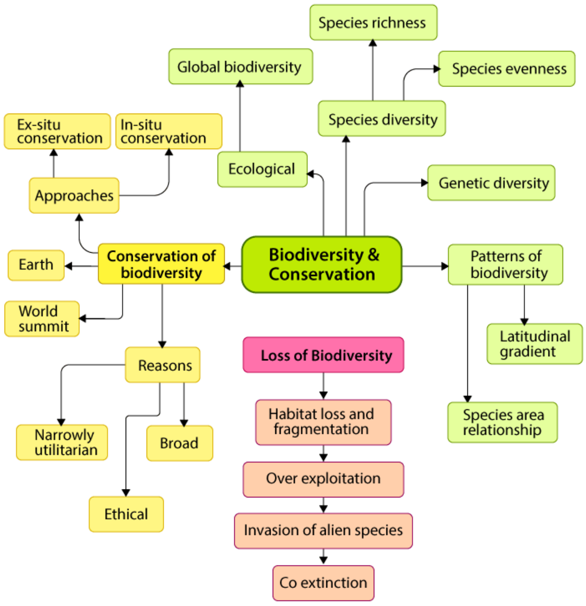

Figure 1: biodiversity and conservation concept map: Diagrame showing the overview of the biodiversity and conservation concept map (Byjus.com).

The various ecosystems

The variety and variability of distinct components in a certain geographical region (e.g., landscape, nation) is referred to as ecosystem diversity. Ecosystem diversity in the context of agrobiodiversity refers to the diversity within and across agroecosystems, such as pastures, ponds and rivers, planted fields, hedges, trees, and so on. Ecosystem services are the benefits provided to humans by well-functioning ecosystems (agroecosystems as well as wild ecosystems such as forests or grasslands). They are typically classified into four broad categories: provisioning (direct provision of goods such as food and water), supporting (agriculturist-related services), and sustaining (agriculturism-related services) [3].

Provisioning

The contribution of agrobiodiversity to supplying services is mostly for food and nutrition. Food biodiversity is defined as "the diversity of plants, animals, and other organisms used for food, covering genetic resources within species, between species, and provided by ecosystems." Historically, at least 6,000 plant species and several animal species have been used as human sustenance. This number is thought to be declining today, raising worries regarding long-term food diversification. Food biodiversity also includes crop subspecies or variants, such as the numerous forms of the Brassica oleracea species (cauliflowers, various broccolis, cabbages, Brussels sprouts, and so on). Many species that have been overlooked by mainstream research ('orphan' or 'neglected and underutilized' species) are rich in micronutrients and other healthful components. There can also be a wide variation in nutrient composition among different varieties of a species; for example, some sweet potato varieties contain negligible levels of beta-carotene, while others can contain up to 23,100 mcg per 100g of raw, peeled Sustainable food security is connected to increasing the conservation, long-term use, and diversification of all genetic resources for food and agriculture, particularly plant and animal genetic resources, in all kinds of production systems.

Supporting

The contribution of agrobiodiversity to supporting services is biological or life support to production, with a focus on conservation, sustainable use, and augmentation of biological resources that support sustainable production systems. The primary objective is to preserve genetic variety in crops and animals so that it may be used to adapt to new and changing climate and weather conditions. Crop and animal development programs rely on genetic variety to breed new types of crops and livestock in response to customer demand and farmer requirements. Crop wild cousins, or wild plant species that are genetically linked to farmed crops, are a significant source of genetic variety. A second supporting function is the preservation of natural biodiversity habitat, especially linked species such as pollinators and predators. Agrobiodiversity may help natural biodiversity by using field margins, riparian corridors, hedgerows, and tree clumps to supply and link habitats. Maintaining healthy soil biota is another supporting function [4].

Regulating and Controlling Pests

Agrobiodiversity contributes to pollinator health by: (a) providing habitat for them to live and breed; (b) providing non-chemical biological pest control options (see below) so that insecticide use can be reduced while insect pollinators are not harmed; and (c) providing a symbiotic relationship of constant flower production, with crops flowering at different times. Agrobiodiversity helps pest control by (a) providing a habitat for pests' natural enemies to live and breed in; and (b) providing a wide genetic diversity, which means genes with resistance to any given pathogen or pest are more likely to exist, and the plant can evolve as pests and diseases evolve.

Carbon Capture and Storage

When employed as part of a package of agro ecological practices, such as supplying cover crops that may be dug into the land as green manure, maintaining tree stands and hedgerows, and safeguarding soil integrity so that local bacteria can flourish, agrobiodiversity helps to carbon absorption. Farmers and breeders may harness genetic diversity to develop varieties that are more resistant to climate change and, when paired with techniques like as. Agrobiodiversity is important for cultural ecosystem services in the form of food biodiversity, which is important for local cuisines throughout the globe. Agrobiodiversity produces regionally valued crops and species, as well as distinct variants with cultural relevance. For example, ethnic traditional cultures influence the conservation of a wide variety of rice varieties in China (e.g., red rice, sweet glutinous rices) developed by farmers over thousands of years and used in traditional cultures, rituals, and customs. Furthermore, some traditional cultures use agrobiodiversity in cultural rituals; for example, many populations of fruit species (pomelo and mango) are maintained in rural communities specifically for use at the 'Chhath Puja' festival, which is celebrated in parts of India, Nepal, and Mauritius. Home gardens are important as culturally constructed spaces where agrobiodiversity is conserved for a variety of social, aesthetic, and cultural reasons.

Agrobiodiversity Extinction

Agrobiodiversity is under threat from changing land use patterns (urbanization, deforestation), agricultural modernization (monocultures and abandonment of traditional, biodiversity-based practices), and Westernization of diets and supply chains. Genetic erosion, or the loss of genetic variety, is caused by agrobiodiversity loss, which involves the loss of individual genes as well as particular combinations of genes (or gene complexes) reflected in locally adapted landraces or breeds. When there is insufficient genetic variety within a plant population, the population as a whole is highly susceptible to disease, pests, or other causes.

Changes in human diets impact and are influenced by reduced agrobiodiversity. Since the mid-1900s, worldwide human diets have grown more diversified in terms of consumption of major commercial staple crops, with a corresponding drop in consumption of locally or regionally significant crops, and hence have become more homogenous internationally. Between 1961 and 2009, the differences in foods eaten in different countries decreased by 68%.

The modern 'global standard' diet contains an increasingly large percentage of a relatively small number of major staple commodity crops, which have increased significantly in the share of total food energy (calories), protein, fat, and food weight that they provide to the world's human population, including wheat, rice, sugar, maize, soybean (by +284%), palladium (by +284%), palla Whereas nations used to consume higher quantities of locally or regionally relevant food biodiversity, wheat has become a staple in over 97% of countries, with other global staples following suit. Other crops that have dropped significantly during the same time period include rye, yam, sweet potato (-45%), cassava (-38%), coconut, sorghum (-52%), and millets (-45%) [5].

Conservation

Attempts to preserve or protect agrobiodiversity usually concentrate on the species or genetic level of agrobiodiversity. Ex situ conservation of genetic variety and species diversity entails removing the materials from their growing place and caring for them elsewhere, while in situ conservation means preserving the materials in their natural or cultivated environment. Ex situ conservation is defined as the "conservation of biological diversity components outside their natural habitats." Ex situ conservation is the conservation of genetic resources (species, varieties, cultivars, sub-species, landraces, and so on) for food and agriculture outside their natural habitat, in a managed environment such as botanical gardens, seedbanks, pollen banks, field gene banks, cryo banks, or herbaria. For seed-bearing crops, ex situ conservation has some advantages: 1) seed requires little space; 2) ex situ conservation can be implemented anywhere; 3) what is conserved is easily accessible for distribution, further use, research, and breeding; and 4) the costs for maintaining genetic diversity that has no immediate production or market value are minimal.

The following are some of the disadvantages of ex situ conservation: 1) it is expensive to keep seeds and germplasm healthy in perpetual storage or in field collections; 2) coverage of the diversity of neglected and underutilized crops or crop wild relatives is currently very limited; gene banks have largely focused on the conservation of major staple crops, while non-staple crops and crop wild relatives are underrepresented; 3) there are species with 'recalcitrant' seeds, which mean

In-situ conservation

In situ conservation is defined as "the conservation of ecosystems and natural habitats, as well as the maintenance and recovery of viable populations of species in their natural surroundings and, in the case of domesticated or cultivated species, in the surroundings where they have developed their distinctive properties". It includes both the conservation of trees and crop wild relatives in situ in the wild, as well as the conservation of landraces and neglected and underutilized species. Conserving agrobiodiversity in situ allows species to continue evolving in response to natural and human pressures. In the case of crops, smallholder farmers retain a large amount of diversity, particularly for many crops in their centers of domestication and diversity. Farmers there continue to plant landraces and retain traditional knowledge and seed management procedures, a process known as de facto conservation. Home gardens, too, are repositories of high levels of species variety, and traditional landraces contain extensive genetic variation. Because most tree seeds cannot be preserved ex situ and because there approximately 60,000 tree species each with several populations, in situ conservation is regarded the most acceptable strategy for forest trees. A meta-analysis of studies comparing biodiversity discovered that when compared to organic cropping systems, conventional systems had significantly lower species richness and abundance (30% greater richness and 50% greater abundance in organic systems, on average), despite the fact that 16% of studies found a higher level of species richness in conventional systems. For high levels of biodiversity, in situ conservation is relatively low cost, particularly for crop wild relatives, neglected and underutilized species, landraces, trees, fish, and livestock; however, in situ conserved species and varieties may be vulnerable to climate change, land use changes, and market demand [6].

Agriculture biodiversity refers to the biodiversity present on agricultural land. The entire variety of species present in a place at all levels of biological organization is referred to as biodiversity.

It is distinguished by a diverse ecological system supported by different habitats. Biodiversity declines in agricultural regions when diverse landscapes are lost and native flora are replaced with produced crops. Biodiversity is a measure of an ecosystem's biotic and abiotic variety, as defined by heterogeneity. With the global increase in food consumption and the success of popular crops, biodiversity loss in agriculture has become a growing concern. The loss of variety on agricultural grounds reduces species diversification.

Extinctions of Biodiversity

Agriculture causes a land-use conflict between animals and people. Land usage for agriculture has been a major contributor to biodiversity loss. Over the last few hundred years, an increase in the quantity of pasture and agricultural land has resulted in the rapid loss of natural ecosystems Agriculture now occupies more than 40% of the earth's land area, according to the United Nations Food and Agriculture Organization. Because so much land has been converted to agriculture, habitat loss has been identified as a major source of biodiversity loss. Farmland biodiversity is declining due to changes in farming techniques and rising agricultural intensity. Despite this, "biodiversity is just as important on farms and in fields as it is in deep river valleys or mountain cloud forests," according to the FAO. By emphasizing cultivated crops above native flora, monoculture lowers biodiversity.

The loss of habitat connectivity in agricultural regions has an impact on biodiversity by reducing population numbers and limiting access to external resources. Species that face habitat fragmentation may also experience a genetic bottleneck. The reduced gene pool endangers species due to factors such as inbreeding depression, in which less favorable populations reduce species survival rates. The abundance of butterflies, for example, has been shown to increase with variety. Non-cropped land, such as fallow land, grass margins between fields, and patches of scrub along field boundaries, increase agricultural variety and hence biodiversity. Plants attract insects, which attract certain bird species, which attract their natural predators. Non-cropped ground provides cover for animals migrating over the terrain. In Asian rice, one study found that planting flowering crops in strips beside rice fields could reduce pests by 70%, increase yields by 5%, and result in a 7.5% economic gain.

The Ecological Revolution

The loss of heterogeneity, defined as the loss of biotic and abiotic variation, is one of the challenges to biodiversity in modern agriculture. Since 1966, the Green Revolution has increased agricultural production through scientific, economic, and political advances in order to promote global food security.

One example is the use of genetically modified crops, which allow for enhanced production, insect resistance, and superior crop variations. Heterogeneity is essential for promoting species heterogeneity, which is required for maintaining stable ecological systems and delivering ecosystem benefits. Land size is one of the characteristics associated with species variety; one study discovered a link between smaller agricultural fields and increased species richness. Agriculture is a process that transforms any ecosystem, with a primary focus on producing food for human consumption. Views on ecosystem services may be presented through perspectives that benefit people ecologically, economically, and culturally in order to promote agricultural practices that sustain ecosystem services [7].

DISCUSSION

The reduction in the variety of living forms on Earth is referred to as biodiversity loss. Many things may contribute to this, including human activities, climate change, and natural calamities. The loss of biodiversity may harm both the environment and human populations. The activity of maintaining the natural environment and its biological variety is known as biodiversity conservation. This involves preserving genetic diversity, ecosystems, and landscapes. Conservationists often encourage the sustainable use of natural resources and public education to accomplish this.

Biodiversity refers to the diversity of life on Earth and is one of the planet's most valuable resources. The process of safeguarding the natural environment and its various species is known as biodiversity conservation. This may be accomplished by creating protected places such as national parks and natural reserves, as well as supporting responsible land-use practices. Biodiversity conservation is essential for a variety of reasons. To begin, it is critical to preserve the ecosystems that supply us with crucial services such as clean air and water. Second, many of the world's medicinal plants originate from biodiversity hotspots, therefore protecting these areas is critical to ensuring that we continue to have access to novel treatments. Third, biodiversity is crucial for tourism, since many people visit parks and reserves to view the incredible variety of flora and animals that live there. Finally, it is just immoral to kill species for the purpose of destroying them when there is no reason to do so.

We may contribute to biodiversity conservation in a variety of ways. To begin, we may minimize our consumption, particularly of resources originating from endangered species. Second, we may advocate for the creation of protected areas and the financing of conservation programs. Third, we may vote for conservation-minded candidates and speak out about the value of biodiversity. Finally, we can teach ourselves and our children the value of preserving our planet's biodiversity. There are many strategies that may be utilized to help protect biodiversity. Protecting the habitats of diverse species is one of the most essential things that can be done to help maintain biodiversity. This may be accomplished by establishing protected places such as national parks and nature reserves. Restoring damaged habitats is another strategy to help protect biodiversity. This might include things like planting fresh trees and repairing wetlands. One of the most serious dangers to biodiversity is habitat degradation. Reduced habitat damage may aid in the conservation of the species that dwell in such environments. Another essential strategy to help protect biodiversity is to promote sustainable resource usage. This covers things like utilizing resources in a manner that does not hurt the environment or reduces their availability in the future. Another key strategy to help maintain biodiversity is to educate the public about its value and the risks it confronts. This might include things like giving information on the many species that exist and the ecosystems in which they dwell [8].

The protection of natural resources within their native settings is known as in situ conservation. This involves the preservation of plant and animal species, as well as their habitats and the biological processes that keep them alive. Conservation in situ is sometimes known as "on-site" or "in-place" conservation. In situ conservation is a vital component of the global biodiversity protection plan. It is also the least expensive and least invasive kind of conservation. We can conserve the maximum number of plants and animals while reducing environmental effect by safeguarding species and their habitats in situ. Because it does not alter the natural ecology of the species or ecosystem, in situ conservation is frequently more effective than ex situ conservation

(conservation outside of their native habitats). Furthermore, in situ conservation is less expensive and more readily adaptable to changing environmental circumstances.

National Parks are areas of land and/or water designated by national governments as natural places for the public's preservation and pleasure. National parks are often enormous regions of natural beauty. National governments set them aside to conserve the environment and the public's right to enjoy it. National parks are often home to a diverse range of plant and animal life, as well as possibilities for outdoor activities such as hiking, camping, and fishing. A biodiversity hotspot is a location with a high concentration of extinction-threatened species. Hotspots are often seen in tropical or subtropical areas. The Amazon Basin rainforest is the most well-known biodiversity hotspot. The Amazon rainforest is home to about 10,000 plant species, 2,000 bird species, and 400 animal species. Other hotspots include Southeast Asia's rainforests, African savannahs, and the Pacific and Caribbean coral reefs.

The Gene Sanctuary is a place inside the research station Biologic Space Laboratories. It is a storage and research facility for Met roids. The sanctuary is a vast, enclosed space with a high ceiling that is packed with Met roids at different stages of development. The Gene Sanctuary may be found on the planet SR388. It is a big, enclosed space with a high ceiling that is teeming with Met roids at different stages of development. Sacred groves are regions of natural plants that are revered by a certain culture. They are often seen around temples or other sacred structures. Sacred woods are often utilized for rites or as refuges. The protection of plants and animals in their native environments is known as in situ conservation. It is the most efficient method of preserving biodiversity.

Ex situ conservation has the major benefit of preserving species even when they are not present in the wild. This is significant because it indicates that species on the verge of extinction may be spared. Ex situ conservation also enables scientists to study and learn more about vulnerable and endangered species. The Convention on Biological Diversity (CBD) is a convention that was established in 1992 to save biodiversity. The equal and fair distribution of the advantages derived from the exploitation of genetic resources. Over 190 nations have ratified the CBD, making it one of the most successful environmental accords in history [9].

The CBD attempts to accomplish its aims in part by developing national biodiversity plans. A national biodiversity strategy is a document that specifies how a country's biodiversity will be protected and managed. It generally comprises a list of conservation priority areas as well as specific conservation measures that will be implemented to accomplish conservation objectives. In addition, the CBD urges governments to develop regional biodiversity initiatives. A regional biodiversity strategy is a plan for a group of nations to conserve and manage their biodiversity. It generally comprises a list of conservation priority areas as well as specific conservation measures that will be implemented to accomplish conservation objectives. In addition, the CBD urges governments to develop international biodiversity plans. A document outlining how a collection of nations will maintain and manage its biodiversity is known as an international biodiversity strategy. It generally comprises a list of conservation priority areas as well as specific conservation measures that will be implemented to accomplish conservation objectives.

The world's biodiversity is under threat. Extinctions are occurring at an alarming pace, and many ecosystems are on the verge of collapse. Humans suffer greatly as a result of biodiversity loss. It has the potential to disrupt the food chain, harm ecosystems that offer critical functions such as water purification and climate control, and limit agricultural and animal genetic diversity.

Human happiness and leisure need biodiversity as well. It is in charge of the natural world's splendor and offers possibilities for hiking, bird viewing, and other sorts of outdoor enjoyment. If we want to secure a healthy, sustainable future for ourselves and future generations, we must take action to safeguard biodiversity.

Protected areas are areas of land or water that have been set aside and maintained particularly to safeguard biodiversity. The two most serious threats to biodiversity are habitat loss and degradation. When an area of habitat is lost, it is referred to as habitat loss, while habitat degradation happens when an area of habitat is harmed, making it less suitable for species. Sustainable natural resource use is defined as utilizing resources in a manner that does not harm or destroy the environment. Genetic diversity refers to the range of genes within a species. It is critical for a species' existence since it enables for adaptability to changing environmental circumstances. Species conservation is the preservation of individual species from extinction. Climate change is a worldwide concern that is wreaking havoc on biodiversity. Climate change must be addressed in order to conserve biodiversity. The goal of biodiversity conservation is to maintain natural ecosystems and the animals that dwell within them. The loss of biodiversity may result in the depletion of important natural resources and the extinction of species .

CONCLUSION

Walter G. Rosen first used the word "biodiversity" in his work. Nature is made up of a diverse range of animals, plants, fungi, and prokaryotic creatures that coexist. Each of the species listed lives and works in an ecosystem to ensure ecological balance. Conservation is the care and preservation of these resources in order for them to be available for future generations. It encompasses preserving the variety of species, genes, and ecosystems, as well as environmental services such as nutrient cycling. Support local and regional biodiversity conservation efforts. Purchasing fewer things and ensuring that the products you do purchase have the least effect on biodiversity. Investing in biodiversity-promoting activities. Reducing waste of consumer products such as food, clothing, and electrical equipment. Nature conservation is a moral concept and conservation movement aimed at saving species from extinction, preserving and restoring ecosystems, improving ecosystem services, and safeguarding biological variety. As a result, they aid in soil formation, pollution reduction, and the preservation of land, water, and air resources. These biodiversity functions are critical for ecosystem function and stability.

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CHAPTER 6

A METHODS FOR THE AGRICULTURAL LAND CLASSIFICATION

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ABSTRACT:

Agricultural land is defined as land that is appropriate for crop and animal production. Agricultural land is divided into two types: arable land and grazing land. Cropland, pasture, orchards, groves, vineyards, nurseries, decorative horticultural zones, and limited feeding areas are all examples of agricultural land. The evaluation of land capacity is used to determine the potential for agricultural and non-agricultural land uses. It takes into account individual land use needs and detects possible degradation hazards. It is an essential instrument in the rural planning system of Western Australia.

KEYWORDS:

Agroforestry Systems, Agroforestry Methods, Biodiversity Conservation, Natural Ecosystems, Natural Resource.

INTRODUCTION

Agricultural land usage in the tropics, like in the temperate zone, nearly invariably comes at the price of natural ecosystems and biodiversity. Humans have sought to domesticate tropical ecosystems and landscapes for millennia in order to redirect a bigger percentage of primary output toward their own use. Initially, they achieved this in subtle ways, such as by replenishing woods around campsites with valuable plant species or by clearing tiny sections of woodland or savanna with crude tools and fire. However, as human populations and technical capacities grew, and markets for tropical agricultural goods emerged, agriculture's influence on tropical ecosystems and landscapes became increasingly dramatic. The destruction of the Brazilian coastal rainforest by European immigration for the cultivation of sugarcane, coffee, cocoa, and other commodities is only one example of inefficient agricultural exploitation of a biodiversity-rich tropical habitat [1].

Human influences on tropical and global ecosystems have taken on new dimensions as tropical populations and worldwide markets grew rapidly in the twentieth century. However, the extent to which tropical ecosystems and landscapes have been altered by human land use varies drastically among areas. Human-dominated tropical landscapes can be completely devoid of tree cover, largely forested mosaics of attractively used primary and secondary forests with small clearings for annual crops, home gardens, and habitations, or anything in between, depending on their natural resource base, population density, land use history, proximity to urban markets, and many other factors. Agroforestry encompasses a wide range of intermediate-intensity land use types in which trees continue to cover a considerable part of the landscape and impact microclimate, matter and energy cycles, and biotic activities. 1 Agroforestry has been widely promoted in the tropics over the last three decades as a natural resource management strategy that attempts to balance agricultural development goals with the conservation of soils, water, local and regional climate, and, more recently, biodiversity. Agroforestry methods such as home gardens, crop-fallow rotations, and the use of wood trees in tree crop plantations are being researched in national and international research centers, and agroforestry courses are being taught at colleges and universities worldwide. As a result, there is a large body of scientific information and practical experience on the effects of trees on soil fertility and carbon stocks, crop and tree species matching for different site conditions, tree management, and related agronomic-technical issues.

On plot and landscape sizes, information on complex biotic interactions, such as the relevance of diverse tree cover in pest and disease dynamics, is scarce. A systematic evaluation of information on the biodiversity linked with various agroforestry methods and the landscapes of which they are a part, however, has not been done. This knowledge gap is evident in both field conservation and development programs and university and college courses teaching tropical agroforestry, conservation biology, and related themes. This book seeks to address this gap by examining current understanding on the potential role of agroforestry in tropical biodiversity conservation and highlighting knowledge gaps that need more study. Its specific goals are to investigate the potential of agroforestry for landscape-scale biodiversity conservation in the tropics; to discuss the biodiversity benefits of agroforestry systems and the landscapes of which they are a part, which could increase private and public support for the use of agroforestry in conservation strategies; and to identify some of the ecological, socioeconomic, and political constraints on biodiversity-friendly land use systems.

Agroforestry in Tropical Landscapes Agroforestry is a catch-all word encompassing activities involving the incorporation of trees and other big woody perennials into agricultural systems via the protection of existing trees, active planting and care of new trees, or tolerance of spontaneous tree regeneration. Following a recent definition by the World Agroforestry Center (ICRAF 2000), agroforestry is defined here as a dynamic, ecologically based natural resource management practice that diversifies production for increased social, economic, and environmental benefits through the integration of trees and other tall woody plants on farms and in the agricultural landscape [2].

Landscapes are made up of discrete parts forests, agricultural or agroforestry plots, woodland corridors, or grazing regions that combine to form patches, corridors, and matrix elements. Relief in landscapes, such as hills, plateaus, and valleys, influences the movement and distribution of energy and matter, as well as biotic activities. The presence of agroforestry systems e.g., shaded tree crops, fallow areas, or crop and pasture areas with trees influences ecological processes and characteristics such as fauna and flora presence and dispersal, water and nutrient flows, microclimate, and disease and pest dynamics within the landscape in many tropical landscapes. These landscapes are appropriately referred to as agroforestry landscapes, reflecting the widely held belief in landscape ecology, conservation biology, and agroforestry that certain important effects of agroforestry on biodiversity conservation, water and nutrient cycling, and soil conservation cannot be fully appreciated by focusing solely on the individual plot or system, because their most significant impacts may occur at the landscape scale.

Furthermore, an agroforestry system does not exist in isolation in the sense that farmers may manage forest gardens or shaded tree crop plantations alongside shifting cultivation plots, irrigated rice fields, or pastures, all of which occur in the same landscape and jointly determine its properties. What agroforestry is and how agroforestry practices influence the structure and composition of tropical landscapes are best illustrated by examples (keep in mind that an agroforestry practice or system is not synonymous with an agroforest, which includes the most complex, forest-like types of agroforestry systems). Tropical smallholder farmers often cultivate basic food crops such as upland rice, maize, and cassava in slash-and-burn systems in rotation with natural tree fallows that may last anywhere from a few years to many decades. This shifting cultivation (or swidden agriculture), which results in a mosaic of crop fields and plots with secondary forest or savanna regrowth in the landscape, is one of the oldest and most widespread forms of agroforestry, despite being frequently excluded from the concept of agroforestry on the mistaken assumption that all shifting cultivation is unsustainable or inefficient as a land management strategy.

From their common root in shifting cropping, many specialized agroforestry methods have emerged in various tropical locations. In the West African savanna, for example, it is common for farmers to retain useful trees which may also be difficult to fell and resistant to fire when preparing a plot for cropping, resulting in the parklike landscapes of scattered trees that are typical of this region. Smallholder farmers in Sumatra and Kalimantan (Indonesia) have changed the conventional crop-fallow cycle by including rubber trees into their cropping systems alongside annual and short-lived perennial crops. Introduction: Agroforestry in Biodiversity Conservation in Tropical Landscapes 3 over several decades and tolerance of spontaneous forest regrowth, these systems gradually evolve into a type of managed secondary forest enriched with rubber trees, known as jungle rubber. Similar systems from the middle Amazon have been documented. Highly complicated systems may also be found in Southeast Asia and sections of the Amazon, where farmers grow a food crop (e.g., upland rice) and intercrop it with one or two tall-canopy wood or fruit tree species. After harvesting the crop, they plant additional timber and fruit tree species with intermediate-level canopies, followed by other tree species with lower canopies, resulting in systems that resemble a natural forest [3].

These Sumatran damar (Shorearobusta) and durian (Durio zibethinus) gardens have been properly dubbed agroforests. Coffee and cocoa (both shade-tolerant crops) are typically planted beneath an open canopy of residual trees that were maintained after a forest plot was cut in portions of Latin America and West Africa, resulting in a different sort of complex agroforest. Northern Thailand and Myanmar have both reported tea-based systems (Preechapanya et al., in press). Smallholders typically cultivate trees in tiny home gardens across the tropics for shade and other goods such as fruits and medicinal items.

A complex agroforest in Sumatra with durian (Durio zibethinus) and cinnamon (Cinnamomum burmanii) trees; a rice field is in the foreground. In addition, as is usual in Costa Rica, farmers keep, plant, or allow the spontaneous regeneration of trees in their pastures for shade, fodder, and lumber production, as well as live fencepost. Trees may also be found on farms as hedges along borders, riparian strips along rivers, palm groves in marshy regions, shelterbelts on wind-exposed locations, and woodlots on slopes, low-fertility sites, and cultural and spiritually significant sites. Conservation biologists and other researchers working on the interface between integrated natural resource management and biodiversity conservation have recently shown an interest in agroforestry systems and the heterogeneous mosaic landscapes of which they are a part. Increased biodiversity has been proposed on both theoretical and empirical grounds as making plant communities more robust, and hence as having a direct relationship with long-term productivity improvements. More importantly, as natural ecosystems shrink and remaining patches of natural vegetation are increasingly reduced to isolated habitat islands (protected or not in parks) in a matrix of agricultural land, understanding what land use systems replace natural ecosystems and the nature of the matrix surrounding the remaining fragments becomes critical. When compared to the severe negative effects, agroforestry could play a role in helping to maintain a higher level of biodiversity in these fragmented landscapes, both within and outside protected areas.

Resulting from more dramatic land alterations. Revegetation using agroforestry methods may increase biodiversity conservation in locations where landscapes have been degraded due to insufficient land usage or degraded agricultural areas have been abandoned. All agroforestry systems, no matter how forest-like they look, eventually replace natural ecosystems, either by outright destruction and replanting with crop and tree species or through varying degrees of "domestication" of the original terrain and ecosystem. When compared to other no forest land use options, such as modern, intensively managed monocultures of coffee, rubber, or oil palm with little genetic and structural diversity, or even vast stretches of pasture or annual crops with little or no tree cover, agroforestry systems may offer greater potential as auxiliary tools for biodiversity conservation strategies while meeting production goals. What is the foundation for the belief that agroforestry methods may aid in the conservation of biodiversity in human-dominated landscapes? Is this expectation experimentally supported? One of the primary goals of this work is to provide answers to these issues. We provide three hypothesis for how agroforestry may help conserve biodiversity in human-dominated tropical settings. These theories are examined in depth in the chapters and assessed in the books [4].

The Agroforestry-Deforestation Hypothesis Agroforestry, when used as an alternative to more extensive and less sustainable land use practices, can help reduce pressure to deforest additional land for agriculture, or it can help the local population cope with limited availability of forest land and resources, such as near effectively protected parks. This hypothesis is largely based on the assumption that certain agroforestry practices, if profitable and sustainable, can occupy available labor and meet the needs of a given population on a smaller land area than extensive land use practices like cattle pasture, reducing the need to deforest additional land. Because of low land prices and limited market access, extensive land use practices are widespread in agricultural frontier areas. More intensive agriculture approaches may be able to reduce area demands per family or unit of output more than agroforestry practices, but they may expose farmers to unacceptable economic and ecological risks (Johns 1999). Furthermore, agroforestry practices may be more sustainable and thus allow the use of deforested plots over a longer time period than alternative land use methods such as pure annual cropping (which may rapidly degrade the soil, particularly on erosion-prone and low-fertility sites) and tree crop monocultures (which may be more susceptible to pest and disease outbreaks than agroforestry p As a result, the use of agroforestry may lessen the need to deforest new regions. However, it should be noted that sustainability is not an inherent feature of agroforestry techniques. Even if it is technically possible to manage a particular land use system sustainably, it may be more advantageous for a farmer not to do so if land for new fields and plantations is readily available or if there is an advantage to occupying a large land area (e.g., acquiring property or land use rights).

Agroforestry systems may offer habitat and resources for native plant and animal species that are largely forest-dependent and would not be able to live in a solely agricultural setting. Agroforestry systems, like agroecosystems in general, include both planned and unplanned components. Agroforestry systems, by definition, have greater intended variety (i.e., more planted and chosen plant species) than monoculture crops, albeit not necessarily more than certain conventional mixed cropping systems. Certain agroforestry systems, such as tropical home gardens, which may include several dozen tree and crop species and variations, are regarded as major repositories of tropical tree and crop germplasm. However, not all agroforestry systems are designed to be diverse; for example, many shaded coffee farms comprise mostly of one crop and a single, occasionally exotic shade tree species, while live fences generally consist of just a few tree species. Unplanned diversity, or the plants and animals that colonize or exploit the structure and habitat established by the planted species, is as important as planned variety for the conservation value of agroforestry systems. More possibilities for local flora and fauna may be found in structurally varied perennial vegetation than in structurally simpler monocultures and pastures. Although little is known about such belowground biodiversity benefits of complex land use systems, a humus-rich soil that is not regularly disturbed by tillage and the permanent litter layer that usually develops under agroforestry may also provide appropriate habitat for a diverse soil fauna and microflora that may not be present in simpler and regularly disturbed agricultural systems. The importance of agroforestry systems as refugia for forest-dependent species is especially important in areas bereft of natural vegetation. In such deforested and frequently densely populated landscapes, agroforestry systems may retain more species of plants, animals, and microorganisms from the original ecosystems than corresponding agricultural monocultures and pastures, and thus may be a better compromise between production goals and biodiversity conservation. It should be noted that just counting the species present in an agroforestry system will usually include species that are acclimated to disturbed circumstances and may not need specific protection. Instead, it is vital to assess whether forest-dependent and vulnerable species utilize agroforestry regions, how much they rely on them for habitat or food, and whether their populations are long-term sustainable [5].

In landscapes that are mosaics of agricultural areas and natural vegetation, the conservation value of natural vegetation remnants which may or may not be protected is greater if they are embedded in a landscape dominated by agroforestry elements than if the surrounding matrix is largely devoid of tree cover. This theory refers to the larger-scale qualities that agroforestry components may impose on landscapes in terms of their appropriateness as habitat for native fauna and flora, i.e. impacts that extend beyond the boundaries of an individual agroforestry system to the whole landscape. Agroforestry components may have a considerable effect on ecological processes and features such as microclimate, water and nutrient fluxes, pest and disease dynamics, and the presence and distribution of fauna and flora in tropical land use mosaics. Agroforestry systems, for example, might operate as biological corridors between patches of natural vegetation or as stepping stones to enable animal mobility. When two forest fragments are separated by a tree crop plantation with a diverse shade canopy of rainforest remnant trees, arboreal forest fauna should be able to disperse from one fragment to the other more easily than if they had to cross an open pasture, which may help to reduce problems of small populations in the individual fragments by maintaining biotic connectivity. Insects, birds, and bats may pollinate trees that exist in low numbers in individual patches by traveling from one forest patch to another through a riparian strip or utilizing remnant trees in a meadow as stepping stones.

Birds may transport seeds from one fragment to the next by migrating through living fences, hedges, and windbreaks or flying from one lonely tree to another, boosting seed distribution in fragmented environments. Where agroforestry systems adjoin forest areas, they may also protect them from the stronger winds and harsher microclimate of open agricultural fields and pastures, thereby increasing the size of the core area available to certain sensitive forest interior species. Such agroforestry buffer zones may also protect forests from fire, which is a common management technique for annual crop producers and pastoralists but frowned upon by owners of precious tree crops and wood trees. The potential role of agroforestry in increasing the conservation value of forest fragments and parks through such landscape-scale processes has received little attention, but it has the potential to be extremely important for landscape conservation strategies in heavily but not completely deforested areas.

The book's intended audience and structure are students and practitioners in tropical agriculture, forestry and agroforestry, conservation biology, landscape ecology, natural resource management, ecological economics, and related subjects. In keeping with the subject's multidisciplinary character and the diversity of the intended audience, every attempt has been made to make the language as plain and generally intelligible as possible. The novel is broken into five sections. Part I offers a foundation in conservation biology and landscape ecology that will aid no specialists in understanding subsequent chapters. It also provides an update on contemporary thoughts and research findings in these areas. In conservation initiatives, conservation concessions are implemented as a complimentary option to agroforestry. It examines the ability of certain agroforestry methods to support biodiversity conservation by acting as habitats, biological corridors, and buffer zones for protected areas, as well as promoting connectedness and genetic exchange within landscapes [6].

This section focuses on the floristic, structural, and managerial features of agroforestry systems that maximize their usefulness for biodiversity conservation at the plot and landscape scales. Part IV's purpose is to examine the trade-offs between conservation and production objectives in diverse tropical land use mosaics. This kind of analysis is critical for avoiding conflict and creating relationships between farmers and environmentalists. Timber and non-timber products, hunting opportunities, and protection from pest and disease outbreaks through biological control mechanisms are among the benefits of biodiversity for farmers; costs may include wildlife damage to crops, livestock, and humans, as well as pest and disease transfer between native vegetation and crops. The risks connected with the use of foreign and possibly invasive tree species in agroforestry for natural habitat biodiversity are discussed. The subject of how to manage animals in tropical land use mosaics sustainably is also addressed. The part also discusses the potential of agroforestry to protect natural ecosystems from climate change. The conclusion of the book summarizes the material offered in the volume, makes suggestions, and highlights research needs.

DISCUSSION

For describing agricultural land uses, two broad kinds of categorization systems and accompanying geographic data are available General land-use and land-cover classifications derived from aerial photography and remotely sensed data, and farm-by-farm censuses and surveys. General land-use and land-cover maps have the advantage of displaying the actual geographic or spatial distribution of general categories of agricultural land in relation to other land uses, regardless of political boundaries, but they have the disadvantage of not being specific in terms of crop types and management practices. The classification of agricultural land use based on activities and production figures from the national Census of Agriculture or comparable data provides the opposite issues. The basic census unit is often the county or census tract, with little consideration given to the distribution of land uses within the unit. However, the activities and production statistics on factors such as the total area of each crop harvested within a county, the number of poultry or livestock, irrigation, chemical and fertilizer expenses, and many other features potentially important for water-quality assessment are very detailed.

The US Geological Survey Land Use and Land Cover (LULC) data housed in the Geographic Information Retrieval and Analysis System (GIRAS) is the highest resolution, nationally uniform categorization of land use and land cover presently available for the United States. The national LULC data were mostly derived from color-infrared aerial imagery obtained in the mid-1970s. Polygons of land use and land cover were manually interpreted and defined on 1:250,000-scale maps, and in certain instances, 1:100,000-scale maps, for the whole United States based on this imagery. Anderson's "Land Use and Land Cover Classification System for Use with Remote Sensor Data was used to create the land cover classifications. Table 1 shows a two-level hierarchy of the Anderson categorization system. For the national LULC data, the minimum mapping unit is 10 acres for urban uses, as well as several other categories such as restricted feeding operations and strip mines, and 40 acres for all other classes. Most of the country's land-use maps have been digitized and are accessible as digital downloads. In most sections of the country, the spatial resolution of the US Geological Survey's national LULC data is appropriate for assessing regional water quality. Its main drawbacks for water-quality evaluation are a lack of detail on land-use features such as dominating crops farmed and irrigation, that it is over 20 years old, and that it is impossible to make equivalent updates using presently available remote sensing data [7].

In addition to the national LULC data recorded in GIRAS, there is a considerably more comprehensive classification of the United States' Major Land Uses (MLU). The MLU map, which is also accessible in digital form, was created from a range of information sources to depict circumstances in the 1960s. Despite being more generic and having a lesser resolution than national LULC data, this categorization of important land use patterns is valuable for national-scale analyses. Since the early 1900s, the United States Department of Agriculture (USDA) has classified agricultural land in the United States. Type of farming research were undertaken from 1908 to 1950. In general, these studies progressed from dividing the country into 10 or 12 major agricultural provinces based on crop or livestock dominance and physiographic conditions to much more detailed subdivisions based primarily on farm income sources.

Combining information on general land-use distribution from the U.S. Geological Survey national LULC data, based on the Anderson classification system, with county-based agricultural census data, a new approach to classifying and mapping the distribution of agricultural land use for water-quality assessment was developed. The LULC data is used to locate agricultural land within each county, while crop distribution census data is utilized to classify agricultural land within each county. Data from the 1987 Census of Agriculture were used to divide agricultural land into two primary categories that correspond to the Anderson Level II categories of cropland and pasture and orchards, groves, vineyards, nurseries, and ornamental horticultural areas, referred to collectively as "orchards, vineyards, and nurseries". Separate classification of agricultural land within the Anderson system's two general categories maintains an organizational link to the Anderson system and allows county-based crop statistics and classifications to be associated with actual geographic areas of agricultural land within each county. According to the Census of Agriculture, Anderson's "cropland and pasture" class covers three basic kinds of agricultural land: row crops (including alfalfa), grass hay (all hay except alfalfa), and pasture (rangeland is distinct). Grass hay and pasture are widely planted and are maintained in a very similar fashion throughout the country, but irrigation is more popular in certain places than others. Row crops, on the other hand, encompass a diverse range of specific crops with distinct geographical trends and management needs, such as vastly different water consumption, tillage, fertilizers, and pesticides. The created categorization methods concentrate on row crops for land in the "cropland and pasture" Anderson class and fruit, nut, and nursery crops in the "orchards, vineyards, and nurseries" Anderson class.

Crop classification in both row-crop and orchard, vineyard, and nursery sectors was based on harvested acreage rather than revenue output or a particular management attribute, such as cultivation technique or chemical usage. Conceptually, the objective is for farmland categorization in a certain county to provide an accurate portrayal of the relative areal expanse of dominating crops. Because of the use of census data on harvested acreage, some land that is harvested more than once gets counted twice in contributing to acreage. In this sense, the categorization is based on a whole county's yearly average crop acreage, including within-year rotation [8].

For water-quality studies, classification based on acreage of distinct crops has the benefit of capturing circumstances typical for most of the land that may contribute runoff or recharge to a specific location. This method has the potential problem of failing to account for tiny regions of specialty crops that may have distinct management techniques, such as excessive irrigation or chemical usage, and hence have a disproportionate influence on water quality. These unusual scenarios, which are not geographically broad, are difficult to assess using national county-level data, and any national system will need to be developed using higher resolution data to identify these patterns.

The acreage of each crop in each county was divided by the total of individual row-crop acreages or orchard, vineyard, and nursery acreages in the county, as applicable. As a result, the categorization was formed based on the relative representation of crops within row-crop and orchard, vineyard, and nursery sectors, but is independent of the county's overall quantity of row-crop or orchard, vineyard, and nursery land. For building the categorization system from this normalized data on proportionate areas of specific crops in each county, two broad techniques were examined. Cluster analysis was explored but not implemented. Cluster analysis findings would alter with various data from different census years and geographical dimensions. Furthermore, rather than unambiguous, quantitative evaluations of circumstances, cluster definitions are regarded as general patterns.

When used to identify minor categories, which may be highly essential in water-quality evaluation, it becomes subjective. The second option examined, and chosen, is to categorize each county using basic percentage criteria based on the relative land area of each crop produced. This strategy has the benefit of being straightforward and immediately tied to what can be seen in the field. It is also adaptable in that it allows minor categories to be identified in a hierarchical fashion without interrupting big categories. The technique is outlined here, along with the benefits and drawbacks.

The census includes acreage totals for counties with 10 or more farm operations that produced or sold $1,000 in agricultural goods during the census year for each specified crop with a census-item number. To reduce the number of crops to categories, total acreages for certain crops with several subcategories, such as "corn," "wheat and other grains," and "sorghum," were totaled from multiple census items for each county. Corn, soybeans, wheat and other grains, and alfalfa account for 24 to 74 million acres of harvested farmland and are farmed to varied degrees throughout wide portions of the country. The majority of the 12 secondary crops in table 2 account for 1 to 10 million acres when totaled [9].

Most secondary crops need more specialized growing conditions, are more confined to smaller locations than main crops, are usually high-value cash crops within the regions where they are cultivated, and may necessitate significant chemical and fertilizer usage as well as irrigation. Because of their tiny area, certain crops, such as pineapple, were not considered secondary crops. The method of defining crop categories from main and secondary crops is hierarchical, with two major stages. Based on a step-by-step application of % criteria, Level I categorization was assessed for all counties with submitted data in the United States (all 50 states). Counties that match the requirements for each phase are eliminated from the database before proceeding to the next step. The overall rationale of the level I classification is that the one, two, or three major or subsidiary crops that comprise each category account for more than half of the harvested land in each categorized county. The following criteria are stated in order of applicability for each kind of category: As specified, two-crop categories might result in the two principal crops accounting for less than half of the harvested land. However, this happened for less than 10% of the counties in these categories, and the threshold for each crop of 20%, rather than 25%, resulted in fewer unclassified counties.

Figure 4 summarizes the categories defined for all of the 26 probable groups with 10 or more counties. Furthermore, level I secondary crop categories were developed if the total area of the secondary crop exceeded 50,000 acres among counties matching the percentage criterion for a possible category even if there were less than ten counties. For example, only four counties in the country had more than half of their harvested area accounted for by potatoes, but the total acreage harvested by the four counties is more than 50,000 acres, therefore a category was formed in the categorization system. This minimum acreage criterion offers an arbitrary but consistent foundation for recognizing agricultural patterns, notably in the western United States, that are dominant in a small number of counties yet cover a large region. The level I classification procedure produced 21 categories that jointly categorize 2,686 of the 3,078 counties in the country that were Level II. Level II subcategories were independently analyzed for all counties in each level I category. Identifying patterns in secondary crops, which may have smaller harvested acreage but follow strong regional patterns and have specialized management practices that may have implications for water quality, is especially important for level I categories defined by the four primary crops, which account for the majority of counties classified [10].

Each county in a level I category was categorized based on the secondary crop (if any) that accounts for more than 10% of harvested land. If two or more secondary crops fulfill the requirements (uncommon), the county was categorized based on the crop with the most acreage. Level II subcategories were created for 46 of the 243 potential categories where there are 10 or more counties, or if the total area of the secondary crop for the particular level II subcategory reaches 50,000 acres among the counties matching the percentage criterion. For each level I category, there are up to eight level II subcategories. By reducing the total of deviations from the % requirements for prospective categories, the 327 counties that were not categorized by the criteria provided for level I categories were allocated to the closest category. A county with 17 percent corn, 18 percent soybeans, and 47 percent wheat and other grains, for example, would be assigned to the "wheat and other grains greater than 20 percent and soybeans greater than 20 percent" category because a 2 percent deviation is less than the deviation for other possibilities, such as "wheat and other grains greater than 50 percent," which has a 3 percent deviation. Reevaluation of level II subcategories after the incorporation of the 327 previously unclassified counties resulted in the establishment of four new level II subcategories.

CONCLUSION

Many people utilize land for various reasons (for example, agricultural production, housing, industry, services, and government). Land also serves social, cultural, and political roles that are tied to the history of each nation. The grouping of land uses for various purposes is known as a land use pattern. In India, the most significant land use patterns are forest area, land not suitable for agriculture, cultivable wastelands, fallow land, and net area planted. The use of land is determined by two factors: human and physical. Reduce production risk while increasing soil capacity to guard against environmental pollution. Protect natural resource potential and avoid degradation of soil and water quality. Make financial sense. Be socially acceptable while yet providing access to the benefits of improved land management. Land usage for agriculture is determined by soil type, irrigation infrastructure, and climate. In India, about 51.09% of the land is under agriculture, 21.81% is forest, and 3.92% is pasture. Built-up areas and uncultivated land account for about 12.34% of total land area.

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CHAPTER 7

AGROFORESTRY APPLICATIONS IN CONSERVATION BIOLOGY AND LANDSCAPE ECOLOGY

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ABSTRACT:

Agroforestry (AF) systems contribute significantly to the protection of natural resources, particularly soil. The soils are shielded from wind and water erosion. The negative impacts of temperature and wind on soil fertility, vegetation and animals are mitigated by AF systems. Trees may enhance physical qualities such as soil structure, porosity, and water holding capacity by supplying organic matter; shade; and litter cover and tree species enrich the soil by bringing both above and below-ground biomass into the soil system.

KEYWORDS:

Conservation Biology, Conservation Strategies, Climate Change, Landscape Scale, Tropical Forests.

INTRODUCTION

This section of the book discusses several important conservation biology and landscape ecology ideas for use in tropical settings. Its goal is to educate non-specialist readers with the required foundation information in conservation science, with an emphasis on landscape-scale concerns, so that they may readily follow the discussions of the biodiversity consequences of various forms of agroforestry in following chapters. It gives an update on current advances in these domains for readers who are already acquainted with the principles. The first chapter discusses the present risks to biodiversity in the tropics, such as habitat loss, fragmentation, overexploitation of ecosystems, and alien plant and animal species invasions. It explores several conservation techniques and emphasizes the importance of strategies that include landscapes, regions, and bigger scales. It emphasizes the role that agroforestry can and cannot play in local, regional, and global conservation strategies: while protected areas and conservation set-asides are the irreplaceable backbone of any sensible conservation strategy, agroforestry can play an important supporting role by linking and buffering reserves and maintaining or reintroducing a modest level of biodiversity in biologically degraded areas where natural vegetation has been lost through degradation. The second and third chapters are concerned with landscape processes that may be altered by agroforestry methods [1].

It covers the demographic and genetic consequences of natural ecosystem fragmentation caused by human land use for plant and animal populations, as well as the main landscape elements area, edge, matrix, and distance impacts that influence fragmented populations. It also considers the prospect of agroforestry land uses partly alleviating some of the negative consequences of habitat fragmentation by minimizing edge effects, increasing fragment connectedness, providing food or shelter for fragmented animal populations, and reducing fire usage. The third chapter explores the possible function of agroforestry components in the agricultural matrix in promoting landscape connectivity by acting as biological corridors for wildlife and flora between remaining forest pieces. As evidenced by natural vegetation corridors, the effectiveness of corridors for different plant and animal groups is highly dependent on their size, structure, and floristic composition, as well as the biology of the target plant or animal species, and such background information must be considered when evaluating and designing agroforestry corridors. The earth's biological resources are depleting at an alarming pace, a process that started with the arrival of humanity.

Figure 1: Landscape approach: Diagram showing the overview of the landscape approach (Research gate).

The bulk of the earth's land area has been colonized during the past few tens of thousands of years, with the agricultural revolution approximately 10,000 years ago and the industrial revolution more recently having a greater impact. If current trends continue, much of the planet's biological resources will be depleted. A more detailed scientific understanding of natural systems and their functioning is required as the foundation for critical global, regional, and local conservation choices (Figure. 2). Tropical environments, in particular, are very sensitive to human effect. The richness and uniqueness of their biodiversity, together with the many challenges they face, make these areas an essential priority for biodiversity conservation. Many critical biological issues have been answered as a result of current scientific study activities in tropical environments [2].

Conservation activities, such as the establishment of protected areas and corridors, as well as attention to the surrounding agricultural and degraded land matrices, must be incorporated into coherent regional planning. The employment of more conservation-friendly land uses, such as agroforestry, to improve bio diverse conservation in tropical environments may help to support such landscape scale conservation efforts. These activities are a critical step toward converting research into effective conservation action. This chapter's purpose is to offer an overview of critical global biodiversity conservation challenges, with a focus on terrestrial tropical habitats. Furthermore, this chapter serves as a platform for subsequent chapters' discussions of biodiversity risks, conservation solutions, and uses, including agroforestry. Tropical ecosystems span a considerable portion of the earth's surface and are home to more than half of all terrestrial species. These ecosystems have had a one-of-a-kind impact on the evolution of the planet's biodiversity.

Tropic habitats, particularly wet forests, were formerly far more common than they are now. Today, forests cover over half of all tropical areas, with savannas and deserts accounting for the balance. There are about 3.87 billion hectares of forest worldwide, with forest plantations accounting for 5%. Tropical, subtropical, temperate, and boreal forests are the four types of world forests. Tropical forests are classified as tropical rain forests, tropical wet deciduous forests, tropical dry forests, and tropical mountain forests. Although there are no precise worldwide evaluations of forest conditions, all forests are touched on some degree by direct and indirect human activities. Between 1990 and 2000, tropical forests were deforested at a rate of 14.2 million hectares per year, with an additional 1 million ha converted to forest plantations. During this period, natural forest growth averaged 1 million hectares per year, with people afforesting an additional 0.9 million ha per year via forest plantations [3].

This deforestation happened in diverse ways at the regional and local levels. For example, over this 10-year period, the Central African nation of Burundi lost 9 percent of its remaining forest every year. This substantial percentage loss is very important to Burundi's national policymakers, but actual deforestation rates of 15,000 hectares per year are significantly lower than in other regions of the globe and hence less relevant from a global viewpoint. The Sudan saw the greatest real loss in Africa, with 959,000 acres deforested per year. During this time span, Indonesia deforested an astonishing 1,312,000 hectares per year. If allowed, forest clearance, fire, logging, and fragmentation will destroy the majority of the world's tropical forests during our lifetime. Since the beginning of the agricultural revolution, the world's wooded lands have shrunk by over 2 billion hectares. The consequences of this devastation on any geographic scale are not well understood. In addition to the release of CO2 from biomass combustion and microbial activity, soil erosion, and disruption of the hydrological cycle, this destruction results in the extinction of numerous known populations and species, as well as the loss of undiscovered species, each with a distinct history and habits that will never be known.

The establishment of tropical agro forested zones or protected parks is an essential method for preventing tropical deforestation. Despite the fact that many parks are underfunded and face significant land use pressure, they are successful in avoiding deforestation and thereby protecting biodiversity. Other strategies, such as agroforestry, may be employed inside the matrix surrounding tropical parks to maintain biodiversity and help mitigate the negative consequences of deforestation and related edge effects. Agroforestry areas may act as biodiversity corridors between protected areas and non-protected remains of natural vegetation by replicating to some degree natural forest cover via the cultivation of tree species with agricultural crops. The Tropical Biodiversity Crisis Biodiversity is more than just a count of the world's species; it also includes genetic variability within and across populations, species' evolutionary histories, and other indicators of life's variety.

Biodiversity patterns differ by area. This diversity stems from species' current ecology and evolutionary history, as well as habitat type, habitat availability, and physical features such as climatic conditions and geologic and hydrological patterns, all of which change throughout place and time. Many tropical species have restricted distributions, and many taxonomic groupings have considerable geographic turnover. The global distribution of species is not uniform; most groups of creatures exhibit a considerable rise in species richness, or the number of species per unit area, closer to the equator. Furthermore, in most terrestrial and freshwater groups, the number of species is larger at lower altitudes than at higher elevations, and in forests than in deserts. These basic trends show that tropical conditions support the development of new species as well as the survival of current ones. Great productivity, low environmental variation (e.g., seasonality), persistent predation and competition, reduced historical climate change effects, and differential speciation and extinction rates are all associated with great diversity in the tropics. Recognizing that these attributes tend to foster high diversity in the tropics, it is crucial to remember that there are considerable intertropical diversity patterns, as well as lower-diversity zones, in the tropics. Tropical forests have received a lot of attention in conservation efforts because they are the richest bastion of terrestrial biodiversity. As a consequence, use of natural resources in the tropics destroys enormous genetic pools [4].

Maintaining species numbers and present biological diversity provides incalculable advantages. Much of the research on ecological and evolutionary advantages is new, and further studies are needed to identify broad patterns and processes. On a small scale, research has demonstrated that the lesser the species variety within a system, the more susceptible it is to species and population extinctions caused by nonnative species invasions. One may deduce that maintaining high variety might minimize the number of invading species, hence significantly minimizing their negative consequences. Other impacts of biodiversity on environmental processes have been proven. Plant variety, for example, impacts plant primary production in European grasslands. Furthermore, diversified habitats contain more functional components (more species with various ecologies) as well as more predictable ecological processes. Unfortunately, short-term economic advantages produced by rising human populations often influence decision-making, leading to resource misuse. Tropical nations have socioeconomic challenges due to high population growth rates. Environmental restrictions, such as climate, can exacerbate existing issues such as starvation and famine. This situation, along with tropical nations' need to depend on more sophisticated countries for technical help and development of their own.

Conservation Biology and Landscape Ecology in the Tropics typically leads to exploitative rather than sustainable usage of resources. Poverty, conflict, and social injustice all contribute to environmental deterioration, which in turn fuels socioeconomic problems in a never-ending feedback cycle. These underlying causes of environmental deterioration and biodiversity loss must be addressed if tropical ecosystems are to be successfully conserved. challenges to Tropical Forest Ecosystems Several primary challenges are driving environmental deterioration, including habitat loss and fragmentation, exploitation, pollution, nonnative species invasions, and human-induced global change. Land use is considered as the most important factor impacting tropical ecosystems for the next 100 years. In this part, we will explore these threats quickly and highlight the possible role of agroforestry, which will be addressed in further depth in subsequent chapters.

Habitat Fragmentation although human presence impacts landscape biodiversity in a variety of ways, habitat fragmentation is one of the most evident and pervasive consequences. Because landscapes are dynamic, fragmentation influences the behavior of natural interactions within the landscape as well as the overall functioning of the landscape. The species composition and variety of a tropical environment, for example, varies near a treefall vs a thick canopy. The temporal recovery of treefalls throughout a full tropical landscape, on the other hand, results in regions at various stages of natural forest development. These habitats support a diverse yet constant species composition and diversity throughout the terrain. In contrast, fragmented landscapes have fewer regions at various stages of forest development, making the average functioning of the landscape less predictable.

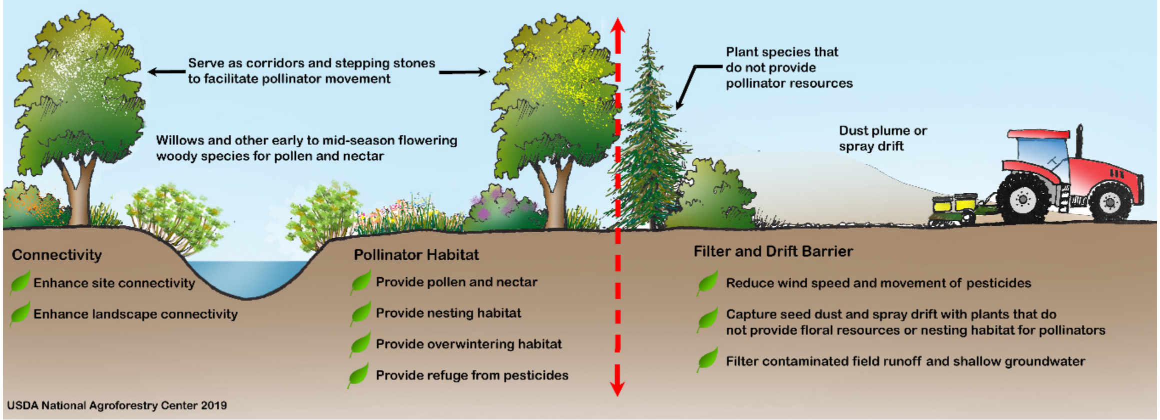

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Figure 2: Agroforestry system: Diagram showing the overview of the agroforestry system.

Deforestation of a significant area of a tropical landscape may permanently change the ecological function of the fragmented landscape from its original condition. These changes in biodiversity and landscape integrity argue in favor of the development of conservation corridors, in which biodiversity-friendly land uses such as agroforestry can be integrated with fragments of natural habitat in interconnected networks that help restore functional aspects of the landscape (Figure.1). Not only does fragmentation affect the functioning of the landscape, but it also affects the behavior and dynamics of people in the fragmented system. Populations often react negatively to landscape changes. If no patches suitable for a certain population exist, that population is likely to perish. Forest fragmentation may result in the survival or extinction of species populations, depending on a variety of variables such as how readily the species can spread across forest patches [5]

Because of the higher closeness of ambient conditions between forest fragments and the surrounding matrix at night, nocturnal species may be better equipped to withstand fragmentation than diurnal counterparts. Aboveground biomass has also been demonstrated to be reduced by fragmentation, particularly on fragment edges. According to a research conducted in Brazil, huge canopy trees in tropical rainforests have a greater death rate when they are in a highly fragmented system. Fragmentation also has an impact on the reproductive of species that survive in forest areas. For example, seed dispersion episodes in dipterocarp tree species that occupy Borneo's lowland forests correspond with El Nio-Southern Oscillation periods. Because these dipterocarp species are dominating canopy species, local and regional logging has a substantial impact on their dispersion and reproduction, which may interrupt their timed reproduction. Finally, on a landscape scale, tropical forest fragmentation might impact species dispersal pathways differently. Local population extinctions are caused by metapopulational dynamics across habitat patches, resulting in diversity losses in patches that are typically unrecoverable in wide expanses of degraded environments.

Genetic isolation between widely separated or dispersal-limited populations reduces overall genetic diversity across groups and increases sensitivity to dangerous genetic influences, such as disease susceptibility. Landscape-scale strategies must be informed by research on a diverse range of habitats, species, and populations. For example, Madagascar, which has a high level of biological variety, has lost more than 90% of its main forest. Threats to the island have not subsided, and forest losses in the few surviving fragments have continued. Many tropical forest species' long-term survival is jeopardized by extensive forest loss and fragmentation. Introduced Species Introduced species are a biodiversity problem associated to fragmentation. Tropical areas contain a great number of endemic species, which are species that are unique to a certain location or region, mainly due to genetic isolation caused by physical barriers (for example, water in the case of island animals) [6].

Local endemic species are often displaced in disturbed regions, such as fragmented systems, by wide-ranging species, particularly those tolerant of disturbed environments. Nonnative species that are successful are frequently those that spread over large regions and endure disturbance well. These imported species have an impact on practically every place on the planet, with island biota being particularly vulnerable. Changes in complex ecological systems, such as prey species introduction, may have a domino impact on fauna. Conservation Biology and Landscape Ecology in the Tropics species are homogenizing the world flora and fauna, resulting in native species extinctions and population declines. The increase in species richness might sometimes disguise the harmful effect on native species. The import of competing species may increase species numbers in a fragmented system, resulting in increased biodiversity loss via species displacements and more local extinctions.

To address these issues, immediate preventative actions, as well as increased connectivity, area-to-perimeter ratios, buffer zones, and matrix enhancements surrounding existing reserves, are required. Outside of protected areas, the use of agroforestry may contribute to such measures by boosting connectivity and acting as buffers, but it may also offer additional dangers if invasive alien tree species are exploited. Exploitation of the Natural Environment Exploitation of the natural environment has always been an aspect of human culture. Human population growth has raised the demand on natural resources. These demands have risen to levels that cannot be met without irreversibly harming natural ecosystems and processes. Subsistence hunting, for example, is expected to damage more than 19 million individual animals in Amazonian Brazil each year. This hunting, together with wildlife commerce and demand for wildlife items like pelts, ivory, and organs, puts a significant strain on local fauna. New highways have enhanced human-induced hazards by allowing access to formerly inaccessible places for colonization. In reality, every nature reserve in Brazilian Amazonia was shown to be 40 to 100 percent accessible by roads or navigable rivers. Landscape planners must be aware of the cascading and synergistic impacts of road construction and development on biodiversity, and they must put a higher value on animals and natural habitats in order to prevent exploitation.

Agroforestry land uses, such as fallows and secondary forests, may assist to minimize overexploitation of natural ecosystems' timber and non-timber resources, and so contribute to integrated natural resource management and forest conservation strategies. Greenhouse gas emissions continue to rise, and we must protect the remaining forests to reduce CO2 emissions.

Indeed, tropical deforestation emits roughly 2 giga tonnes (Gt) of carbon every year; in the 1980s, this was believed to account for 25% of human-caused carbon emissions (FAO 2001). Shukla et al. studied the Amazonian hydrological cycle and discovered that fast deforestation might result in a prolonged dry season. This disturbance in precipitation patterns would have far-reaching ecological consequences, such as increased fire frequency and disruption of pollination vector life cycles. The possible alterations are so severe that if huge regions of Amazon tropical forests are lost, they may never recover.

The conservation of tropical habitats is a critical component of global climate change solutions. Human-caused climate change will have a significant impact on biodiversity. Species ranges will follow climate trends, such as temperature and precipitation. The varied character of climate change through time and geography makes predicting the consequences on local or even regional scales problematic. In general, species ranges will migrate independently toward the poles and higher in altitude as the climate warms, while there is no clear linear trend. Protected areas must not only benefit the flora and animals inside their boundaries, but they must also allow for natural migrations and range changes caused by climate change [7].

As landscapes experience fast temporal changes, the surrounding matrix will be critical to mitigating biodiversity losses caused by global climate change. Biodiversity conservation cannot be done at static spatial scales, therefore matrix regions must be employed. Agroforestry methods may contribute to the creation of a permeable matrix that facilitates such migrations and may also aid to reduce carbon emissions following forest conversion. Riparian strips and contour plants may also aid to prevent nutrient and sediment losses from agricultural fields, limiting agriculture's impact on biogeochemical cycling. Conservation Strategies Recent scientific knowledge about how tropical rainforests are affected by fragmentation, logging, road construction, and encroaching agricultural frontiers suggests that only a few factors can account for much of the resulting ecological degradation (post fragmentation).

The existence and magnitude of abrupt forest margins, as well as the activities in the surrounding matrix, are all factors in conservation biology and landscape ecology in the Tropics. Smaller estuaries have fewer species per unit area than bigger ones. Smaller patches also have better edge to area ratio than bigger ones. Most ecological variables and markers of forest dynamics, such as species distributions, tree mortality and recruitment, biomass loss, and tree community composition, are also influenced by abrupt forest borders. Only the biggest forest fragments (>50,000 ha), according to certain recent estimates of the scope of edge-affected processes, are exempt from discernible ecological consequences of isolation. The activity and intensity with which the matrix habitat around isolated forest patches is used may have dramatic and permanent consequences on the patches' capacity to maintain themselves. Species that can utilise the modified matrix habitat, for example, will be prioritized for preservation in the habitat patches. As a result, landscape management should take these factors into account by incorporating them into public policy at all levels. This might include promoting agroforestry in locations where habitat fragment connectivity is crucia.

Global Conservation Strategies In conservation efforts, two primary global strategies are often used: one that integrates risks and one that employs ecological representation. The first sort of global conservation plan focuses on the most vulnerable and unique places and biota. Conservation International's hotspot method is an example of this sort of worldwide conservation strategy. Hotspots are regions of land that have more than 0.5 percent of all vascular plant species indigenous to them and have lost at least 70% of their natural main habitats. Plant diversity is used as a proxy for ecological and taxonomic group diversity. There are 25 recognized hotspots (Figure 1.2), which span 11.8 percent of the earth's land surface, but due to habitat degradation, natural main habitat in these places covers just 1.4 percent. These places represent the sole surviving home for an estimated 44% of all vascular plant species and 35% of all animals, birds, reptiles, and amphibians. Many species in the hotspots are particularly vulnerable, with declining populations, fragmented habitat, and stressors from a variety of human causes [8].

Since 1800, about 80% of all extinct bird species have been lost from biodiversity hotspots. Furthermore, Conservation International has named three major Tropical Wilderness Areas, which retain most of their basic habitat and have high levels of biodiversity. The hotspot method examines individual vulnerabilities in controllable land areas by designating conservation priority regions based on endangered and unique biota. Although dangers differ, abnormally large human population pressures are common to all hotspots. Hotspot regions, which span less than 12% of the earth's land surface, are home to an estimated 1 billion or more people, or close to 20% of the world's population. Human population increase in hotspots is 1.8 percent every year, whereas it is 1.3 percent outside of hotspots.

Human demand for resources may be much greater in and near hotspots than in other locations. Even in the three major tropical wilderness areas (New Guinea and Melanesian islands, upper Amazonia, and the Congo River basin), which have low population densities of about eight people per km2 (including several urban areas), population growth rates are significantly higher than the current global average of 1.3 percent per year. A representative method is used in a second major worldwide conservation effort. The ecoregion method is a descriptive illustration of this conservation technique utilized by the World Wildlife Fund. This strategy aims to concentrate conservation efforts on representative regions in important ecosystems and habitat types. Some regions that have been isolated for extended periods of time, such as oceanic islands, mountain ranges, karst, and caverns, are typically repositories of extraordinary levels of biodiversity.

The development of flora and fauna in these areas has resulted in unique and unusual creatures, many of which are found nowhere else. As a result, these issues are key priorities for consideration. Landscape and local conservation strategies are often used in smaller-scale conservation initiatives to conserve biodiversity the landscape scale, which includes conservation corridors, is described here as tens of thousands of square kilometers. Because this technique is the easiest to include into predictive computer models, it is used to forecast changes or shifts in ecosystems driven by natural and anthropogenic causes such as human population growth and climate change. Landscapes are made up of spatially varied regions with biodiversity that interacts actively between them. The composition of these regions, as well as the dynamic interactions between areas and landscape features, comprise biodiversity on the landscape scale. Interactions may happen due to the movement of nutrients, water, energy, organisms, and other resources. To reflect the dynamic character of landscapes, detailed location-specific data collection and understanding of the pattern of spatial interactions, such as biodiversity impacts, are required. This method may be used everywhere without regard to the restriction.

A deeper knowledge of the patterns and processes of ecosystems across diverse landscapes would enable for more accurate prediction of human activity's influence on landscape structure, as well as the potential of mitigation via land use techniques such as agroforestry. Regardless of the conservation method used to select priority regions or the scale at which that plan is implemented, the utilization of detailed data is critical. Because both the volume of data and the technology for integrating and com piling data have increased, collecting and integrating data on species distribution, habitat associations, and abundances should be a focal focus of conservation networks. Understanding biodiversity trends is critical for developing scientifically sound conservation strategies. A coordinated global framework may be used to quantify trends of endemism, rarity, and endangerment [9].

The International Union for the Conservation of Nature and Natural Resources (IUCN), an organization with 900 Institutional Members (governments, government agencies, and non-governmental organizations) and a network of approximately 10,000 scientists and other conservation specialists, has made an important contribution. The Species Survival Commission (SSC) is coordinating the development of a publicly available biodiversity database by the IUCN. The IUCN SSC collects data on species identification, range, and conservation status. If this and other programs succeed, conservation managers will be able to make better scientifically informed judgments. The majority of terrestrial vertebrates have had their conservation status reviewed via the IUCN Red List, and there are continuing attempts to add plants, invertebrates, and marine taxa that have not yet been evaluated. This systematic designation of individual species' conservation status allows conservation efforts to focus on species of immediate concern, such as the critically endangered muriqui (Brachytelesarachnoides) of the Brazilian Atlantic Forest and the Ethiopian wolf (Canis simensis), which is limited to a few grassland areas in Ethiopia, and prioritize conservation efforts.

Conservation Implementation Over the last decade, conservation research has generated a significant body of information that has shifted practical conservation efforts away from a limited concentration on discrete protected areas and toward a set of coordinated measures at the landscape scale. Although we are increasingly scientifically aware about the consequences of various forms of land use on biodiversity, such as logging and agriculture, we still have a long way to go. We have yet to transfer much of this knowledge into meaningful steps to prevent and mitigate these negative consequences in Conservation Biology and Landscape Ecology in the Tropics. Large networks of protected areas linked by reforestation and agroforestry projects and the promotion of less destructive land uses surrounding protected areas (such as pesticide elimination and controlled use of fire) are just a few of the guidelines that should be included in a comprehensive practical conservation plan.

Unfortunately, many of these landscape conservation principles have not been converted into integrated public policy in countries with abundant and threatened biodiversity. Any sustainable conservation plan is jeopardized in the absence of legislation that connects the most current scientific breakthroughs to land use and economic development rules and regulations. Once geographic priority areas have been identified, the difficulty is to execute effective conservation in these places. Although the establishment of protected areas has been the foundation of site conservation, several additional components are required for long-term ecosystem and biodiversity preservation. These include the utilization of sustainable development initiatives and other novel proposals such as conservation concessions, landscape corridors for conservation, and greater use of the landscape matrix around less degraded regions. Such solutions may benefit greatly from sustainable agroforestry practices. Conservationists have traditionally concentrated on patch-scale landscape processes.

Unfortunately, geographic scale limits that pit conservation and development goals against one other have hampered many previous initiatives to integrate conservation and development aims. As a result, in addition to these conservation approaches, efforts are required to broaden conservation applications to a landscape scale and broaden the focus of conservation planning in order to promote conservation and development goals concurrently while addressing both ecological and economic needs (Fonseca et al. in preparation). By directly ensuring biodiversity, protected areas provide the groundwork for long-term conservation. Many critics of reserves point to ineffective protection from human activities like as logging and hunting. Landscape conservation must be examined in context of significant worldwide changes such as global climate change, pollution, invasive species, and other human-related concerns in the present environmental crisis. Because the magnitude of human disruption is such that nearly no region is untouched, the conservation value of most locations may be increased. This includes highly degraded landscapes, such as fallow agricultural fields, that may be included into a region's broader landscape protection. Although there are several limits, such as with forestry initiatives, sustainable development projects may be beneficial to conservation efforts. According to studies on protected areas in tropical nations, governments are efficient in conservation efforts despite their 1. With inadequate budget and strong human constraints, more parks and more effective parks are required [10].

The management of parks in and around them is important to their success. According to one research, individuals lived inside park borders in nearly 70% of the 93 protected areas in 22 tropical nations. Protected areas are not the end goal of conservation; the land around stringent reserves is critical to maintaining biodiversity and ecological function. Changing the terrain around reserves to boost conservation utility will improve the medium- and long-term advantages of human land use. Agriculture and agroforestry may increase productivity while conserving resources by using natural processes. Landscape corridors exist to integrate conservation measures, such as improving plant and animal population distribution, with unavoidable economic growth. Landscape corridors enable huge regions to be subdivided into biologically and ecologically appropriate sub regional spaces, allowing conservation planning and implementation. Landscape corridor sub-divisions may be appropriated by planners to meet biodiversity and economic aims. Planners may, for example, put essential biodiversity regions under tight protection, designate crucial areas to economic growth, and enable other areas with mixed purposes to be utilized as needed. As a result, a landscape corridor is an integrated and physically linked network of parks, reserves, and other less intensively used places whose administration is incorporated into the landscape matrix.

DISCUSSION

Landscape corridors optimize present biodiversity survival while not interfering with essential economic development demands (Fonseca et al. in progress). Landscape-scale conservation provides for the most efficient use of resources to maintain biodiversity at the lowest possible economic cost to society. This cannot be done by Individual Park and buffer zone development. Long-term trends and changes in ecological and economic dynamics may be handled more effectively at the landscape scale. Finally, patch-scale mosaics that exist throughout the landscape might be designated using landscape-scale conservation. These mosaic patches can be defined in ways that benefit both conservation and development goals, such as protected areas to conserve watersheds and tourism resources and compatible development to encourage species movement between protected areas or to provide important buffers. Landscape Management

Human-dominated landscapes may be managed for conservation purposes. Scientific information developed over the previous many decades must be integrated into agricultural management, including agroforestry regions.

The underlying concept of agroforestry, or the practice of cultivating tree species and agricultural crops together or in sequence, has been in practice throughout human agricultural history and has been used to maintain soil fertility while supporting crop growth. Before contemporary agricultural innovations, for example, it was usual practice to clear and burn forests before cultivating crops, and this is still the preferred strategy in many tropical places today. Trees are often planted alongside agricultural crops. Combinations of plants with varied growth tendencies, such as coconut, bananas, coffee, and maize, are being used to improve agricultural land scapes in central and equatorial South America. Cassava is produced in tiny cleared plots inside the broader matrix of the Miombo forest in Zambia. Contoured hedgerows for soil and water conservation, trees in croplands, improved fallows, and shaded perennial crops are some more agroforestry approaches. Hedgerow, trees in farmland, and shaded perennial crop system mix trees and crops in the same field, while fallow systems entail crop and tree rotation over time. Agroforestry, in addition to providing some secondary habitat, may be utilized as an indirect conservation measure to safeguard natural areas from exploitation.

To strengthen connectivity between patches, corridors linking protected areas must be reconstructed. Many regions where corridors would be advantageous and protected woods are exposed to significant human activity, such as fuelwood gathering, might benefit from them. When unprotected woods run out of fuelwood, protected areas are often targeted. Agroforestry systems may be incorporated into such corridors to play a conservation role by generating wood and non timber forest products and therefore reducing exploitation of protected areas. Similarly, for greater conservation value, managed forest plantings and forest mixed with farmland may be planned and maintained. The indirect utility of agroforestry systems may also include carbon sequestration, watershed management, and buffering against climate change biome change. Furthermore, nutrient cycling in natural forest systems is generally very conservative because nutrients are swiftly and effectively recycled within the system, while agricultural systems often exhibit large nutrient losses. Agroforestry may aid in the maintenance of a sustainable agriculture-forest linked system in which nutrients are maintained.

The application of research to lead the search for new agroforestry systems that connect production goals with environmental services may assist to complete a sound biodiversity conservation plan based around protected areas, therefore aiding in the mitigation of biodiversity losses. Many of the current challenges to tropical biodiversity have played out in temperate areas during the last several centuries. Current technologies have allowed habitat loss to expand at an unparalleled pace and size from mostly temperate to tropical locations. The worldwide consequences of tropical area degradation should be enough of a case for all nations to collaborate on global conservation objectives, with local, national, and regional peoples and governments working together. Because of the reciprocal benefit to all nations, wealthier countries, organizations, and people are urgently needed to contribute to tropical conservation initiatives. Current state policies, on the other hand, are focused on short-term benefit; for example, an estimated $1.5 trillion per year is spent on subsidies that are both economically and ecologically damaging. The complete application of environmental sciences to tropical ecosystem conservation may provide the foundation for strong social, economic, and political choices to best protect tropical biodiversity.

CONCLUSION

Nitrogen fixing trees and nutrient absorption from deep soil layers boost nutrient inputs in agroforestry systems. They minimize nutrient loss through tree root and micorrhizal systems. The breakdown of trash, pruning, and root wastes in agroforestry systems recycles nutrients. Agroforestry, which combines trees with crops or cattle on a same agricultural plot, is increasingly seen as an important component in the agro ecological transition to sustainable farming and food systems. Reduced strain on the forest. Deep-rooted trees on the site recycle nutrients more efficiently. Improved environmental protection. Surface run-off, nutrient leaching, and soil erosion are all reduced as a result of the imminent influence of tree roots and stems on these processes. Soil conservation methods such as creating buffer strips and windbreaks, as well as restoring soil organic matter, considerably improve the quality of the habitat for all types of animals. The significance of agroforestry policies improving the economic situation of small farmers via increased production and the use of agroforestry systems. Preserving the environment while supplying the growing demand for wood and other agroforestry products. Growing the country's forest and tree cover.

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CHAPTER 8

ECOLOGICAL IMPLICATIONS OF TROPICS HABITAT FRAGMENTATION

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ABSTRACT:

In anthropogenic ally transformed landscapes, habitat fragmentation is one of the most significant processes leading to population reduction, biodiversity loss, and changes in community structure and ecosystem functioning. Tropical forest fragmentation causes habitat and biodiversity loss, as well as an increase in carbon emissions. The edge effect increases animal mortality owing to either a shortage of food in the region or an increased likelihood of being pursued by other predators. For example, the mountain caribou has become one of North America's most endangered animals.

KEYWORDS:

Edge Effect, Forest Fragmentation, Forest Fragmentation, Habitat Fragmentation, Species Richness.

INTRODUCTION

This chapter examines the ecological effects of habitat fragmentation on tropical biota. We begin by discussing the demographic and genetic consequences of fragmentation on individual populations, followed by a discussion of major landscape characteristics affecting fragmented populations, including area, edge, matrix, and distance effects. We next look at how habitat fragmentation interacts with other concurrent environmental changes that occur often in human-dominated tropical environments, including as fire, logging, and overhunting. We end by suggesting some methods that agroforestry and reforestation might help to mitigate the negative consequences of habitat fragmentation (Figure.1) [1].

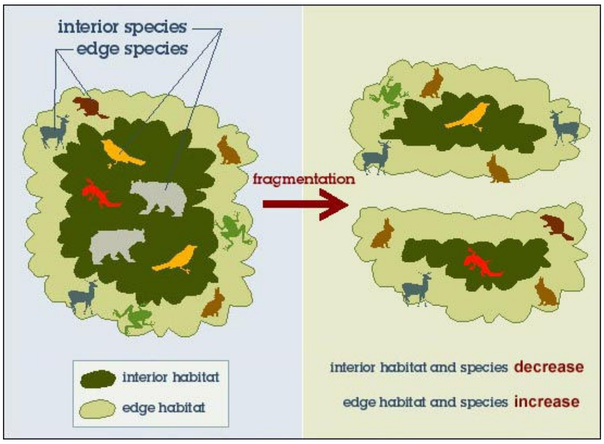

Figure 1: Habitat Fragmentation diagram showing the overview of the habitat fragmentation (Blooming Boulevards).

Forest fragmentation occurs when whole forest blocks are fragmented and decreased in size. This also decreases and subdivides natural populations, frequently dramatically increasing the rate of extinction of local species. Such losses arise for a variety of causes. For starters, tiny populations are more subject to random demo graphic occurrences. Consider the destiny of a colony of 20 short-lived animals that experienced two consecutive breeding seasons with few females coming into the population by chance. The population's reproductive ability would be greatly decreased, and it may simply vanish. Such chance occurrences have minimal significance in big populations, but simple random variations in births and deaths may have disastrous consequences in tiny populations. Such occurrences are most likely significant in nature. Many species tend to reside as Meta populations, or groups of tiny subpopulations that are somewhat separated from one another. These subpopulations may vanish due to random demo graphic events, but they are usually rebuilt by immigration from neighboring subpopulations (Figure.2). However, in fragmented habitats, most species' migratory is stopped or greatly restricted [2].

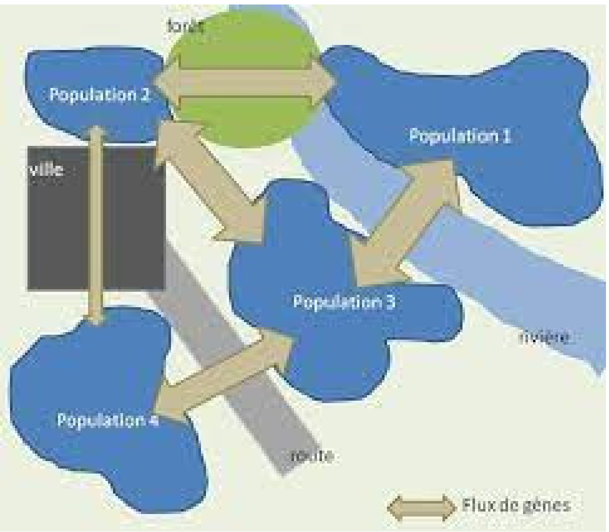

Figure 2: Meta population Diagram showing the overview of the metapopulational (Future science).

Small populations may then weaken and die, never to be replaced. Second, tiny, isolated populations are prey to inbreeding and genetic drift. Individuals are driven to reproduce with close relatives, which reduces genetic hetero zygozity and frequently reduces fertility and offspring survivability. Outbred individuals have greater heterozygosity than inbred individuals and generally suffer fewer genetic problems. As a result, inbred populations may grow more slowly and be more susceptible to random demographic events. In small populations, genetic drift random loss of alleles is accelerated, and the ensuing loss of genetic variety may diminish a population's susceptibility to novel illnesses or environmental problems. Finally, natural environmental changes and local disasters often exacerbate the consequences of random demographic events and genetic disorders.

Environmental factors like as severe weather, increased predator or competitor concentrations, or virus outbreaks may reduce a tiny population to a critical level. Once a population reaches a particular size, the interacting and possibly reinforcing impacts of random demographic events, genetic issues, and environmental differences may create a significant driving factor of extinction. Forest Fragmentation's Impact on Tropical Biota Forest fragmentation has a wide-ranging impact on tropical species and ecosystems. We highlight the most significant implications of fragmentation as well as the interplay of fragmentation with other concurrent environmental changes such as logging, fires, and hunting that are frequent in human-dominated land scapes. Large habitat fragments often have more species overall higher species richness and a higher density of species per unit area than smaller fragments. There are at least four explanations for this. For starters, big pieces are less affected by sample effects. Smaller areas of forest sample fewer species than bigger forest patches simply by chance. The fact that many forest creatures have patchy ranges and complicated patterns of endemism in the tropics serves to amplify this phenomenon.

Another distinguishing feature of tropical rainforests is that many species are locally uncommon over all or a portion of their range. Predators and large-bodied animals, for example, are more uncommon than herbivores and small-bodied species; for example, a single jaguar (Panthera onca) may have a home range covering hundreds of square kilometers. In fragmented settings, rarity may have a significant impact on whether or not species survive. Even if a rare species exists when a fragment is separated, its population size may be so small that it has limited chance of long-term survival. Second, larger pieces often sustain a broader diversity of habitats than smaller fragments, implying that more species will be present. In the tropics, where many species need specialized food supplies or microhabitats, habitat variety is critical [3].

Many herbivorous insects, for example, graze on just one or a few closely related plant species, and many birds have distinct foraging specialties, such as following swarms of army ants to 2. Species-area relationships for nine terrestrial insectivorous bird species (mean SE) in central Amazonia, demonstrating that larger forest fragments typically support greater species richness than smaller fragments and that forest fragments have fewer species than equal-sized tracts of intact forest (controls). Catch fleeing insects, grazing primarily on flower nectar, or foraging only in clusters of dangling dead leaves. Critical habitats are likely to perish if they are not present or are poorly represented. Third, large portions are less influenced by edge effects, which are the physical and ecological changes caused by the sharp border between forests and adjacent changed ecosystems. Area and edge effects are difficult to differentiate, and few studies have done so successfully.

This is mainly due to the fact that samples in tiny pieces are near edges, but those in big fragments are distant from edges, resulting in a significant correlation between edge and area predictors. Many population and community changes in habitat fragments that were formerly assigned to area effects are now being shown to be the product of edge effects. Edge effects are covered in more depth later in this chapter. Finally, big pieces have lower rates of population extinction than small fragments, which is particularly important for species that need vast territories, are sensitive to edge effects, are unable to traverse even tiny clearings, or are unable to withstand conditions in the surrounding changed habitats. The specialized ant-following birds of the Neo tropics, which accompany marauding swarms of army ants in order to grab fleeing insects, are a fascinating example. Each ant colony patrols large regions of up to 30 ha, and the birds' home ranges must travel through two or three colonies since each colony spends several weeks each month dormant. Because their ants need broad regions and access to several colonies, specialist artful lowers are particularly vulnerable to extinction in tiny pieces. Despite these variables, and contrary to the expectations of the island biogeography hypothesis, greater habitat pieces do not necessarily sustain more species. When there is an influx of species from surrounding modified habitats or when conditions near edges become more favorable for a particular species or guild of species, species richness can actually increase in fragments. No forest species as well as those that were previously restricted to naturally damaged forest regions may thrive along borders or in the matrix.

Inter fragment distance may influence the passage of animals and plant propagules between pieces, and even minor clearings can become impenetrable barriers for many rainforest creatures. Many terrestrial insectivorous birds in the Amazon have vanished from forest remnants and failed 36 I. Conservation Biology and Landscape Ecology in the Tropics to recolonize even those separated from surrounding forest tracts by just 80 m. For some dung and carrion beetles, and arboreal animals, clearings of 15-100 m represent impassable obstacles. Peccaries and several insect-gleaning bats are likewise wary of clearings. Even a 30-40 m wide unpaved road changes the community structure of understory birds and impedes the passage of numerous species [4].

Some species are able to traverse tiny clearings but are hampered by broader areas of damaged ground. Translocations, for example, prompted wood creepers (Dendrocolaptidae) to travel between Amazonian forest fragments and neighboring (80-150 m) forest tracts, but they have gone from somewhat more isolated regions, such as Barro Colorado Island in Panama. Large predators like as jaguars and pumas may traverse meadows and regrowth, although they avoid these regions when hunters are present or human density is high. Animals in the rain forest avoid clearings for a variety of reasons. Because most understory species have had little incentive to cross clearings throughout their evolutionary history, avoidance of such habitats is most likely an instinctive reaction.

Other species are restricted by shape or physiology; purely arboreal animals, for example, will find even a small grassland an insurmountable barrier. Others are likely to be limited by specialized habitat requirements. Finally, few species are migratory, which reduces inter fragment migrations among rainforest birds. In temperate forests, even genuinely isolated fragments may be colonized by migratory species throughout the mating season, but rainforest birds are significantly less inclined to do so. Edge Effects Habitat fragmentation always results in the formation of edges where none previously existed. These margins, however, vary from natural transition zones (ecotones) in that they are abrupt and artificial. Along fragment margins, both physical and biological changes occur.

The magnitude and significance of these changes are influenced by the difference between the fragmented habitat and the adjacent modified habitat; in general, the larger the contrast, the higher the edge impact. Recent research suggests that tropical forest fragments are especially vulnerable to edge effects. Increased insolation and wind penetration along freshly developed forest borders influence the forest microclimate, making it warmer and drier. However, if margins are partially sealed by a profusion of 2, these microclimatic changes may lose relevance after a few years. Second growth makes them less permeable to lateral light penetration and the penetration of hot, dry winds from adjacent agricultural regions. Forest structure is also significantly affected, owing to a rise in tree death rates. Some trees just shed their leaves and die standing when a new edge is formed, presumably due to abrupt changes in relative humidity, temperature, or soil moisture that exceed their physiological tolerances. Winds that speed through cleared area and impact forest borders break or fallen other trees. Finally, lianas (woody vines), which are major structural parasites that impair tree growth, survival, and reproduction, proliferate significantly along edges and may increase tree mortality. This sudden increase in tree mortality profoundly changes canopy gap dynamics. Smaller pieces are often hyper disturbed, resulting in gradual changes in floristic composition. Within 100 m of forest borders in the Amazon, young trees regenerating are considerably skewed toward disturbance-loving pioneer and secondary species and against old-growth, forest interior species.

In fragmented settings, pioneer plants like Cecropia sciadophylla may increase density by thousands of percent. Because pioneer trees have faster leaf turnover, litter fall rates tend to be greater along forest borders. Litter depth is often larger at 100 meters of the forest border than within 100 meters of the forest core. Changes in litter cover along forest borders not only have a significant impact on plant and animal populations, but also render forests prone to destructive surface fires during droughts. Despite an initial boost in tree seedling recruitment, particularly of pioneer species, seedling density along forest boundaries tends to decline. The causes for this are unclear, but they most likely entail decreased seed rain and dissemination, as well as increased seed and seedling mortality along margins. A high layer of secondary vegetation at forest margins, in particular, may increase seedling mortality by reducing light availability and increasing damage from heavy litter fall. Microclimatic changes, particularly lower soil moisture, may potentially be at work. Even when seedlings are shielded from litter damage, survival is poorer along fragment margins than in interiors, according to research on the understory shrub Heliconia acuminate [5].

Changes in forest structure along margins have a variety of effects on Est wildlife. Some species are unaffected by these changes and continue to utilize edge 38. Others, such as many insect species, react quickly to edge-related events. In the Amazon, insect numbers and variety often increase at the borders of the understory, most likely due to increasing understory plant density and productivity. However, insect abundance is lower in the higher forest layers, possibly because periodic canopy disturbances limit the density of over story plants. Likewise, species accustomed to damp, dark forest interiors, such as some beetles, ants, and butterflies, are declining in number near margins. Some arboreal insectivores, hum kingbirds, and habitat generalists that browse in treefall gaps become numerous along edges. However, a number of insectivorous understory birds, particularly solitary species, obligatory ant followers, and those that forage in mixed-species flocks, avoid edges. Wood-decomposing insects, as well as some marsupia and rats, are preferred and grow in number near edges. Small animal population and species richness rise in Amazonian pieces, most likely due to increased availability of insect food along the edge. However, in Brazilian Atlantic forests, tropical Australia, and Thai land, the opposite reaction was seen. Similarly, while ants increase in abundance near forest edges in central Amazonian rainforests, they decrease in dry tropical forests of Madagascar, implying that local climatic factors can influence species responses to habitat fragmentation. The character of the edge reaction is affected by edge age in at least some circumstances. For example, in Colombian montane forests, new and ancient forest margins showed differing fruit richness and fruit-eating bird groups.

Given the wide range of edge effects, it is not unexpected that various edge phenomena penetrate to diverse depths inside pieces. Different types of edge effects have been observed to penetrate fragment interiors from 10 m to at least 400 m in central Amazonia. The penetration distance (d) of an edge effect is an important quantity because, if determined experimentally, it may be used in conjunction with a mathematical core-area model to forecast the sensitivity of any fragment to that specific edge effect. Wind damage to trees is the furthest-penetrating edge impact observed to far in the middle Amazon, measurable up to 400 m from edges. However, recent evidence shows that certain other edge effects, such as destructive fires and feral animal invasions, can penetrate at least several thousand meters into tropical.

The matrix is the mosaic of modified habitats that surrounds habitat fragments. The ecology of fragmented forests may be greatly influenced by different matrix ecosystems. In the Amazon, forest fragments bordered by 5- to 10-m-tall regrowth forest had less intense microclimate shifts and had lower edge-related tree mortality than comparable fragments surrounded by cow pastures. When pieces were bordered by regrowth forest rather than cow meadows, mixed-species bird flocks avoided the edges less. The matrix is the patchwork of modified habitats that surrounds habitat fragments, such as pastures, crops, plantations, and secondary. The ecology of fragmented forests may be greatly influenced by different matrix ecosystems. In the Amazon, forest fragments bordered by 5- to 10-m-tall regrowth forest had less intense microclimate shifts and had lower edge-related tree mortality than comparable fragments surrounded by cow pastures. When pieces were bordered by regrowth forest rather than cow meadows, mixed-species bird flocks avoided the edges less [6].

Agroforestry has the ability to help dispersed populations and ecosystems in a variety of ways if it is introduced on existing deforested areas rather than replacing natural vegetation. For starters, it is clear that establishing dense, tall-statured vegetation along the edges of forest fragments may mitigate many of the negative edge impacts outlined in this chapter. Forest fragments bordered by tree plantations or agroforestry are likely to experience significantly less severe microclimate changes and wind turbulence than fragments flanked by cow pastures or herbaceous crops. Given the clear relevance of edge effects in fragmented tropical landscapes, lowering the severity of such impacts might be a significant advantage of wise agroforestry methods. Second, agroforestry techniques have the potential to improve fragment connectivity and species survival, particularly when combined with land-scape planning ideas like as corridor systems. Forest-dependent species are substantially more likely to cross modified fields with significant tree cover than regions devoid of trees. However, the most vulnerable species in fragmented landscapes sometimes avoid changed habitats altogether, thus the potential advantages of agroforestry may be restricted for these species. Third, in certain cases, agroforestry may be utilized to provide food or shelter for animal populations that are dispersed.

The use of "framework" tree species that attract a broad range of frugivorous birds and bats as an approach for landscape restoration has been promoted in tropical Queensland, Australia. These mobile frugivores deposit the seeds of a variety of different plant species underneath the planted trees, hastening the process of forest regeneration. Similarly, almost all tropical forests exhibit significant seasonal or inter-annual reductions in fruit availability. These decreases may induce severe famines among fragmented groups that are unable to relocate to places with better fruit availability. Plants near fragments that have continuous fruit yields, such as figs and numerous palms, or that reproduce during times of yearly fruit shortage, might help fragmented animal populations significantly. Another evident advantage of agroforestry is that it lowers the usage of fire. Farmers that depend on perennial flora such as fruit trees and lumber plantations fear fires. Given the startling sensitivity of fragmented forests to fire, one of the most major environmental advantages of agroforestry systems in the tropics may be less burning.

DISCUSSION

The fossil record contains evidence of habitat degradation caused by natural processes such as volcanism, fire, and climate change. For example, habitat fragmentation of tropical rainforests in

Europe 300 million years ago resulted in a significant loss of amphibian variety, while the drier environment resulted in a surge in reptile diversity. Humans commonly create habitat fragmentation when native plants are destroyed for human activities such as agriculture, rural development, urbanization, and the construction of hydroelectric reservoirs. Habitats that were formerly continuous have been fragmented into discrete parts. Many tropical and temperate ecosystems have already been extensively fragmented as a result of human activities, and the degree of fragmentation will only increase in the near future. Following extensive clearance, the individual shards are often extremely tiny islands separated from one another by crops, pasture, pavement, or even desert terrain. The latter is often caused by slash and burn farming in tropical forests. 90% of the original vegetation in central-western New South Wales, Australia, has been destroyed, while almost 99% of the tall grass prairie in North America has been cleared, resulting in considerable habitat fragmentation [7].

There are two mechanisms that might result in habitat fragmentation. Exogenous processes and endogenous processes exist. Endogenous processes are those that emerge as a result of species biology, and they often involve changes in biology, behavior, and interactions within or across species. Endogenous hazards may alter breeding or migratory patterns and are often induced by external activities. Exogenous processes are unrelated to species biology and might include habitat deterioration, subdivision, or isolation. By fundamentally modifying animal behavior, these mechanisms may have a significant influence on endogenous systems. Variations in dispersion or movement of species, including variations in seasonal migration, may result from habitat fragmentation or isolation. These changes may result in a fall in species density, greater competition, or even increased predation. Habitat fragmentation has a significant impact on biodiversity by limiting the quantity of appropriate habitat accessible to species. Habitat fragmentation often includes habitat degradation as well as the segmentation of formerly continuous habitat. Because they cannot adjust fast to the changing spatial arrangement of the environment, plants and other sessile creatures are disproportionately impacted by various forms of habitat fragmentation.

The most serious hazard to species is habitat loss, which may occur as a result of habitat fragmentation. However, it has been hypothesized that the influence of the layout of habitat patches within the landscape, irrespective of the effect of the quantity of habitat within the landscape (referred to as fragmentation per sequre), is negligible. According to a study of empirical research, 76% of the 381 documented significant effects of habitat fragmentation per se on species occurrences, abundances, or diversity in the scientific literature were positive, while 24% were negative. Despite these findings, the scientific literature emphasizes detrimental impacts over good outcomes. The positive impacts of habitat fragmentation suggest that multiple tiny patches of habitat might have more conservation value than a single big area of comparable size. As a result, land sharing methods may have a greater beneficial effect on species than land sparing measures. Although the negative consequences of habitat loss are often seen to be much greater than those of habitat fragmentation, the two phenomena are inextricably linked, and findings are seldom independent of one another. Numerous highways in the vicinity of Indiana Dunes National Park have disrupted the habitat.

The fundamental predictor of the number of species in a fragment is its area. And the respective contributions of demographic and genetic processes to the probability of global population extinction are affected by habitat layout, stochastic environmental variation, and species characteristics. Minor changes in climate, resources, or other variables that would be unnoticed and rapidly adjusted in huge populations may be disastrous in tiny, isolated communities. As a result, habitat fragmentation is a major driver of species extinction. Asynchronous population dynamics are common in fragmented populations. A diminishing population in a fragmented area may be "rescued" by immigration from a neighboring increasing population. The distance between pieces in a fractured landscape may prevent this from occurring. Furthermore, vacant habitat pieces distant from a source of immigrants by some barrier are less likely to be repopulated than adjacent fragments. Even tiny species rely on the rescue effect, such as the Columbia spotted frog. According to studies, 25% of adolescents wander more than 200m compared to 4% of adults. 95% of these people stay in their new location, proving that the migration is important for survival [8].

Furthermore, habitat fragmentation causes edge effects. Microclimatic variations in light, temperature, and wind may influence the environment surrounding the fragment as well as its interior and exterior. As the humidity declines and the temperature and wind levels increase, fires become more probable in the region. Exotic and pest species may readily establish themselves in such disturbed areas, and the presence of domestic animals often disrupts the natural ecosystem. Furthermore, habitat near the edge of a fragment has a distinct climate and attracts different species than inside habitat. Small pieces are therefore detrimental to animals that need inner habitat. The proportion of continuous habitat preservation is directly connected to both genetic and species biodiversity preservation. In general, a 10% loss of contiguous habitat results in a 50% loss in biodiversity. Much of the remaining terrestrial animal habitat in many third-world nations has been fragmented as a result of urban growth, such as roadways that interfere with habitat degradation. Dams and water diversions have fractured the habitats of aquatic creatures. These habitat fragments may not be big or well-connected enough to sustain animals that need a broad area to locate mates and food. Migratory animals struggle to find locations to rest and eat along their migration paths due to habitat loss and fragmentation.

Habitat fragmentation is often cited as a factor in species becoming vulnerable or endangered. The availability of viable habitat is important to the survival of any species, and in many situations, the fragmentation of any remaining habitat may force conservation biologists to make tough choices. Given the limited number of conservation resources available, is it desirable to maintain existing isolated bits of habitat or to acquire back property to get the greatest feasible continuous piece of land? In rare circumstances, a conservation-reliant species may acquire some disease protection by being dispersed in isolated habitats, and when overall habitat loss is accounted for. Some studies have shown a positive association between species richness and fragmentation this phenomena is known as the habitat quantity hypothesis, albeit its validity has been called into question. The continuing dispute about which size pieces are more important for conservation is known as SLOSS (Single Large or Several Small). In general, habitat degradation in a biodiversity hotspot region may be a useful indication or predictor of the number of vulnerable and extinct indigenous species.

One approach to the issue of habitat fragmentation is to connect the pieces by conserving or creating natural vegetation corridors. In rare circumstances, a bridge or an underpass may be sufficient to connect two parts. This has the ability to alleviate the isolation issue but not the loss of inner habitat. Wildlife corridors may enable animals relocate and inhabit new places when food or other natural resources are scarce in their primary habitat, and they can also help animals find new mates in neighboring regions, increasing genetic variety. Seasonal relocating species may do so more safely and successfully if they do not conflict with human development obstacles. Because urban landscapes are constantly expanding, recent study is looking at green roofs as potential vectors of habitat corridors. According to a recent research, green roofs are effective in linking arthropod habitats, notably bees and weevils [9].

Enlarging tiny remains to improve the quantity of inner habitat is another mitigating method. This may be problematic since developed property is frequently more costly and may need a large amount of time and effort to repair. The optimum option is often determined by the species or environment under consideration. More migratory species, such as most birds, may not need linked habitat, although smaller animals, such as rodents, may be more vulnerable to predation on open territory. These topics are often classified as Meta populations and island biogeography. Because the surviving habitat areas are smaller, they sustain fewer species and smaller populations. Small populations are more vulnerable to a number of genetic repercussions that affect their long-term survival. Remnant populations often have just a fraction of the genetic diversity present in the formerly continuous environment. In these instances, mechanisms such as adaptation that work on underlying genetic diversity have a smaller pool of fitness-maintaining alleles to survive in the face of environmental change. However, in certain cases in which subsets of genetic variety are partitioned among numerous habitat pieces, practically all of the original genetic diversity may be preserved despite each individual fragment showing a decreased subset of diversity.

When members of the same species reproduce, they share genetic information. This is known as gene flow. Migration may help populations retain genetic variety. Gene flow and migration are often limited when a habitat becomes fragmented and reduced in size. Fewer people will move into the surviving pieces, and tiny unconnected communities that were formerly part of a larger population will become reproductively isolated. The scientific evidence that fragmentation reduces gene flow varies depending on the species under consideration. While trees with long-range pollination and dispersal capabilities may not suffer decreased gene flow as a result of habitat fragmentation, the majority of species are at risk of reduced gene flow as a result of habitat fragmentation.

Inbreeding between related individuals may occur as a consequence of reduced gene flow and reproductive isolation. Inbreeding does not necessarily result in negative fitness effects, but when it does, it is referred to as inbreeding depression. As the percentage of homozygosity grows, inbreeding becomes more of a worry, favoring the expression of detrimental genes that impair fitness. Because of restricted gene flow, habitat fragmentation may cause inbreeding depression in many species. Inbreeding depression is linked to conservation problems such as local extinction.

Genetic drift is more likely in small populations. Genetic drift is the result of random changes in the genetic composition of populations, which leads to a decrease in genetic diversity. The smaller the population, the more probable genetic drift, rather than natural selection, will be the main force of evolution. Because genetic drift is a random process, it prevents animals from becoming better suited to their surroundings. Habitat fragmentation is connected with increased genetic drift in small populations, which may have a detrimental impact on population genetic diversity. However, research reveals that certain tree species may be resistant to the harmful effects of genetic drift until the population size reaches 10 individuals or fewer [10].

Habitat fragmentation reduces the size of plant communities and increases their geographic isolation. With more genetic heterogeneity and ways of inter-population genetic divergence owing to increased impacts of random genetic drift, inbreeding and gene flow within plant species are increasing. While remaining population size may reduce genetic variety, not all fragmentation episodes result in genetic losses and diverse forms of genetic variation. Fragmentation may sometimes boost gene flow among residual populations, disrupting local genetic structure. To develop in response to natural selection, populations must be big enough that natural selection is a greater evolutionary force than genetic drift. Recent research on the effects of habitat fragmentation on adaptability in certain plant species suggests that organisms in fragmented landscapes may be able to adapt. However, in many circumstances, fragmentation lowers adaptability potential due to limited population size.

CONCLUSION

The scientists discovered pieces using high-resolution satellite data that identifies holes in tree canopies and discovered fragmentation patterns in the world's three primary rainforest areas - Africa, Southeast Asia, and South/Central America - that meet physicists' "percolation theory." Forest fragmentation is the splitting of vast, continuous wooded regions into smaller parts; these pieces are generally divided by roads, farms, utility corridors, subdivisions, or other human activities. Humans commonly create habitat fragmentation when native plants are destroyed for human activities such as agriculture, rural development, urbanization, and the construction of hydroelectric reservoirs. Habitats that were formerly continuous have been fragmented into discrete parts. Wildlife movement is hampered by fragmentation. Individuals find it difficult to travel across habitat patches, which may result in inbreeding and genetic variety loss. This decreases a population's long-term health, making it more susceptible to illness and at danger of extinction.

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CHAPTER 9

ENVIRONMENTAL SERVICES PROVIDED BY AGROFORESTRY: ECONOMIC EVALUATION

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ABSTRACT:

Scientific literature confirms that agroforestry has a lot of environmental advantages. Climate change mitigation via carbon sequestration, biodiversity protection, soil health enrichment, and improved air and water quality are the four key environmental advantages of agroforestry. Agroforestry is popular among farmers because it produces monetary revenue from the sale of tree products. It also supplies things that the farmer would have to buy otherwise, which a significant concern is given the shortage of operating cash in many agricultural systems. Typically, economic valuation of ecosystem services reflects marginal values, or the value of a minor incremental change in the quantity or quality of the ecosystem service, which is determined by the relative scarcity of the ecosystem service and, hence, its existing levels of availability.

KEYWORDS:

Costs Benefits, Carbon Sequestration, Environmental Advantages, Economic Value, Environmental Services.

INTRODUCTION

Agroforestry approaches differ, but they all have one thing in common: they are expressly meant to be multifunctional, producing numerous goods and services. Conservation outcomes, such as biodiversity conservation, may be included in these outputs. Each of these goods and services has a monetary value. It is not an exaggeration to state that all ecological services have an economic equivalent, that is, they have a monetary worth. Understanding these values and how they relate to other land use systems, particularly potentially harmful systems such as certain kinds of slash and burn agriculture, pasture, or monoculture plantations, is critical to providing incentives for agroforestry growth. This chapter discusses the connections between economy and biodiversity. It explains the fundamental economics of land use choices, including agroforestry, explores the economic advantages of agroforestry, and exhibits them in three case studies for northern Nigeria, Sudan, and Peru [1].

The Peru research has received the most attention because it gives valuable insights into how agroforestry techniques should be evaluated. Economics and Biodiversity on far, economic studies of agroforestry systems have mainly ignored the benefits of agroforestry on biodiversity. This book clearly demonstrates that agroforestry increases biodiversity profiles when compared to less diverse and land-degrading alternatives. However, there are various reasons why economic research lags behind ecological research. To begin, economists have made significant attempts to assign economic values to many of the products and services provided by naturally and sustainably maintained systems. However, biodiversity has traditionally been defined as wildlife services (for example, the supply of meat) as well as larger environmental advantages, such as the economic worth of genetic material for medicines. These have been researched in the context of tropical forests but not in the context of agroforestry. Second, it is important to differentiate between biological resources and biological diversity.

Diversity's ecological advantages should include the function it plays in supporting an ecosystem's resistance to stress or shocks such as climate change. The literature on valuing biological resources in economic terms is very well established, but pricing larger ecosystem functions such as resilience has not been tried. Third, there has been no motivation to put economic value on biological variety until lately. The ultimate goal of discovering economic values is to create marketplaces that capture those values. Payments for watershed protection services offered by upstream forest owners are one example, as are payments for carbon stored in biomass. Such markets are fast growing, but biodiversity markets have tended to lag behind. Debt-for-nature exchanges were the first marketplaces in biodiversity protection. Conservationists would buy secondary debt owed by a debtor government in such exchanges. In exchange for an agreement to protect a biodiverse region, the conservationist would offer to discharge the debt or, more often, have it changed from foreign money to local currency. Though popular in the 1980s, such exchanges fell out of favor in the 1990s but are showing indications of resurgence. Conservation concessions or payments are more recent instances of marketplaces [2].

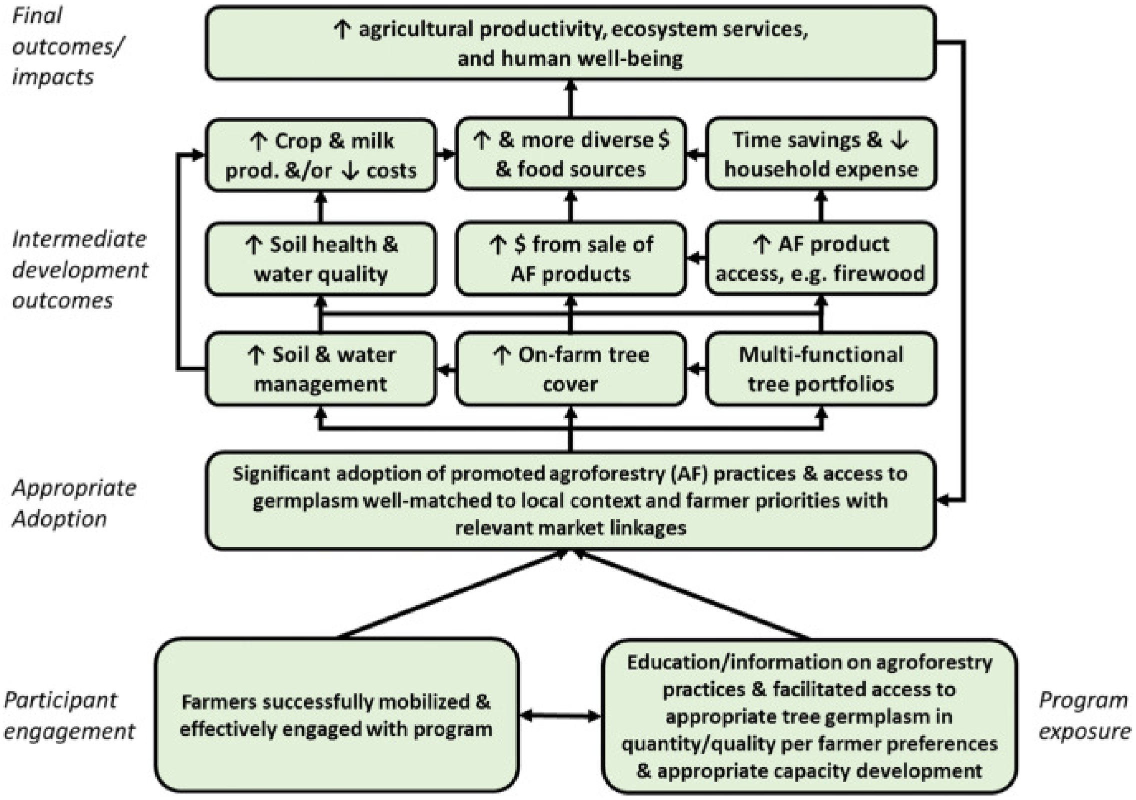

Figure 1: Agriculture productivity: Diagram showing the overview of the agricultural productivity (Environmental evidence).

These are being promoted by organizations such as Conservation International and essentially entail payments to landowners or land users in exchange for refraining from ecologically damaging land uses. Clearly, it will be critical to address this gap in economic research into agroforestry. Many varieties of agroforestry may be able to pay for themselves, in comparison to other land uses, with more easily identifiable benefits like as carbon storage. However, biodiversity benefits must be assessed economically to ensure that agroforestry systems with economic returns lower than those of certain less diverse and possibly unsustainable land uses are not destroyed due to insufficient economic research (Fiugre.1). The Economics of Land Use Selection Agroforestry is a kind of land management. If land is not used in this manner, it will be managed in other ways, such as for pasture, slash-and-burn (which can actually be viewed as a form of agroforestry; see Chapter 8, this volume), logging under various management regimes, or outright preservation, in which no consumptive uses are permitted. If the net economic gains from agroforestry are smaller than those from these other land uses, there will be little motivation to participate in agroforestry. In fact, if any one alternative use of the land has a greater net eco 68 II, agroforestry will be disfavored. The Ecological Economics of Nomic Return in Agroforestry.

Demonstrating that agroforestry offers various advantages is a critical first step in making the case for agroforestry. To provide some weight to this seemingly simple argument, we need to go further into the definition of net economic gains. The image rapidly grows more complex. To begin, we must differentiate between economic rewards to farmers and economic returns to society as a whole. The farmer is more concerned with what economists term private economic rewards. These are simply the financial income generated by the particular land use minus any financial expenditures. Revenues and expenses are not eternal; they occur throughout certain time periods. The farmer typically sets the horizon for these costs and benefits, but any biological variables altering the horizon are equally significant. For example, whether land use includes the removal of native tree species or the cultivation of plantation species, the time horizon may be influenced by the rotation period or the duration until optimum production. Such biological horizons may or may not correspond with the farmer's temporal horizon. Although there are exceptions, temporal horizons in impoverished societies tend to be short; individuals do not plan ahead [3].

Poor individuals, in economic parlance, are considered to undervalue the future. Their attention is focused on what they can acquire this year, next year, and in a few years. Looking far into the future is a luxury that many impoverished people cannot afford. Other variables influence the degree of discounting. In traditional slash-and-burn systems, for example, the time horizon for a specific piece of land may appear very short because it is determined by the period over which crop yields can be sustained from the initial (often poor) capital endowment of fertile soil, plus the nutrient base derived from the initial burn. If it is known that there is more frontier area that can be colonized, there may be no need to look beyond this time, say 5-10 years. There is evidence that if the border is closed (i.e., no alternative land is available), farmers will take better care of their present property and endeavor to make it more productive. Land with secure property rights is also considerably more likely to be farmed sustainably than land with unstable property rights. Farmers may be readily dispossessed by more powerful forces, including governments, in the latter situation. Farmers tend to discount the future at a relatively high rate in this instance because the discount rate includes the risk of dispossession. We'll come back to this discounting argument later. For the time being, we may say that the greater the rate of discount is expected to be, the less secure property rights are, and the more frontier land is available. High discount rates are compatible with extracting terrestrial nutrients (i.e., considering land as an exhaustible resource rather than a sustainable, renewable resource).

The flow of economic benefits and costs to society as a whole must be differentiated from the flow of revenues and costs to farmers. Because farmers are part of society, their private costs and benefits are subsets of the larger societal costs. Society here does not have to be limited to those living inside a single national boundary. Consider the role agroforestry might play in preserving watershed functioning to learn why. Agroforestry, as opposed to tree clearance, helps to keep forest soils from washing into rivers. Because silt settles and moves in water, it may have an immediate impact on downstream fisheries and other economic activity. As a result, agroforestry may provide what are known as external benefits that help others in society. The benefit is external since the farmer is not compensated for performing this protective role. As it happens, this institutional aspect of protective land use regimes is changing as downstream users recognize the advantages of upstream soil conservation activities. This is a basic illustration of how social benefits may outweigh private profits.

The societal costs of disruptive or detrimental land use regimes, on the other hand, outweigh the private costs. However, the nation's social benefits and expenses may not be con fined. If a land use system produces advantages in the form of biodiversity protection, such benefits may accrue not just to local people or the country, but also to the whole planet. The presence of accords such as the Convention on Biological Diversity demonstrates that the world cherishes biodiversity. As a result, social benefits might include both national and global advantages. So far, nothing has been revealed in the economic analysis concerning how these costs and benefits might be priced or if they are related with real cash flows. This leads us to the second issue of the earlier-mentioned simple rate of return parameter. Contrary to popular belief, cash flows do not define a benefit or cost in the eyes of an economist [4].

Any increase in human well-being is described as an economic advantage. Any loss of well-being is an economic cost. In turn, happiness is defined in terms of human preferences. To claim that I am happier in context A than in context B is to suggest that I prefer A over B. As a result, economic assessment is preference-based, reflecting the fundamental democratic value judgment that human preferences should be taken into account. It is important to recognize that preferences may be motivated by a variety of factors. Another common misconception about economics is that choices are supposed to be based on self-interest, or what the person likes for himself or herself. This is untrue. Preferences may represent pure self-interest, a care for what an immediate family group wants, a concern for children, grandchildren, and future generations in general, an innate concern for the environment, and so on. Although there is scientific dispute within economics regarding the specific methods in which these values might be aggregated without double counting, the key idea is that an individual's preference can be motivated by a variety of factors. This turns out to be significant, as we will see. As a result, social costs and benefits may or may not be related to a monetary.

Agroforestry Ecological Economics flow

The downstream advantages of upstream soil conservation may be accompanied with a financial flow, such as the value of a preserved commercial fishery. However, the financial flow does not benefit the farmer who is conserving the land. As a result, it remains an externality. The advantages of biodiversity to the globe as a whole are unlikely to be correlated with economic flows. They might be accumulated by ecological tourist expenditures, for example. However, if individuals in the United States or Europe appreciate biodiversity in Asia, this is an economic gain even if no money is involved. Finding Total Economic Value Efficient judgments should be founded on what is best for society as a whole. As a result, it is the societal benefits and costs that matter, not the private benefits and costs, and they should be utilized to identify the ideal arrangement of land uses. Nonetheless, it is simple to understand why, even if a social benefit analysis shows that agroforestry is the greatest option, it may not become the preferred land use. Actual land usage are determined by private costs and advantages. Social assessments offer a gauge of how land should be utilized, but if the farmer has control over that particular land use, private costs and rewards define the actual usage.

By power, we mean that institutions created to represent broader societal interests may not work in such a manner that farmers' choices are influenced. This is particularly true if land use monitoring and enforcement are lax, as is often the case where the border is broad (e.g., Indonesia, Brazil) and public resources are few (nearly all low-income developing countries). Land usage tends to follow low open access solutions in such conditions (i.e., land is not owned by anybody in the sense that property rights are enforced). The same argument may be conveyed in many ways. Farmers disregard the external costs and benefits of their land usage since they do not get any revenue or resource flows that correlate to nonmarket benefits and costs. For example, if farmers were paid to protect biodiversity or store carbon in trees rather than emit it as carbon dioxide, their income and cost flows would shift to reflect the nonmarket advantages. This last outcome is crucial. It is one thing to assess land use possibilities and claim that one is socially superior to another. It is quite another to design incentive systems that capture nonmarket costs and benefits in order to influence private land use choices. Environmental economics is particularly concerned with the process of developing incentives. There are several instances. Hydroelectric firms may be required to pay upstream forest [5].

The Ecological Economics of Agroforestry

Owners to protect their forests instead of harvesting them for lumber, as is done in Costa Rica. Logging would open up the canopies, allowing rain to wash away certain forest soils, resulting in sediment in rivers and silt in reservoirs, limiting hydroelectric production. The value of the lost electricity is the maximum amount that the hydro company is ready to pay to avert the harm. In this method, the externality has been monetary valued, and an incentive structure (direct payment) has been developed to include the external costs and benefits into the actions of forest owners. Other examples of payouts include Ecuador's Watershed Conservation Fund and tax breaks for funds invested in biodiversity-friendly initiatives (as in the Netherlands).

In these agreements, an agent aims to mitigate the harm caused by its own carbon dioxide emissions by sequestering or storing carbon that would otherwise be released in another site. As a result, it pays the added cost of storing carbon and receives a paper credit indicating that what it has stored has offset its own emissions. These carbons offset agreements are explicitly sanctioned under the Kyoto Protocol as part of the Clean Development Mechanism, which allows affluent nations to pay poor countries to reduce carbon emissions. Again, the externality has been internalized and valued, since storage is worth whatever the wealthy nation is prepared to pay for it. Such ecosystem service payment arrangements are critical because the context for agroforestry is likely to be one in which the net financial returns to farmers from agroforestry are less than the net returns from some unsustainable land use, while the social rate of return from agroforestry is higher than the alternatives.

In essence, there is a misalignment between social and private rewards. This can only be solved if farmers are rewarded for foregoing net financial profits from unsustainable land use, with such compensation coming from resource flows connected with agroforestry's nonmarket advantages. Agreements to compensate farmers in agroforestry programs for creating national and global benefits are uncommon at the time. However, the Global Environment Facility is sponsoring many programs in Nicaragua, Colombia, and Costa Rica that compensate farmers for adopting silvo-pastoral systems that promote biodiversity and carbon sequestration. As previously noted, we are interested in calculating the whole economic value of agroforestry to society, which includes both private values to farmers and social external values to other members of society, whether national or international [6].

The Economic Valuation of Agroforestry's Environmental Services

Nonuse values are advantages that are unconnected to any sort of use. To demonstrate the importance of these terms for agroforestry, direct use advantages include farmer profits from the sale of agricultural and forest goods, as well as things like shade and wind protection. Indirect use benefits include the majority of the natural services supplied by forests conserved by agroforestry, such as watershed protection, which may benefit others in society indirectly. The value of maintaining bio diversity and forests via agroforestry for potential future benefit, such as the potential therapeutic application of a species or chemical or the creation of new crop types, is known as option value. Furthermore, numerous segments of society including farmers may benefit from the simple awareness that agroforestry systems safeguard ecosystems, forests, and biodiversity as compared to more dam aged land uses. This is referred to as an existence value by economists. Society may also place a premium on the fact that these ecosystems, forests, and biodiversity are being preserved for the benefit of others (altruistic value) or future generations (bequest value).

DISCUSSION

Agroforestry components of overall economic value. The estimate of subcomponents of that overall value is relatively easy using a variety of methodologies. Use values are often simpler to estimate than nonuse values. For example, the economic returns from crops, timber, and other forest products direct use values or the indirect gains of fishers and hydroelectric companies benefiting from forest conservation indirect use values could be estimated simply using market prices or, in a less straightforward but superior way, using shadow prices, which are prices corrected for internal distortions that could cause them to deviate from true economic costs. If the location where the agroforestry system occurs has the potential for ecotourism, the tourist benefits may be estimated indirectly by looking at how much tourists spend to get to the site and how much they spend once there. This is referred to as the trip cost approach. Needless to say, the extent of the territories concerned influences what these possibilities are.

Alternative land uses, such as ecotourism, may be severely constrained if the analysis is confined to a narrow region. This implies that, in order to optimize alternatives, relatively large regions must be united to fully harness conservation economic benefits. Only a few years ago, nonuse values were often referred to as intangibles since they are inherently more difficult to quantify. However, economists have developed a variety of sophisticated approaches for estimating the whole economic worth of natural resources, including nonuse values. These approaches, which are largely survey-based, are known as expressed preference methods. The most often used approach is contingent valuation (CV) (Car son 2004 cites over 5,000 CV research encompassing a broad variety of topic areas and more than 100 nations). CV works by directly asking individuals how much they value a certain environmental improvement presented in a specially crafted questionnaire.

They may be asked, for example, how much they are willing to pay (WTP) to secure the environmental benefits of agroforestry; alternatively, how much individuals are willing to accept (WTA) to incur any losses associated with the adoption of agroforestry (in comparison to alternative land uses). These WTP and WTA metrics are monetary assessments of how much individuals value the land use change of interest. People are willing to pay for an environmental improvement (or require compensation for a deterioration) for a variety of reasons, which may include personal gains in tandem with concerns about the benefits that may befall other members of their family, third parties, or future generations, or simply concerns about the environment itself; thus, WTP and WTA measures reflect both use and nonuse values. To provide a comparison, the contingent valuation approach functions similarly to survey-based market research studies that analyze people's preferences and willingness to pay for new market items and services [7].

There is a basic four. However, there is a twist: whereas market research typically deals with private goods, the majority of whose benefits accrue to users (e.g., cars, toothpaste, hamburgers), CV focuses on goods and services that have a value not only to users but to society in general, and a portion of the value is not related to any form of present or future use. The next three sections show how the methodologies given here have been effectively utilized to quantify the economic value of agroforestry systems in a range of situations and geographies. Bateman et al. provide further information on this and other ways. Acacia senegal in Sudan Acacia senegal grows in Africa's Sahelian-Sudan region. When a tree is injured, it produces a sticky gum to protect the wound. This gum, known as gum arabic, has several applications ranging from candy, lithography, and drinks to medications and insecticides. It is superior to the gum produced from Acacia seyal, which yields talha. Gum arabic collection is a key aspect of Sudanese agricultural practices. It is particularly important for small farmers in the "gum belt" of central and western Sudan, where gum gardens form part of a crop cycle with other crops.

Farmers allocate some land to crops and some to A at any one moment. Senegal, as well as some to fal low. A. Senegal is unique for the variety of advantages it generates. Aside from gum arabic, benefits include leaves and seed pods for cattle feed, fuel wood, soil conservation due to deep tap roots and lateral root systems, nitrogen fixation with subsequent impacts on grass development surrounding the trees, shelterbelt microclimatic protection, and dune fixing. The tree's roots have been utilized to line water wells. Several investigations have been conducted on gum arabic systems. Pearce projected a total internal rate of return1 of 36 percent for gum, fodder, and fuelwood production, which is extraordinarily high for developing-country investments. Barbier states that due to the great variety of the numerous combinations implemented in the gum belt, no study can be genuinely representative of gum agroforestry techniques. Furthermore, A. Senegal's gum output varies according on age and soil type.

Barbier therefore analyzes gum and agricultural production returns for numerous places. The findings are presented in two ways: in financial terms (by examining revenues and expenses in

Sudanese pounds) and in shadow pricing terms (commonly referred to as economic returns). The concept of shadow pricing holds that domestic prices may not accurately reflect genuine economic costs. A waged worker, for example, may be jobless if not working in this profession. The worker's opportunity cost approaches zero since he or she would otherwise be generating anything. The shadow pay is the salary that the employee might earn in the next best employment. If no other occupation exists, the shadow pay approaches zero. The concept here is that hiring someone has a positive social benefit, and therefore initiatives having this impact have bigger social profits than seems to be the case at first glance. A second example is related to international commerce. Crops would have to be imported if they were not produced locally. Similarly, each crop raised and eaten domestically foregoes agricultural export profits that might have been exported. As a result, the relevant shadow price becomes the price that the crop would have received if it were traded globally, or its so-called border price [8].

Barbier's research considers both traditional financial expenses and revenues as well as shadow pricing. Looking first at the financial analysis, we can observe that, on average, all crops other than sesame incur financial losses, while A. Senegal is profitable. Second, only three locations benefit from mixed agricultural systems: the Blue Nile, North Kordo fan, and South Kordo fan. In comparison, A. Senegal is lucrative across the board. Sesame is also thought to be particularly lucrative in areas where agriculture revenue is evident. This begs the question of why a variety of crops, including gum trees, are cultivated in areas where sesame is lucrative. There seem to be two viable options. First, diversified outputs are a risk-aversion strategy: occurrences that harm one crop may not harm others. Second, the crops serve a market strategy as well as a subsistence plan. Sorghum and millet are largely farmed for sustenance. Third, there are links between the crops and gum arabic. These interdependencies show the environmental advantages of gum arabic; without the external benefits of gum arabic, crop returns would be lower. All systems become socially profitable after the shadow pricing procedure is completed. This is almost completely due to the impact of pricing outputs at border prices, which are much higher than domestic costs. While the financial returns on gum arabic outperform all crops except sesame, the economic (shadow priced) returns on gum arabic are the lowest. The reason for this is because the financial returns already reflect border pricing since practically all gum arabic is exported (save for the fuelwood and fodder components of A. Senegal benefits), but the other crops are not. Barbieri was unable to separate A's broader environmental advantages. The extent to which these extra advantages extend is a delicate topic. For example, if they boost agricultural production, the advantages are already reflected in crop yield; they have been internalized. It would be double counting to count them again.

As a result, many of the environmental advantages may have already been accounted for. Thus, three major responsibilities of gum arabic are proposed: it serves as a relatively reliable and steady source of revenue, it creates positive net financial and ecological advantages, and it operates as a support system for other crops. Barbier's main warning is that gum arabic only makes financial sense if the international price of gum arabic remains stable. This is a complicated problem since there are synthetic starch replacements accessible, and political instability in Sudan threatens supply stability. Anderson provides a second example of a full cost-benefit evaluation of agroforestry for rural afforestation projects in the Kano area of northern Nigeria in Agroforestry. Mixed Crops and Trees in Kano, Nigeria. Anderson observes that trees in African farmlands are often given little importance, resulting in increased soil erosion.

The background to this could be land tenure issues: tree growing assumes some form of longer-term tenure, the agricultural sector is generally given low priority in African macroeconomic policies, the wider benefits of tree growing are not perceived, and there is the classic externality issue mentioned previously. Anderson simulated two types of tree growth: trees as shelterbelts on farms and farm forestry a combination of crops and trees, both of which qualify as agroforestry. Simply looking at timber and crop yields does not capture the wide-ranging benefits of agroforestry. Anderson lists the benefits as reduced crop loss due to avoided reductions in soil fertility, increased crop yield due to improved moisture retention and nutrient cycling, increased livestock productivity due to the availability of dry season fodder from trees, and the value of the tree products themselves as fuelwood, poles, and fruits. A significant portion of the study is devoted to the physical calculation of response functions, or how agricultural yields and fodder supplies react to tree planting [9].

Economic valuation processes are straightforward because market prices are always available to value increases in productivity and output. This is more descriptive than stating absolute amounts for net present values. The basic scenario permits the tree-growing operation to yield advantages despite an expected 1% annual loss in soil fertility. The "no erosion" and "wood benefits only" instances assume 0% erosion, but the low- and high-yield cases, as well as the "soil restored" scenario, assume 1% erosion. The fast erosion example, on the other hand, estimates a 2% annual reduction in soil fertility. To be considered worthwhile, a project's benefit-cost ratio should be greater than one. If projects were evaluated only on the basis of their timber benefits, they would fail a benefit-cost test ratios of 0.3 and 0.6, indicating that costs outweigh benefits. However, if the extra advantages are included in, the ratios soon exceed one. Furthermore, the ratios for agricultural forestry are high, consistently exceeding 2 and with the potential for 4-6. These are very high return rates. The policy implication is a well-known but sometimes overlooked one: the temptation is to invest in regions where soil is most severely damaged, yet it is typically wiser to safeguard mildly degraded soil first. There has been no follow-up evaluation to Anderson's cost-benefit analysis, therefore it is unclear if such programs were successful. Anderson is clear that success is dependent on farmer engagement, which brings up another key point. Agroforestry initiatives are unlikely to succeed unless farmers collaborate. As a result, such methods have a game theory context: each farmer must be certain that the other farms will cooperate. There is an incentive for any one farmer not to participate, so avoiding the expenses of tree planting while assuring the benefit of tree planting if all others join. This results in a typical free-riding potential for such programs, emphasizing the significance of community consensus and participation in such schemes, with well-designed incentives to remain in such schemes and penalties for defecting from them. It is also worth mentioning that Anderson's analysis does not take into account biodiversity or carbon storage.

As previously stated, no economic research addressing the estimation of biodiversity benefits are known. Zelek and Shively obtained carbon price estimates for agroforestry systems in Bukidnon, Northern Mindanao, Philippines. The carbon price is the amount of money that farmers would have to pay to compensate them for moving from conventional crops (maize and vegetables) to agroforestry programs. If the land would otherwise be fallow, an agroforestry program compensates the carbon stored in the agroforestry system with $6-$10 per hectare. However, if maize is grown instead, the required compensation is $58-$61 per hectare, and for foregoing vegetables, the compensation is $211-$283 per hectare. Although the compensation for giving up vegetable production looks to be substantial, the estimates are in present value terms, that is, discounted yearly returns that are then averaged. The comparable yearly payments would be low, implying that compensating farmers for carbon sequestration would be cheap and adequate to entice them to transition to agroforestry. Estimating the Benefits of a Hypothetical Land Use Change to Agroforestry in Peru It is believed that small-scale farmers are responsible for one-third of tropical America's deforestation [10].

Farmers in a slash-and-burn method often clear land for agriculture and grow crops for one or two years, following which the area is kept fallow for variable amounts of time while another section of the farm is cleared for agriculture. As a consequence, after a few decades of slash-and-burn colonists settling in a region, only tiny patches of primary forest are frequently remaining. 80 II. Mourato and Smith calculated the environmental advantages and financial costs of implementing agroforestry systems for slash-and-burn farmers in the Peruvian Amazon. According to satellite pictures from 1993, 70% of the study area in the Peruvian Amazon (the District of Campo Verde) was deforested defines multi strata agroforestry as the combination of crops and valuable tree species that imitate natural succession. Thus, by reducing deforestation and encouraging tree planting, agroforestry systems have the potential to generate significant local and global benefits, including: timber and non-timber forest products; increases in soil fertility, watershed protection, and local climate regulation; provision of carbon sequestration services and biodiversity protection; and existence and bequest values. Data from the Peruvian Amazon reveal that slash-and-burn agriculture has a net present value of -$2,176 per hectare over a 10-year time horizon under controlled experimental settings. Multi strata agroforestry, on the other hand, has a net present value of $1,137 per hectare at a discount rate of 25%, which is deemed adequate for smallholders. However, only around one-fifth of local farmers pursue agroforestry on a tiny area (0.5 ha on average) of their farms (about 30 ha on average). Farmers said that this was due to the fact that only results from the first few years were significant to their decision-making. Adjusting the data to a two-year time horizon and decreasing yields for annual and semi perennial crops in agroforestry to match agronomic circumstances in farmers' fields reveals that agroforestry provides lower returns than slash-and-burn.

Other studies have demonstrated that seasonal labor restrictions, market risk, a lack of technical understanding about trees, and an availability of natural forest products all hamper agroforestry adoption. These findings indicate that farmers are unlikely to modify ecologically detrimental farming methods in the absence of external incentives. Mourato and Smith utilized the contingent valuation approach in this context to determine the compensation needed for Peruvian farmers to transition from slash-and-burn agriculture to agroforestry. A questionnaire was sent to 214 farmers, who were presented with a potential future project in which utility companies in industrialized nations were prepared to reimburse farmers who implemented multi strata agroforestry systems due to the likelihood of emission reduction legislation.

Each hectare of agroforestry would receive a predetermined yearly payment (payments would stop if the agroforestry land was removed for slash and burn). Farmers were then asked to provide a minimum annual WTA compensation for converting 1 ha of slash-and-burn agriculture to multi strata agroforestry, taking into account the potential financial impacts of the proposed land use change in terms of investment, labor, yields, and available products. According to the findings, the average compensation demanded. The Economic Value of Agroforestry's Environmental Services 81 is $138 per hectare per year to convert agricultural land to agroforestry. The compensation sum determined here accounted exclusively for the financial losses suffered by farmers as a result of agroforestry adoption. The investigation, however, revealed that Peruvian farmers benefit from the environmental services given by trees retained or cultivated as part of agroforestry. Preserving forests was deemed vital by almost all respondents (96 percent). Forests were primarily viewed as a source of construction materials and non-timber forest products (primarily game animals, medicinal plants, and firewood), but non-consumptive forest services such as air purification, shade, wind shelter, and water quality were frequently mentioned as well.

The average remuneration was determined to be $97 per hectare each year. In other words, the implicit value of forest environmental services was calculated to be about $41 in terms of forgone compensation (i.e., the difference between the two compensation values, or $138 - $97). This startling result demonstrates not only that Peruvian farmers benefit from environmental services associated with forest conservation through agroforestry practices, but also that the value attributed to these environmental externalities is surprisingly high, accounting for roughly 30% of the total compensation required to change land use. Mourato and Smith also looked at whether forest carbon markets may help slash-and-burn farmers gain some of the favorable global externalities of agroforestry while also driving land use reform. Based on the needed compensation for farmers, the cost of carbon in the research region was calculated to vary from $8 to $31 per ton of carbon, depending on the discount rate utilized. These estimates are on the higher end of cost estimates from comparable forestry-based carbon sequestration projects in developing countries: the average cost per ton of carbon in an analysis of eight developing country carbon sequestration forestry projects was $12, ranging from $3 to $35. Previous cost estimates, however, made no allowance for project durations that are often shorter in comparison to the residence period of carbon in the atmosphere. Although there are clearly some very low-cost projects in the energy sector, the carbon costs estimated for agroforestry conversion in the Peruvian Amazon are significantly lower than the average cost of reducing carbon emissions through fuel-switching projects in nine countries, which is estimated at $165 per ton of carbon.

This implies that, despite the limitations and uncertainties associated with these estimates (such as the lack of consideration of transaction and implementation costs, the difficulty in proving additionality, and the quality of carbon data used in the calculations), there may be room for gains from trade. Conclusions From an economic aspect, the case studies described in this chapter reveal essential elements of agroforestry land uses. First, agroforestry systems give several advantages to producers as well as local and national people. Some advantages, like as biodiversity conservation and carbon sequestration, may extend beyond boundaries. Many of these advantages are not self-serving and are unconnected to any specific use of the resources; rather, they reflect environmental concerns and a desire to protect environmental and forest resources for others and future generations.

Economic studies have not yet embraced efforts to quantify the biodiversity advantages from agroforestry. This reflects, in part, the difficulty of employing economic valuation tools to value biodiversity, but it also, we suggest, indicates a lack of an incentive to value biodiversity since, until recently, the possibility for collecting its worth via market development was minimal. Second, economists have developed methodologies for assessing the vast variety of benefits associated with agroforestry land uses in monetary terms, including nonuse values. These vary from simple methods like utilizing market pricing to assess cash flows from agroforestry systems to more advanced survey approaches like contingency valuation that may evaluate nonuse values. The use of these methodologies seems to validate the intuition that once nonmarket benefits are accounted for, agroforestry economics may be altered.

The second step required for genuine policy targeted at encouraging aged agroforestry includes the development of incentives and mechanisms to capture these nonmarket advantages. Third, even if it is part of a wider land use plan that involves a change to multistate agroforestry as a means of producing agricultural and forest products, farmers are unlikely to conserve primary forest on their farms. The initial expenses of developing agroforestry systems are thought to be overly costly, and farmers often have limited time horizons, resulting in agroforestry's long-term advantages being greatly undervalued. This shows that less intensive alternatives to multistate agroforestry and enhanced systems that draw on farmers' present practices may be more likely to be adopted. Smith et al., for example, indicate that farmers in the Peruvian Amazon prefer to vary their agricultural systems with modest areas of perennial crops and to restore considerable amounts of secondary forests as part of their slash-and-burn techniques. Enriching these secondary forests may give many of the economic and environmental advantages of agroforestry systems while requiring much less investment. Fourth, the importance farmers place on environmental externalities from agroforestry systems and nonuse values suggests that the widely held belief that smallholders are only concerned with short-term survival is incorrect, and that intergenerational issues and environmental factors should be prioritized in the design of improved land use systems. The consequence is that land uses like agroforestry, which includes forest. Agroforestry protection and regeneration may benefit not just the global society, but also slash-and-burn farmers. Finally, the possibility for farmers to be reimbursed for losses incurred by converting to agroforestry land uses should be investigated further. Carbon trading might enhance the possibility of more sustainable land use systems being adopted, and it is one of numerous environmental improvement initiatives that could be pursued without the need for subsidies or laws while helping resource-poor forest residents.

CONCLUSION

The trees' filtration and capture of water resources may assist enhance water quality and quantity, potentially benefiting the whole watershed. Agroforestry may help promote and maintain local biodiversity by creating optimal conditions for a wide range of plants, insects, and animals. Increasing internal and external market competitiveness through strengthening customer and contractor trust. Improving the natural environment's conditions. Increasing market share by addressing the market demand of "caring for the environment" Improving ties with the local community. Economic value evidence may be used to compare financial costs to environmental costs, hence influencing investment, policy, and budget allocation choices. Economic valuation allows for the measurement and comparison of the many advantages of fishery resources and ecosystems, and it may be a strong instrument for assisting and improving their sensible use and management.

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CHAPTER 10

BIOLOGICAL CORRIDORS AND LANDSCAPE CONNECTIVITY

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ABSTRACT:

Corridors are supposed to promote migration across linked patches of habitat, enhancing gene flow, reestablishing locally extinct populations, and increasing species diversity within otherwise isolated locations. In certain circumstances, connectivity is unwanted or unsuccessful. Corridors may be dominated by edge effects, raise the danger of parasitism and illness, and enhance invasive species dispersion. Establishing vegetation ally varied field borders and/or hedgerows that may act as biological corridors for the movement and distribution of important arthropod species is one strategy to restore biodiversity into large-scale monocultures.

KEYWORDS:

Animal Migration, Biological Corridors, Costs Corridors, Landscape Connectivity, Plant Species.

INTRODUCTION

Tropical natural habitats are being converted to agricultural land at a greater rate than any other biome. The consequences of such fast clearance will be seen in the next decades, when the majority of the surviving tropical forest will exist as isolated remnants. The kind of ecosystem around these relics may be critical to their protection. Adjoining habitats that are structurally and floristically similar to the remains (e.g., agroforestry lands rather than pasture or open agricultural fields) would be most advantageous to the long-term maintenance of biodiversity. Agroforestry areas may help to biodiversity conservation by strengthening the connectivity of people, communities, and ecological processes in fragmented landscapes, in addition to sustaining local plant and animal species. Biological corridors, or simply corridors, are habitats that may preserve this connectedness throughout the terrain. Corridors may be made up of many kinds of habitat, but they always vary from the surrounding vegetation and connect habitat remnants that were formerly connected [1].

It is critical to determine the properties of a corridor will make it beneficial for a certain organism when employing agroforestry to promote landscape connectivity. Because few research on animal migration within agroforestry corridors have been conducted, this chapter summarizes the pertinent literature on tropical forest corridors. It explains how rainforest animals choose and utilize linear habitat remnants, as well as which characteristics tend to be most important for corridor efficacy. The chapter also examines some pertinent findings on animal usage of agroforestry systems in order to explore their use in linking landscapes. Landscape connectedness is determined by both the natural characteristics of a corridor and the behavior of animal species that may seek to utilize it. The general assumption underlying the value of landscape connectivity is that an interconnected fragmented landscape is more likely to support viable faunal and floral populations and intact ecological processes than an isolated fragmented landscape. This assumption is based on two theories: island biogeography theory and Meta population models. According to the idea of island biogeography, the number of species contained in an isolated community (such as an oceanic island or forest fragment) is the outcome of a dynamic balance between opposing forces of colonization and extinction. The idea predicts that as forest pieces become more isolated from one another, the rate of immigration by species unable to cross the transformed environment would decrease.

Numerous studies have shown that land bridge islands (i.e., islands formed by flooding a portion of land) and forest fragments lose species after being isolated, a process known as species relaxation. Rather than looking at complete species assemblages, Meta population models look at a single species' population, which exists in geographically different subpopulations linked by dispersion. Although there are many other kinds of Meta population models, there are two main ones. The first identifies a large source population, which then disperses to smaller sink populations. A condition in which tiny habitat fragments are partially detached from a larger region of undamaged habitat. The second kind of population is one that is dispersed throughout the terrain and is patchily distributed, as would be the case if only little forest remnants remained in a formerly wooded area.

Small populations in the models are vulnerable to local extinction, and movement of individuals between patches can both bolster dwindling populations through genetic and demographic contributions and result in recolonization of local patches where the species has gone extinct. The extinction rate of a species is determined by the quantity and quality of the remaining habitats in both island biogeography theory and Meta population models, while recolonization is determined by the amount of landscape connectivity. The distance between remnant patches, the nature of surrounding matrix (modified habitats), and the availability of corridors or tiny habitat patches that might operate as stepping stones can all have an impact on connectedness. Corridors for conservation planning were initially suggested in 1975, based on fragmentation and island studies. Many studies have now proved the significant advantages of corridors, which include aiding animal migration, providing habitat, Identified landscape connectivity and biological corridors as beneficial environmental processes [2].

Alternatively, some studies have warned of the potential costs of corridors, such as the risk of biotic and abiotic disturbances spreading to remnant populations and habitats, the possibility of increased wildlife mortality in corridors, and a lack of information on whether the financial costs of corridors could be better invested in other conservation initiatives (e.g., purchasing land). The advantages and costs of corridors are discussed in the sections that follow. Corridor Benefits Major landscape functions of corridors include allowing animal migration across the terrain, providing habitat, and assisting ecosystem processes. Facilitating Different Types of Movement Several studies have shown that habitat corridors may help animals travel. Local, migratory, and dispersion movement have all been reported.

A graphic representation of the four key landscape functions of corridors: passageway, habitat, population sink, and barrier. Dors throughout their home range or between foraging and breeding locations. Mammals, birds, and amphibians have been documented migrating along corridor. In these research, wildlife species were found migrating preferentially via wooded corridors rather than the surrounding agricultural matrix. For example, one research in Costa Rica found that big tropical frugivores required forested corridors from montane to lower elevational forests so that birds could track seasonal changes in their food supply. Dispersal movements are often defined as one-way travels of young animals seeking vacant territory to reproduce in. Corridor studies have shown that habitat links may aid in the dispersion movements of animals, birds, insects, and plants. Dispersal migrations are crucial for population dynamics because they enable individuals to relocate to other populations or recolonize populations that have been extinct in their home area. One of the most difficult issues in demonstrating the efficiency of corridors is demonstrating that dispersed individuals not only migrate via corridors but also establish themselves in fragment populations. Only in this manner can immigrants mitigate the detrimental effects of isolation on fragmented communities.

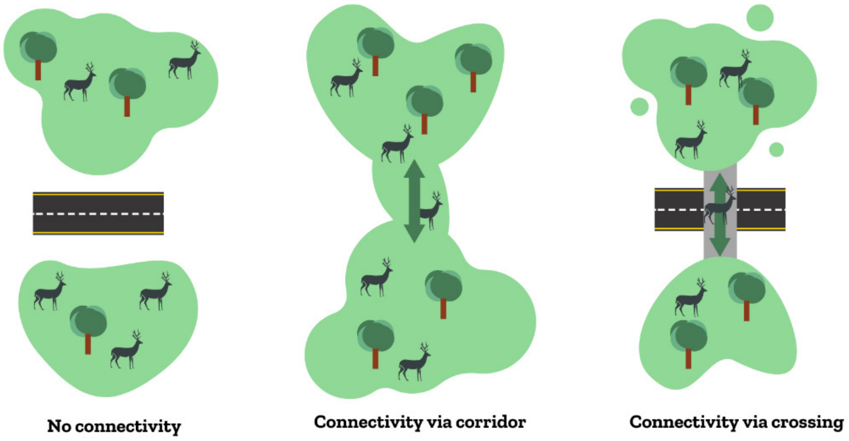

Figure1: Corridor concept: Diagram showing the overview of the Corridor concept (Center for large landscape conservation).

Genetic data is accumulating that demonstrates gene flow across fragmented faunal populations connected by corridors, confirming the effective establishment of immigrants in the population. Providing Habitat for Resident Species Corridors may be home to a variety of wildlife species depending on their form, habitat structure, and floristic composition. Although some forest species may be present, edge and generalist species are likely to be the most common occupants of corridors, predominating in narrow habitat strips that occur along roadsides, riparian areas, and windbreaks, although some edge and generalist species are likely to be the most common occupants of corridors. These corridors are often only short strips of edge habitat with little or no interior (Figure.1). Rare and endangered species often avoid such places, preferring to live in larger corridors with higher-quality. Residency in corridors is the most efficient approach to preserve population connectedness, especially for less mobile species or those that travel large distances. Corridors must offer appropriate resources, such as food and shelter, for such animals [3].

Aiding Ecosystem Processes Habitat corridors may also offer extra landscape services by assisting ecosystem processes, such as safeguarding watersheds and creating windbreaks. By shading streams and so decreasing the excessive development of aquatic plants, including exotics, riparian vegetation along streams may minimize soil erosion and preserve water quality and stream flows. Furthermore, suitable streamside vegetation may assist to preserve water quality and restrict the development of aquatic algae by reducing the intake of agrochemicals and nutrients. Windbreaks and fencerows may lower wind speeds, therefore protecting pastures, crops, cattle, and natural habitats from erosion. Corridor Costs Wildlife corridors have detractors. A variety of possible negative consequences have been proposed that should be taken into account when advocating corridors as part of a regional conservation plant. Increased immigration may also impair species' local adaptations and possibly reduce genetic variety by causing outbreeding depression, which happens when extremely dissimilar individuals mate. Such occurrences are unlikely to occur, however, when corridors are utilized to unite ecosystems that have been separated by human land uses rather than connecting naturally disconnected habitats. Second, corridors may help abiotic disturbances like fire spread.

Fires are more prevalent in managed pastures or slash-and-burn fields, according to Conservation Biology and Landscape Ecology in the Tropics. Agroforestry regions are often less vulnerable to fire than pastures and fields because the closed or semi-closed tree canopy produces a dark, humid environment with low fuel loads and, more importantly, because agro foresters preserve their investment in tree planting (e.g., via firebreaks). As a result, agroforestry zones may operate as possible fire buffers to remaining ecosystems, inhibiting rather than promoting fire spread. Corridors might operate as population sinks by luring people to locations where they have a lower chance of survival or reproduction. Corridors may route wildlife through private holdings, increasing their vulnerability to hunters, poachers, predators, and domestic animals by seeking to promote wildlife migration throughout the landscape. Furthermore, corridors may maneuver organisms into environments with limited resources and potentially superior competitors, such as generalist and edge species, reducing reproductive success and jeopardizing survival. Most research showing higher mortality in corridors has been extrapolated from edge effect studies in fragmented habitats, and little data on mortality rates in corridors compared to other habitats is known [4].

Some argue that the financial costs of corridors outweigh the advantages, and that precious conservation resources would be better spent on other efforts. For example, in eastern Madagascar, where less than 5% of the original rainforest remains, conservation options may include purchasing land to protect remnant natural habitat, creating corridors between remnant reserves (which may not function for all species), and revegetating lands adjacent to reserves to provide additional habitat area. Given the scarcity of conservation resources, supporting corridors at the cost of other efforts may not always be the best choice. As previously stated, the efficacy of movement corridors is frequently evaluated not only in terms of their ability to facilitate individual movement, but also in terms of the successful establishment of dispersing individuals as breeding members in a new Landscape Connectivity and Biological Corridors have a population of 55 people. Dispersal may be caused by density-dependent variables such as scarcity of resources (food, shelter, mates) or density-independent causes such as avoidance of inbreeding (not breeding with closely related individuals; However Individuals may improve their chances of acceptance in a new community by being open to breeding upon arrival (Figure.2). The ability of a species to move across a corridor may be determined by its food and space requirements, agility, denning requirements, social behavior, and other variables.

Bennett classified species-specific mobility along corridors into three kinds. First, movement might be a single motion that runs the length of the corridor and is seasonal in character. This form of movement is often done by huge, mobile creatures. For example, Grim shaw and Foley discovered that forest elephants on Mount Kilimanjaro in East Africa used the last forest connection between the summit and Amboseli National Park on a seasonal basis. Second, corridor travel may be interrupted by breaks for food or shelter that might last hours, days, or even weeks. This condition might be typical of tiny species with high energy requirements and restricted mobility. Finally, people may live in a corridor, resulting in immigration and gene flow among residents. Recent research has shown that numerous species, including sensitive fauna such as rainforest birds and arboreal marsupials, live in corridors [5] .

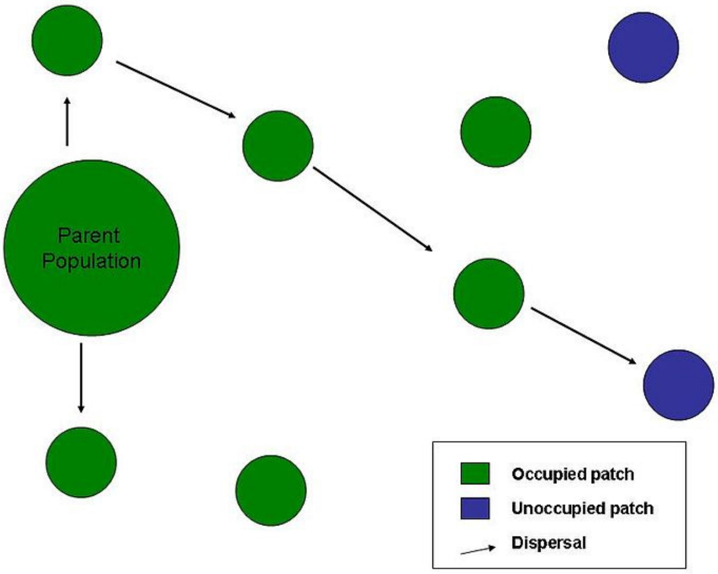

Figure 2: Dispersal: Diagram showing the overview of the dispersal in ecology (Wikipedia).

Many of the corridor characteristics that help animals travel across the landscape also help plant pollination and dispersion. Plant pollen, seeds, spores, and other propagules may be transported by vectors such as wind, water, and flying and terrestrial animals. Although little attention has been paid to plant pollination and dispersion in habitat corridors, two movement patterns have been observed. First, certain plant species have been found to traverse short distances by vegetative spread or neighboring seed distribution. Second, wind or animal dispersion of seeds some distance along the corridor has been the most prevalent movement. Plants that rely on wind pollination and dispersion are unlikely to be as sensitive to corridor elements like habitat quality and structure as plant species that rely on an animal's capacity to move across the terrain.

Plants that successfully establish themselves in a suitable setting, regardless of their dispersion strategy, and reproduce enable species to move farther throughout the landscape. There are four key physical corridor elements that will impact species usage and movement in a corridor, in addition to the sorts of species-specific motions. These include habitat quality, corridor breadth, corridor length, and corridor continuity.

Habitat quality is an important aspect of corridor efficacy because, regardless of species mobility, survival rates in high-quality habitats are projected to be significantly higher than in marginal or bad habitats. Although the variety of species and their demands makes it hard to concentrate on every species, certain broad patterns do occur. High-quality habitat is that which most closely mimics primary forest in tropical rainforests. Depending on the dispersing species, structural factors including as canopy height, canopy connectedness, canopy and understory structure, and floral composition may all be essential. Laurance and Laurance discovered that only primary rainforest corridors maintained the whole array of arboreal animals in a survey of 36 rainforest corridors or linear remains in northern Australia.

Mature (tall and floristically rich) regenerating forests supported more arboreal mammal species than younger or less diversified regrowth, but not the sensitive forest species most at danger of extinction in forest fragmentation. Even a little amount of forest cover is preferable than none at all for animal migration. The negative impacts of fragmentation on certain faunal communities were greatly reduced at the Biological Dynamics of Forest Fragments Project near Manaus, Brazil, after the grazing lands around the fragments were abandoned to forest regrowth. Many understory bird species, for example, rebounded dramatically in tiny sections when forest regeneration gave continuous cover to undisturbed rainforest. Traditional agroforestry systems in Indonesia and Central America are often havens for great biological variety. Several comparative studies have shown that traditional rubber and coffee plantations support more species than more simple commercial plantations [6]. Many forest species benefit from the increased structural complexity of these plantations, including uncommon forest trees, invertebrates, and migrating birds. Similarly, floristic diversity has been proven to be an essential contributor to high biodiversity in both natural habitat corridors and agroforestry plantations. Many resident and dispersing animal species may be supported by a broad variety of flowering and fleshy-fruited plant species in the canopy and understory. Furthermore, the existence of plant species (for example, fig trees and palms) that produce fruit for extended periods of time.

Edge effects include a wide range of ecological and microclimatic changes that may occur at or near the forest-agricultural border. The penetration distance of different edge effects in tropical rainforests may reach up to 200 m. Furthermore, since corridors are often lengthy and straight in construction, they have a high edge-to-interior habitat ratio. An efficient corridor will help the most vulnerable species survive in a reserve or landscape. Because many forest interior species have fallen dramatically in fragmented habitats, corridor studies are often targeted. Avoidance of edge-affected habitat is a crucial correlate of certain extinction-prone species. As a result, large pathways often sustain significantly more forest interior species than smaller corridors. Only passageways wider than 250 m were discovered to accommodate the most sensitive of tropical Australia's arboreal animals. Similarly, several understory rainforest birds in central Amazonia showed lower abundances within at least 70 m of forest borders, and some may have avoided them much more. A 250-m-wide corridor may offer just around 100 m of forest interior habitat for this bird population and may still fail to sustain particularly sensitive species. Corridor Length Corridor length may also be an important consideration.

A lengthy corridor may be a population drain for slow-moving animals with limited lifespans. The likelihood of successful dissemination across a corridor is inversely proportional to the length of the corridor. A lengthy corridor must meet all of a species' habitat requirements. If this is not possible, the presence of larger habitat patches acting as stepping stones along the corridor path may enable dispersing individuals achieve crucial habitat demands. Closed-canopy ecosystems, such as tropical forests, may be more significantly influenced by habitat discontinuities than other habitats. In the Tropics, Conservation Biology and Landscape Ecology may play an essential role in the mobility of canopy and understory species.

A discontinuous canopy may function as a barrier for predator-protected species or arboreal species that migrate primarily through top forest layers. Some corridors may be divided by highways or rivers, which may impede animal travel. Even short road and powerline clearings (less than 80 m wide) in tropical forests may obstruct migration of sensitive understory birds, small animals, and arboreal marsupials. As a result, if feasible, such habitat discontinuities should be avoided by encouraging animal mobility via replanting gaps and structural corridors like as high way underpasses. Agroforestry Corridors and Endangered Wildlife Agroforestry systems may not be good wildlife corridors for all species. There are two categories that will need particular consideration. The first are rainforest experts who shun damaged environment. Large, understory, or terrestrial insectivores were not discovered in agroforests in two comparative investigations of complex agro forests and primary forests, for example. As a result, since they are vulnerable to extinction in fragmented landscapes, even in the presence of agroforestry corridors, these species must become one of the focus groups for future study and monitoring. The second threatened wildlife category is game and big predator species [7].

Agroforestry corridors have the potential to become major population sinks for game and predator species that are aggressively hunted for food, revenue, or to protect domestic animals. Large predators like as jaguars and harpy eagles, for example, are commonly drawn to domestic animals on central Amazon farms and are therefore killed by farmers. Conclusions Wildlife corridors have been proposed as a strategy to reduce the consequences of habitat fragmentation for over 25 years. Despite a growing corpus of study on corridors, some scientists believe there is currently insufficient information to support using corridors in regional conservation efforts. However, as natural wooded areas shrink in size, there are fewer possibilities to purchase or conserve residual ecosystems that may sustain habitat connectivity. A wait-and-see strategy might be devastating in these situations. Acting now to conserve and develop wildlife corridors may include certain risks, but removing a corridor in the future will be significantly simpler than creating one where the original habitat has been destroyed.

Agroforestry systems have the ability to improve plant and animal movement throughout the landscape, contributing to biodiversity conservation. The habitat quality, structure, and natural dynamics of various agroforestry systems vary greatly, affecting the wild species that utilize them. A windbreak in a meadow, for example, may offer habitat for edge and generalist species like insects and rodents, but riparian corridors may include residual plants and be more helpful to forest interior species. Many agroforestry systems have one aspect in common: they are located on high-quality sites, while forest remnants are more likely to be kept on infertile soils or steep terrain. These fertile regions may have formerly supported dense populations of native plants and animals and served as significant dispersal sites. As a result, agroforestry lands might play an important role in wildlife conservation if plantations strive to implement some basic recommendations aimed at facilitating the migration and persistence of animal and plant species. First, remaining primary and riparian forests should be conserved, and any primary rainforest portions should be included within the plantation. Small remains may be home to regionally unique species and serve as stepping stones for faunal and floral dissemination.

Second, traditional shade plantings that retain native canopy species or plant mixed canopies should be encouraged, and some spontaneous recruitment should be permitted. Third, agroforestry plantings should be diversified, including native fruiting and blooming species that produce enormous fruit yields over extended periods of time (for example, fig trees or giant palms). Fourth, rather than a single tree row, linear plantings such as windbreaks should be as broad as feasible and have a complex structure. Fifth, tree plantings should close gaps in the canopy and preserve canopy connection. Finally, domestic animals should be kept in cages wherever feasible, and hunting should be restricted, particularly for extinction-risk species.

Agroforestry strategies that strive to meet these objectives will help species most susceptible to habitat loss, disturbance, and fragmentation. Such techniques should be included into regional conservation efforts in the tropics [8].

DISCUSSION

The movement of individuals (animals, plants, fungi, bacteria, etc.) from their birth location to their breeding site ('natal dispersion') as well as movement from one breeding site to another ('breeding dispersal') is referred to as biological dispersal. The movement of propagules like as seeds and spores is sometimes referred to as dispersal. Dispersal is technically defined as any movement that has the potential to result in gene flow. The act of dispersion comprises three parts: departure, transfer, and settling, and each of these processes has distinct fitness costs and benefits. An individual's dispersion affects not only individual fitness but also population dynamics, population genetics, and species distribution by simply shifting from one habitat patch to another. Understanding dispersion and its implications for evolutionary strategies at the species level as well as processes at the ecosystem level requires knowledge of the kind of dispersal, the dispersal range of a specific species, and the dispersal mechanisms involved.

Biological dispersion is distinct from geo dispersal, which is the mixing of formerly isolated populations or whole biotas as a result of the eroding of physical barriers to dispersal or gene flow. Dispersal differs from animal migration usually round-trip seasonal movement, while the terms' migration' and 'dispersal' are sometimes used interchangeably in the population genetics literature. Some creatures are motile throughout their lifetimes, whereas others are only suited to move or be moved during certain, restricted stages of their life cycles. This is referred to as the dispersive phase of the life cycle. The type and conditions of organisms' dispersive phases often influence their overall life cycle strategies. That take use of numerous sources of kinetic energy that occur naturally in the environment. This is known as density independent or passive dispersion, and it occurs in many groups of animals including certain invertebrates, fish, insects, and sessile species like plants that rely on animal vectors, wind, gravity, or current for dissemination.

Many species' density-dependent or active dispersion is heavily influenced by variables such as local population size, resource competition, habitat quality, and habitat size. Organismal dispersal is an important mechanism for understanding both regional isolation in evolution and the broad patterns of present global distributions (biogeography). A difference is sometimes made between natal dispersion, in which an individual usually a juvenile travel away from the site where it was born, and breeding dispersal, in which an individual usually an adult moves away from one breeding area to breed another.

There are many advantages to dispersion, including the ability to locate new resources, escape harsh surroundings, avoid competing with siblings, and avoid reproducing with closely related individuals, which might lead to inbreeding depression. There are additional expenses involved with dispersion, which might be thought of as four basic currencies: energy, danger, time, and opportunity. The additional energy necessary to move, as well as the energetic investment in movement apparatus (e.g. wings), are examples of energetic costs. Increased damage and death during dispersion, as well as the likelihood of settling in an undesirable habitat, are all risks. Time spent dispersing is typically insufficient for other activities like as growth and reproduction. Finally, dispersion may cause outbreeding depression if an individual is more suited to its natal environment than the one in which it ends up. A dispersing individual in a social species (such as many birds and mammals) must locate and join a new group, which may result in loss of social status. The "dispersal range" of a species is the distance it may travel from an existing population or the parent organism. Individuals and populations must be able to spread from one habitat patch to another for an ecosystem to function properly. As a result, biological dispersion is crucial to ecological stability [9].

Few species are ever dispersed equally or randomly within or across landscapes. Species vary substantially throughout the landscape in relation to environmental characteristics that impact reproductive success and population persistence. Spatial patterns in environmental elements for example, resources allow people to flee dangerous situations and seek out other places. This permits the organism to "test" new surroundings for acceptability, as long as they are within the geographic range of the species. Furthermore, a species' capacity to spread across a progressively changing habitat may allow a population to endure harsh circumstances (e.g., climate change). Prey and predators must adapt to survive when the environment changes. Many creatures, including Southern Rock hopper Penguins, are affected by this. Because of their morphological flexibility, these penguins can survive and prosper in a wide range of conditions. This time, though, they are expected to react by dispersion rather than adaptation.

This may be attributed to their extended life spans and delayed microevolution. Penguins in the sub antarctic have considerably different foraging behavior than those in subtropical seas; keeping up with the constantly changing environment would be very difficult, since these habits take years to evolve. A dispersion barrier may cause a species' dispersal range to be significantly lower than the species distribution. Human land use fragmentation is an artificial form of habitat fragmentation. Mountain ranges and rivers, on the other hand, are natural obstacles to dispersion that restrict species spread. The Congo River, for example, separates the territories of the two kinds of chimps. Human actions, on the other hand, may increase a species' dispersion range by offering new dispersal means (for example, ballast water from ships). Many such scattered species become invasive, such as rodents or stinkbugs, while others, such as honeybees and earthworms, have a modestly beneficial influence on human settlements.

Most creatures are capable of locomotion, and migration from one location to another is the main process of dispersion. Locomotion permits the organism to "test" new habitats for compatibility, as long as they are within the range of the animal. In most cases, inherited habits govern movement. The creation of dispersion or gene flow barriers between contiguous places may isolate populations on either side of the forming split. Allopatric speciation may occur when segments of an ancestral population are geographically separated and then genetically isolated. The movement or transmission of seeds away from the parent plant is referred to as seed dispersion. Plants' vegetative reproduction is restricted, thus they depend on a range of dispersion vectors, including both abiotic and biotic vectors, to transfer their propagules. Seeds may be disseminated away from the parent plant either individually or collectively, and in both space and time. The unique dispersion method determines seed dispersal patterns in major part, which has substantial ramifications for the demographic and genetic structure of plant populations, as well as migratory patterns and species interactions. Gravity, wind, ballistic, water, and animal dissemination are the five basic means of seed distribution [10].

Sponge, bryozoans, tunicates, sea anemones, corals, and oysters are examples of non-motile animal forms. They all have one thing in common: they are all either marine or aquatic. It may seem strange that plants have thrived in fixed existence on land while animals have not, but the reason rests in food supplies. Plants make their own sustenance from of sunshine and carbon dioxide, both of which are typically more plentiful on land than in water. Animals that are stuck in place must depend on the surrounding medium to deliver food near enough to capture, which happens in the three-dimensional aquatic environment but much less abundantly in the atmosphere.

Corals are an excellent illustration of how stationary organisms disperse. Corals reproduce by immediately releasing sperm and eggs into the ocean. During certain warm months, these release events are coordinated by lunar phase, such that all corals of one or more species on a specific reef release on the same single or many consecutive nights. The released eggs are fertilized, and the resultant zygote swiftly grows into a multicellular planula. This motile stage then looks for a suitable substratum to settle on. Most fail and die or are eaten by zooplankton and bottom-dwelling predators like anemones and other corals. Untold millions are created, and a few are successful in identifying areas of exposed limestone, where they settle and develop into polyps. If everything goes well, the single polyp develops into a coral head by budding off other polyps to create a colony.

Many animal species, particularly freshwater invertebrates, may disseminate as latent eggs, dormant embryos, or, in some circumstances, dormant adult stages by wind or transfer with the help of bigger animals (birds, mammals, or fishes). As adult dormant stages, tardigrades, some rotifers, and some copepods may tolerate desiccation. Many additional species (such as Cladocera, Bryozoa, Hydra, and Copepoda) may disseminate as latent eggs or embryos. For such dissemination, freshwater sponges often feature peculiar dormant propagules called gemmulae. Many types of dispersal dormant stages may endure not only desiccation and low and high temperatures, but also the action of digestive enzymes as they pass through the digestive systems of birds and other animals, high salt concentrations, and a variety of toxicants. Many freshwater creatures' long-distance spread from one water body to another was made feasible by such dormant-resistant phases.

The dispersal rate also known as migration rate in the population genetics literature or probability indicates the likelihood that any person would leave a region or, more accurately, the predicted percentage of individuals to leave an area. A dispersal kernel, which offers the probability distribution of the distance traveled by every person, is often used to characterize the dispersion distance. In theoretical models of dispersal, a variety of functions are used for dispersal kernels, including the negative exponential distribution, extended negative exponential distribution, normal distribution, exponential power distribution, inverse power distribution, and two-sided power distribution The inverse power distribution and distributions with 'fat tails' depicting long-distance dispersion occurrences (called leptokurtic distributions) are regarded to best fit actual evidence on dispersal. Many populations have patchy geographic distributions, with distinct yet interacting subpopulations inhabiting discrete habitat patches. Individuals disperse across subpopulations, increasing metapopulational connectedness and potentially lowering the probability of stochastic extinction. If a sub-population becomes extinct by accident, it is more likely to be recolonized if dispersion is rapid. Increased connection has the potential to reduce the degree of local adaptation.

CONCLUSION

A wildlife corridor, habitat corridor, or green corridor is a section of habitat that connects animal populations that have been isolated by human activity or constructions. Landscape corridors, which are narrow strips of habitat that link isolated patches of habitat, provide lifelines for native plants that reside in the connected patches and are therefore an important tool for biodiversity conservation. A corridor or linked route has high functional connectivity if it promotes dispersion and mobility while also protecting natural processes. Functional connection emphasizes the corridor from a species' viewpoint, while structural connectivity highlights the corridor from a land- or seascape perspective. Corridors are often classified into two types: riparian ribbons, such as those found in rivers and streams, and hard surfaces, such as a hedgerow or road verge. Corridors serve human purposes such as property boundary barriers and landscape components. Green corridors, also known as biodiversity corridors, are extensive areas of land where concerted activities are taken to conserve biological variety. Corridors help many species survive by expanding food supplies, providing important shelter, minimizing the likelihood of predation, and uniting fragmented and isolated populations.

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CHAPTER 11

ROLE OF THE AGROFORESTRY IN THE REDUCTION OF THE DEFORESTATION

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ABSTRACT:

Agroforestry is important in reducing deforestation because it promotes sustainable land use practices that blend trees with agricultural products and/or animals. It provides an alternative to conventional agricultural methods that depend on large-scale forest removal for agriculture. Agroforestry systems contribute to biodiversity protection by providing habitat and corridors for animals. Agroforestry helps safeguard endangered species and improves ecosystem resilience by keeping existing trees and establishing new ones. Carbon sequestration occurs when trees in agroforestry systems absorb atmospheric carbon dioxide and store it in their biomass and soil. This contributes to climate change mitigation by lowering greenhouse gas emissions and encouraging carbon sequestration.

KEYWORDS:

Agroforestry Methods, Tree Crop, Land Capital, Land Tenure, New Technology.

INTRODUCTION

"People deforest in search of new lands to replace depleted nutrient-rich land. Profitable agroforestry systems may deflect deforestation on remaining patches of primary forest by boosting returns to land in current agricultural regions. This is known as the land degradation-deforestation hypothesis: land-degrading farming methods push farmers to destroy new forestland in order to make a livelihood. Introducing agroforestry methods, on the other hand, has paradoxical consequences on farmers' motivations and possibilities to convert additional natural forest to agriculture or agroforestry. Farmers might use agroforestry to make forest conversion more lucrative, providing an incentive for more forest encroachment. Better profitability may also attract new migrants, magnifying the benefits even more. Higher production raises agricultural surplus and lowers capital limitations, allowing farmers to invest more in EST clearing. This chapter presents a comprehensive assessment of the reasons for and against using agroforestry to mitigate deforestation. We begin by discussing the agroforestry-deforestation argument. According to a Peruvian research first published in Sanchez and Benites, 1 ha of modern agroforestry systems saves 5 ha of forest [1].

We show how a single case study has been misapplied and generalized to make worldwide predictions about how agroforestry would prevent tropical deforestation. The logic overlooks the existence of market consequences and the fact that farmers are sensible and will seize new possibilities. We next present three common agroforestry adoption scenarios and how the deforestation effect is expected to differ across them. The subsistence logic underpinning the land degradation-deforestation theory is then discussed, as well as why farmers should not extend their agricultural land into forests if a new and lucrative agroforestry technique becomes available. The next sections go over three main sets of conditioning elements that determine the agroforestry-deforestation connection in further detail: farmer characteristics, technology, and market and land tenure circumstances. We provide various instances to support our claims. This chapter builds on previous research on the effects of new agricultural technology on the pace of tropical deforestation.

Considering agroforestry to be one sort of technological development, we may use the developed framework and investigate some of the case studies to answer the title's question. It should be noted that we concentrate on the influence of agroforestry on the conversion of natural forests to agroforestry, and consequently on off-site biodiversity. This chapter does not address the issue of on-site biodiversity, which is addressed in various other chapters throughout the book. However, a critical problem is the potential trade-offs between on-site and off-site biodiversity, which is only briefly addressed in this chapter. Furthermore, we concentrate on deforestation rather than the consumption of forest products and the influence of agroforestry on forest product reliance. Agroforestry Research and the Deforestation discussion A few observations pertinent to the theme of this chapter emerge from a study of agroforestry research and discussion over the last couple of decades. For starters, as Mercer and Miller point out, "biophysical studies continue to dominate agroforestry research while other important areas have not received the attention they deserve [2]."

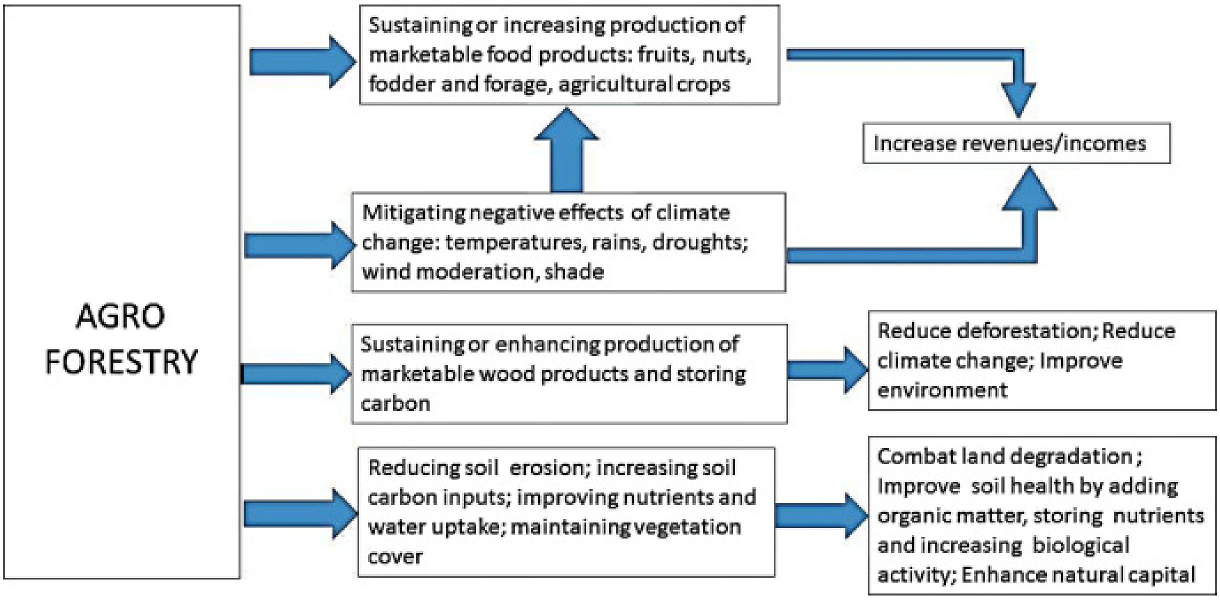

Figure 1: Agroforestry benefits: Diagram showing the overview of the agroforestry (Springer link).

They discovered that only 22% of the articles published in Agroforestry Systems between 1982 and 1996 dealt primarily with socioeconomic issues. More than half of these papers are quantitative economic research, with cost-benefit analysis being the most prevalent approach. The Ecological Economics of Agroforestry, which was published in four important agroforestry publications between 1991 and 1996, was substantially lower: just 10%. Second, the emphasis has almost entirely been on small-scale forestry (i.e., plot, field, or farm level). According to Nair, fewer than 5% of the publications in his sample were based on global, regional, or watershed scales. Issues that must be evaluated on a bigger scale have been overlooked. Given these results, it is not surprising that there has been relatively little study conducted to explicitly measure the influence of agroforestry on deforestation.

A third and intriguing observation is how the assertion that one hectare of agroforestry saves five to ten hectares of forest has practically become an accepted fact in the agroforestry world. As a result, it's intriguing to trace the origins of this 1:5 ratio and how it's been incorporated in the agroforestry literature. This number seems to be based on a single research conducted in Yurimaguas, Peru, and published in the reputable journal Science by Sanchez and Benites. The article does not directly address the impact of deforestation, but it does state that "to produce the grain yields reported, a shifting cultivator would need to clear about 14 ha in 3 years, in comparison to clearing 1 ha once, by means of the low input system." The low-input system described in the article was not agroforestry, but rather an improved cropping system with selected varieties of rice, cowpea, and chemical weed control.

Sanchez and colleagues extended their findings to the deforestation and global warming issues in later studies. Sanchez and Sanchez et al. claim that "for every hectare put into these sustainable soil management technologies by farmers, five to ten hectares per year of tropical rainforests will be saved from the shifting cultivator's axe, because of their higher productivity." Brady et al., presenting the Alternatives to Slash and Burn (ASB) Programme, make a similar extrapolation: "Research has suggested that for every Although no actual yield or revenue figure for agroforestry was available from the Peruvian study, agroforestry is presented as one of the primary sustainable management options and alternatives to slash-and-burn, along with paddy rice production on alluvial soils, low-input cropping, continuous cultivation, and legume-based pastures [3].

This difference between the real agricultural systems analyzed in the Peruvian instance and agroforestry vanishes in 1990s studies on agroforestry and global warming by other writers. Agroforestry has the ability to lower atmospheric CO2 levels by minimizing forest loss (Figure.1). "Direct evidence of this potential is limited," they write, "but one research study indicated that a low input agroforestry system, involving the rotation of acid-tolerant crops, produced agricultural products on a single hectare equivalent to the volume normally produced on 5 to 10 ha under slash-and-burn agriculture," citing Sanchez and Benites. Later in the essay, they use an average of 7.5 ha to infer that developing 1 million ha of agroforestry each year would conserve 7.5 million hectares of forest.

Diversification of a cropping system such that overall production from multiple products is more stable over time (lower downside risk) and actions that promote a system's lifetime (sustainability) 90 II. As a result, the Ecological Economics of Agroforestry also qualify as technical advancement. In most circumstances, introducing agroforestry methods would qualify as technical development under this criterion. Agricultural intensification, defined as greater inputs (or output) per hectare, is often related to technological improvement, although the ideas are distinct. Technological advancement may or may not entail intensification, and intensification may (and often does) occur in the absence of any change in the underlying technology. Agroforestry may be used at different phases of agricultural development. Because the situations vary, they will assist shape the conversation concerning agroforestry's potential influence on deforestation.

The first is when tree crops, often fruit or multifunctional trees, are introduced into altering farming systems. They tend to increase labor inputs per hectare and are more labor demanding than shifting cultivation or pastures, but not more labor intensive than continuous yearly cropping. Population growth (higher land scarcity and the need to provide more food from a limited land area) is the primary driver of development, and agroforestry is a low-cost intensification in response to the need to supplement subsistence food production (e.g., fruits or protein banks as fodder supplement for cattle) and products traditionally collected from forests. The setting for the second scenario is identical to the first in that land is plentiful and the forest boundary remains open. The main distinction is that the aim to generate commercial tree commodities for an outside market drives the development of agroforestry. A new market outlet (e.g., a new road) or a new technology or production method offered by government extension agency, commercial companies, or entrepreneurial people might be the trigger. Commercial tree crops may be introduced and modified existing systems, as in the case of rubber agroforestry in Indonesia, which arose from the introduction of rubber trees into the traditional shifting farming system. Commercial tree crops may eventually grow so dominant that the system is no longer regarded as agroforestry.

Sunderlin et al. discovered evidence of such dominance in Indonesian rubber, cocoa, and coffee. An extensive survey of more than 1,000 households in Indonesia's outer islands found that nearly one-third cleared forests for sedentary agriculture of primarily tree crops (more than half chose rubber), another third for 1-2 years of annual food crops only, and the remaining combined the two. The third instance depicts a distinct scenario in which land and forest product scarcity are important motivators for adopting agroforestry on cropland to produce forest products. The demand for these forest goods is often from local or regional markets rather than worldwide markets (in contrast to the second instance, when markets might be either national or international). Because most of the forest has vanished in this scenario, the influence of agroforestry adoption on deforestation is indirect through production and labor market consequences, as detailed later in this chapter. The Economic Logic The key arguments in what we call the land degradation-deforestation hypothesis are that land-degrading and productivity-reducing agricultural practices force farmers to clear new forestland to make a living, that agroforestry is a sustainable practice that allows farmers to generate more food and income over time from the same amount of land than previously, and that agroforestry thus reduces the need to convert forestland. Farmers may extend their farms to gain more money if a new agricultural method or technology is more lucrative than prior land uses, according to the counter-hypothesis. Consider a farmer who wishes to maximize his farm's surplus (net income) [4].

He may hire as much workers as he wants from the local labor market, borrow as much money as he wants from the local bank to fund any investments, and sell as much product as he wants at a set price. He may expand his agricultural land by removing forest that is either open to the public or part of his property. When a new technology becomes accessible or known to him, he embraces it in order to boost his revenue. Will he also cut down more trees? Certainly! We made at least four significant assumptions here, which we shall quickly address. Each of them has the ability to change or even reverse the outcome. First and foremost, growth may not be a possibility. The remaining area, for example, may be protected by land use rules (e.g., a park or wildlife reserve), inaccessible or unsuitable for agricultural production, or already occupied by agriculture or other land uses.

Obviously, the most interesting instance to analyze from a research standpoint is when growth is a viable possibility. However, from a practical and policy perspective, the contrast between open and closed borders is critical, with significant policy consequences. Second, farmers may have "full belly" preferences, which means that they strive for a specified subsistence objective and, once there, prefer leisure or social activities. Although evidence of such situations may be uncovered, the idea that farmers lose all interest in growing their income and consumption after a subsistence aim has been met seems to be fairly unreasonable. However, we contend that "full belly" desires are not as frequent as many deforestation assessments and development and conservation interventions presume. It is dangerous to base strategies and programs on this premise. Third, farmers are unable to expand their agricultural acreage due to manpower and capital restrictions. Such limits at the home or village level may greatly limit the potential for converting forest, especially when the new technology is labor or capital demanding, as is typically the case [5].

This point will be expanded upon later. Fourth, technology advancements are unlikely to affect just one home. If a big number of farmers embrace a new technology, the production and labor markets will suffer economically. Large fluctuations in production may have an impact on the price of farmers' products. Changes in labor demand are expected to have an impact on local wages and migratory patterns. Farmer traits, agroforestry technology, and market and tenure conditions are all potential constraints to agricultural development, which we will address in the following sections. Farmers' options are limited by available technology, assets, market circumstances, land tenure, and other reasons. Technological advancements may adjust these limits and give incentives to farmers to spend their resources differently. To comprehend farmers' reactions to technological development, one must first comprehend farmers' constraints and motivations. Farmers in poor nations have several constraints, notably in terms of labor and monetary resources, and the marketplaces in which they operate are far from ideal. Consider a farm family that is unable to sell its labor in a nonfarm labor market or hire employees to work on the farm. Assume that the available family labor permits the household to develop 3 hectares of land using the previous technologies. If they use an agroforestry method on all agricultural land that is 50% more labor demanding (labor days per hectare), they may only farm 2 ha; the remaining 1 ha reverts to secondary forest. Thus, in the situation of labor restrictions, the adoption of labor-intensive technology may help to lower deforestation rates.

Farmers vary from impoverished, isolated subsistence farmers to wealthy, commercial estates. Because each kind of farmer specializes in distinct crops and production processes, many developments are only relevant to certain groups of farmers. Farmers react to new technological developments differently in terms of both technology uptake and forest effect. Smallholders are more financially limited, which may prevent them from adopting certain technical breakthroughs. For example, an agroforestry technique may need the acquisition of costly tree crop seedlings, and fruit tree agriculture may necessitate the costly conveyance of the yield to an urban market. Capital-intensive technologies may harm already poor farmers in multiple ways: they may be unable to buy the new technology, they may face decreased salaries and output prices, and deforestation may impair forest-based income and environmental benefits. The poor's major asset is usually their own labor. As a result, impoverished farmers may have a competitive advantage in labor-intensive technologies such as many agroforestry approaches. However, wealthy farmers may be in a better position to 5.

Is it possible that agroforestry will reduce deforestation? On a big scale mobilize (hired) labor. For the extremely poor, the fast cash argument may cause them to depend more on short-term wage labor and forest product gathering, making medium- to long-term investments in agroforestry problematic. Tropical farmers often use a variety of agricultural strategies, complicating study of the influence on deforestation. These systems interact; they compete for family work and generate food and financial money to meet the requirements of the family. Consider a simple example in which a farming family runs one intense lowland rice cultivation system and one vast upland slash-and-burn scheme. A set quantity of work is to be apportioned between the two systems, and a new labor-intensive rice technology (e.g., a new rice variety) is to be introduced. This definitely removes work from the entire system and reduces deforestation [6].

Consider a labor-intensive agroforestry system for the uplands that includes the planting of nitrogen-fixing legume trees or the interpolating of annual food crops with tree crops. If we study this system in isolation, the consequence will be less deforestation due to manpower restrictions in the family. However, with two systems, farmers may move resources between them, potentially expanding the labor-intensive agroforestry method. The lesson here is that labor restrictions for certain systems and deforestation operations are often changeable since farmers may move resources to more lucrative pursuits. It is also crucial to pinpoint the location of the change. In general, more intensive agricultural technologies—typically situated further from the forest frontier—have a higher potential to minimize deforestation due to their impacts on both the labor market (absorb workers) and the output market (compete with frontier crops). Agroforestry methods exist in both forest-abundant and forest-scarce contexts, although the first two scenarios in the table account for a major portion of agroforestry adoption. As a result, one should exercise caution when claiming that agroforestry is equivalent to the green revolution as a deforestation-reduction approach, as Sanchez et al. do. Whereas green revolution technologies are aimed at intensive farming systems and hence tend to divert resources away from forested regions, agroforestry technologies often do not.

The properties of new agroforestry technologies are significant in determining their influence on deforestation, however such a study is difficult. The effect is decided by the qualities of the technology in conjunction with the farmer and market parameters. In general, as we move away from the "perfect markets" of economic textbooks—the world in which farmers have perfect information and may sell or purchase as much as they want at a set price—technological aspects become increasingly relevant. The Ecological Economics of Agroforestry Labor and capital requirements (factor intensities) are important characteristics of emerging agroforestry methods. We assume that they are fixed for a particular technology, neglecting the fact that farmers may alter the labor and capital inputs in each technology or production system (for example, how often and thoroughly weeding is done).

In reality, however, the technology used obviously limits the useful spectrum of inputs. Because the majority of farmers are capital or manpower restricted, the impact of new technology on overall capital and labor demand limits how much land farmers can produce. When markets are imperfect, families' labor and cash endowments have a significant impact on the result of the deforestation. When markets are flawed and farmers are limited, a labor- or capital-intensive agroforestry approach is more likely to encourage forest protection. Labor and capital intensities are less relevant for deforestation outcomes when farmers are neither capital or labor limited or when these markets are operating properly. Most agroforestry methods seem to be labor demanding, while certain techniques, such as using tree shade to minimize weed pressure (and substitute manual weeding) in cropping systems, attempt to reduce labor demands (albeit tree shade is more labor intensive than herbicides).

Permanent agroforestry approaches, in instance, require more effort per unit area than conventional shifting cultivation, grazing, and slash and burn annual cropping systems. Indeed, manpower shortages are often cited as a reason why agroforestry methods are not implemented. Surprisingly, the same technical feature (labor intensiveness) that makes farmers hesitant to embrace agroforestry practices is also the same feature that makes the method, if accepted, less likely to lead to primary forest encroachment. There are, however, exceptions. Kudzu (Pueraria phaseoloides) is a leguminous vine that fixes nitrogen and increases the availability of nutrients in the soil, therefore hastening soil recovery. It also inhibits weeds, lowering the need for personnel to clean and weed. As a result, kudzu allows for shorter fallow periods. This should minimize the amount of fallow land available, allowing for a bigger forest area. This is a low-cost, labor-saving solution that boosts yields and may conserve forests. What more could you want? It is not surprising, therefore, that kudzu is specifically identified as one of the potential species for managed fallows in the Sanchez and Benites paper. However, no one can guarantee the result of the forest. According to Yanggen and Reardon, a study of 220 farm families in Pucallpa, Peru, farmers who employ kudzu fallows may remove much less forest to produce the same land area (traditional secondary forest fallow needs 40-116 percent more land). However, increased production and labor savings work in the other way. According to the authors' econometric study, kudzu lowers main forest clearance while increasing secondary forest clearing, resulting in a slight increase in overall forest clearing. This study illustrates a key point in this chapter: higher yield can reduce deforestation in theory, but higher benefits (increased yields or lower costs) of a technique can more than offset this effect by providing an incentive to cultivate a larger total area. And since kudzu saves labor, farmers will be able to do so [7].

One should use extreme caution when making broad inferences regarding enhanced fallows based on a single research. First and first, kudzu is not a tree, albeit its introduction in certain situations may be seen as a technical development in an agroforestry environment. Second, better tree fallows may need more labor than kudzu fallows; cleaning some planted tree fallows requires more effort than clearing a spontaneous fallow. The overarching lesson is that the influence on natural forests is determined by the features of the agroforestry practice in issue, as well as farmer and market factors in the region, as well as government policy. Agroforestry has the potential to minimize forest strain if it lowers the farmer's ecological and economic risks.

DISCUSSION

Agriculture, especially rain-fed tropical agriculture, is a dangerous enterprise, and farmers' decision-making processes are heavily influenced by risk factors. Farmers may overexploit natural resources as (short-term) insurance against yield and price risk, ensuring that their revenue exceeds their subsistence requirements even in a poor year. In their research from northern Mindanao, the Philippines, Coxhead et al. discovered evidence of this. As a result, risk-reducing technology should allow farmers to convert less forest to farmland. Another goal of agroforestry is to make the system more robust to environmental shocks such as drought years or insect outbreaks, which do not affect all species in a mixed system equally. The system's multi-output nature also protects against shifting market pricing; all eggs are not placed in the same basket. In this regard, mixed tree crop systems multi strata agroforestry should be favored over monoculture systems in order to lessen pressure on natural forests. However, not all systems lessen risk. Introducing cash tree crops (for example, fruit trees) at the cost of domestic crops (for example, cassava) or livestock exposes the farmer to increased market risks. Furthermore, when a large number of farmers adopt new tree crops at the same time, the increased supply puts downward pressure on pricing and may quickly make them unprofitable. Furthermore, we must assess the technology's sustainability and suitability for cultivation on newly cut woods. According to Ruf and Schroth, cocoa is especially suited to newly removed forestland, and cocoa growers benefit from "forest rent" (i.e., a greater profit compared to planting on previously farmed land) in recently converted forests. Suitability also relates to the infrastructure required. Fruits, for example, need closeness to markets and strong infrastructure (both of which are often lacking near the forest boundary), but rubber and cattle are less reliant on frequent transit [8].

The amount to which a new practice or technology comprises of fixed investments is a final feature of agroforestry technology that is significant for the deforestation effect. The land degradation-deforestation theory applies more to annual crops than permanent crops. Farmers who have made significant investments in their property, such as planting perennials or terracing, are more hesitant to go on and destroy more forestland. Coffee plantation, for example, has helped to maintain the forest boundaries. Overall, our discussion focuses on what happens when farmers embrace new agroforestry methods, neglecting the problem of technology uptake. Farmers, on average, prefer to use technology that expand rather than restrict their options. Long ago, the work of Bose up on the demographic drivers of agricultural intensification and Hayami and Ruttan on induced innovation based on relative factor shortage indicated this. As a result, if farmers confront severe labor shortages, they will be hesitant to employ labor-intensive methods or technologies. Similarly, if land is plentiful, there are little incentives for them to embrace land-saving methods or technology.

As previously stated, labor- and capital-intensive practices that bind farmers' resources on small, intensively managed plots have the greatest potential to reduce forest pressures; however, labor (and capital) scarcity and land abundance are typical characteristics of the situation at the forest frontier. As a result, the paradox is that the practices or technologies with the greatest promise for conserving forests are more likely to be embraced after the forest is gone. In forest-abundant areas, farmers may adopt these labor-intensive and land-saving strategies or technologies if they are particularly lucrative or have other attractive attributes such as decreasing risk or fitting in well with the farmers' seasonal labor demands. Adoption of coffee by smallholder settlers in Ecuador exemplifies this argument. Adoption of agroforestry methods is also influenced by a variety of criteria, which Franzel classifies as feasibility, profitability, and acceptability. Nonetheless, the overall issue remains valid: it is difficult to encourage farmers to adopt techniques or technologies that preserve resources that are not viewed as limited, such as forestland in an open border environment.

The current market conditions have a significant impact on the deforestation result of a certain technical advance. A significant number of farmers using agroforestry methods may shift demand and supply in different markets, causing commodity prices to fluctuate. Such impacts, known as general equilibrium effects in economic parlance, may be critical for the ultimate forest results of agroforestry in certain circumstances. The tread mill effect refers to the premise that technical advancement increases supply, lowering output prices and, in certain cases, farmer income. Because food demand is inelastic in general, tiny increases in supply may result in big price decreases, thus net consumers benefit but net producers lose. The degree of this pricing impact is an empirical issue that is the result of two factors: total market demand elasticity and relative supply rise. The pricing impact will be limited if a yield-increasing agroforestry method launched in frontier agriculture is extremely location specific and adopted by just a tiny proportion of producers. Similarly, if the crops in issue are exported and each nation has a limited portion of the global market, price drops will have little effect on the growth. Commodity booms involving export crops may therefore result in a fast rise in planted area and, as a result, deforestation. One example is the fast expansion in cocoa output by smallholders in West Africa over the twentieth century, although via monoculture cocoa plantations rather than cocoa agroforestry [9].

Frontier agriculture, on the other hand, is often characterized by high transaction costs, inadequate infrastructure, and restricted market access. Some income crops are exclusively available in local markets, which may quickly become saturated as supply grows. If the primary outputs of agroforestry are for local markets, any growth will be swiftly stifled due to low pricing, with little or no new deforestation. The problem of pricing reactions to supply increases presupposes a conundrum or trade-off. From the standpoint of rural development (farm income), one should seek crops sold in markets that can absorb an increase in supply, such as major domestic (urban) or export markets. However, these are the kind of marketplaces that may set the groundwork for new technologies, such as agroforestry methods, to be used to clear enormous areas of forest. Labor Markets and Migration In isolated forest-rich nations, labor-intensive agroforestry methods may be expected to have a positive or little influence on forests. Labor shortages and excessive pay restrict any growth.

Labor shortages, on the other hand, are less likely to hinder growth if regional or national labor markets work relatively effectively and there is considerable labor mobility (migration). The degree of interregional labor and capital transfers therefore plays a critical role in determining how much the agricultural sector grows, especially in the long run. Active labor markets may assist reduce deforestation when labor-intensive technology progress happens outside of frontier regions. As evidenced by a Philippine irrigation study by Shively and Martinez, employment opportunities beyond the border will draw workers away from forest-clearing efforts in the uplands. Labor-saving technologies, on the other hand, encourage more people to migrate to the border. According to Ruf , green revolution technologies (e.g., automation) in Sulawesi saved labor and accelerated the conversion of forests to cocoa estates in the uplands. A study of rubber agroforestry at selected areas in Indonesia's Borneo and Sumatra highlights the essential role of the labor market in influencing forest result. Many observers have attributed large-scale forest conversion on the introduction of rubber into changing agriculture patterns in Southeast Asia.

The ASB Programme has performed substantial study on rubber agroforestry in Sumatra. Although rubber agroforestry has many appealing aspects, it has not halted the conversion of primary forest to small holder rubber holdings for the reasons stated previously: high productivity in conjunction with considerable in-migration of labor. According to De Jong's research, adding rubber gardens (or rubber-enriched fallows) and extra tree cover on formerly slash-and-burn agricultural areas yielded both economic and ecological advantages. Several variables, including improved forest management in the Borneo examples, explain this discrepancy. The distance and little in-migration to the Borneo locations were significant differences. Because the adoption of rubber in Sumatra was followed by significant in-migration from Java and other regions of Sumatra, manpower shortages had little effect on the conversion of forests to rubber agroforestry. The scenario was quite similar to that of West African cocoa agroforestry, which was able to expand due to in-migration from the savanna zone into the rainforest. Furthermore, the growth had no effect on the global price of rubber.

Land Tenure So far, we haven't spoken anything about property rights and land tenure. Insecure land rights and open access circumstances are often identified as significant underpinning causes of deforestation, acting as a deterrent to investments in land, particularly agroforestry. The actual data, however, is more nuanced than the simplistic hypothesis predicts. The forest effect of technological development in general, and agroforestry in particular, is significantly dependent on the current property system. In general, free access settings may stimulate investments in cutting new forests, while contexts with well-defined property rights may encourage investments in the resource base via improved land management of existing land. Although this may be true in general, it is subject to various limitations. Private forest owners who have sufficiently solid land rights may elect to convert portions of their forest to crops or grazing. However, moderately secure tenure, which is often associated with individual property rights, gives no incentives to consider land use externalities. Property rights that are poorly defined or insecure, it is often thought, decrease the incentives to invest in agroforestry. Again, there are several caveats to this broad statement. The term "secure tenure" is often misunderstood. Individual use and income rights are often granted under customary land tenure, whereas transfer rights are held by the lineage, chief, or community [10]. This strategy often offers enough tendril incentives for agroforestry investments. Detailed study often identifies additional issues limiting investments in land conservation and agroforestry, such as labor and capital restrictions and high discount rates. Neef and Heidhues conclude in a Benin study that "the key issues holding up agroforestry investments in Benin would not be addressed by land titling programmer." However, they point out that land tenure can become a key factor in the success of agroforestry programs, particularly in densely populated areas. A farmer's right to land is determined by human actions rather than the institutional framework. Planting tree crops tends to promote tenure security in large kinds of tropical agriculture such as shifting farming. Planting trees becomes a technique for claiming land rights. As a result, the usual notion that tenure instability promotes deforestation is reversed: insecurity becomes a justification for growing trees and investing in land since it strengthens the farmer's claim to the land. This impact has been seen among Sumatran rubber smallholders.

In reality, when there is de facto free access to natural forests and land rights are created or reinforced via tree crop planting, there are incentives for both deforestation chopping down natural forest and reforestation planting trees rather than annuals on the cleared area. To conclude, the property regime is significant, but its influence on the for est cover is complex. More emphasis must be placed on the establishment and strengthening of land rights. When comparing alternative systems, researchers and policymakers should consider not just changes in outcomes and inputs, but also the influence on tenure security. Improved land tenure security should encourage investment in current agricultural land, lowering the demand for land expansion. However, the greater predicted income of agroforestry over shifting agriculture makes the investment in forest conversion more profitable. The latter consequence may increase the number of land races.

Agroforestry scholars have given little attention to the influence of agroforestry on deforestation. A Peruvian case study on yield disparities has been used as a worldwide gauge of deforestation consequences to some degree. As a result, many people believe that agroforestry lowers deforestation by a factor of roughly 1:5. Extensive research, including farmer and market responses, shows that technological change often leads to more, rather than less, deforestation, and this may also apply to agroforestry if it increases the profitability of land use, unless there are factors such as labor, capital, or market constraints that limit agricultural expansion into forest areas. The Sanchez and Benites research was a major component of the ASB Programme, with previous studies demonstrating its deforestation-reducing potential. It would be fascinating to see how the ASB-Indonesia investigations conclude, based on their results in Sumatra: "It is naive to expect that increased productivity will necessarily slow forest conversion or improve the environment." In fact, the inverse is feasible. ASB study in Indonesia has shown that "normally, land use change involves tradeoffs between global environmental concerns and poverty alleviation and national development objectives. This is not to say that agroforestry cannot help to reduce deforestation in certain circumstances. Our message is that the general claim that agroforestry reduces deforestation including the 1:5 is incorrect, that basing deforestation policies and programs on unqualified assumptions will not help reduce deforestation and can lead to misallocation of development and research efforts, and that the impact of introducing agroforestry practices is conditioned by the type of practice, farmer characteristics, market and tenure conditions.

In summary, win-win situations in which agroforestry can meet both local development and forest conservation objectives are characterized by technologies tailored specifically for forest-poor areas; labor-intensive technologies when labor is scarce and in-migration is limited; promotion of intensive systems when farmers engage in extensive, low-yielding practices; and technologies that significantly increase aggregate supply when demand is inelastic. We have also shown that trade-offs are more widespread than is often supposed. When agroforestry practices are successful and widely adopted, and forest areas remain accessible, a trade-off is frequently presented: land under agroforestry practices has desirable ecological characteristics compared to alternative land uses, but the area of primary forest is shrinking. And the agroforestry systems that are most likely to be implemented and hence most advantageous to farmers are those that save labor while producing commodities for huge national or worldwide markets. After criticizing those who answered "Yes" unconditionally, we will avoid going to the other extreme and answering "No." Instead, we will argue that it depends on the specific circumstance, and our goal has been to point to a number of elements that decide net impacts on deforestation.

CONCLUSION

Agroforestry systems may improve local lives by providing rural people with sustainable supplies of food, fuel, and revenue. Agroforestry may reduce poverty and increase the well-being of local inhabitants by encouraging self-sufficiency and lowering dependency on forest resources. Agroforestry methods may be included into national and regional land-use planning plans and policies. Governments may support sustainable land management methods and prevent deforestation by recognizing the importance of agroforestry and offering incentives for its adoption. Overall, agroforestry is a feasible and sustainable agricultural technique that combines human needs with environmental protection. Agroforestry helps considerably to the reduction of deforestation and the preservation of precious ecosystems by incorporating trees into agricultural landscapes.

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CHAPTER 12

COCOA GROWING THEIR SIGNIFICANCE IN TROPICAL DEFORESTATION AND FOREST CONSERVATION

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ABSTRACT:

Cocoa cultivation, especially in tropical countries, has both contributed to deforestation and has the ability to save forests. Cocoa production has historically been a cause of deforestation in various tropical locations. Farmers have often cleared land by chopping down trees to build cocoa plantations, resulting in habitat loss and biodiversity degradation. Cocoa is an important cash crop for many tropical nations, giving revenue and a life for millions of farmers. Because of its economic importance, finding sustainable methods to combine cocoa production with forest protection is critical.

KEYWORDS:

Cocoa Trees, Cocoa Plants, Cocoa Farmers, Forest Trees, Southern Cameroon.

INTRODUCTION

In the 1950s, an American scientist who visited southern Bahia on Brazil's southeastern coast expressed his impression of the region's cocoa cropping systems, locally known as cabruca cocoa, as follows: "Only slowly does the initiate become aware that this 'forest,' and the 'forest' that had appeared as formidable to him in the latter stages of his trip into the cacao region is that same huge orchard which he had sought from the air and He learns to identify the towering trees as jungle trees left behind after land clearance to provide shade for the low cocoa plants". These chocolate forests, created by under planting selectively thinned natural forest with cocoa trees (Theobroma cacao), not only protect the tree crops from climatic hazards and pests, but also conserve some of the original forest's characteristics, including some of its biodiversity. As agricultural land use, including cocoa cultivation, has transformed the formerly vast and highly diverse Atlantic rainforest into isolated fragments in an agriculturally dominated landscape, conservationists and natural resource managers have become increasingly interested in the potential role of cabruca agroforests for biodiversity conservation [1].

"In Southern Bahia, the merits of the cabruca cacao are that the system allows economic development." After the late 1980s cocoa price slump and the arrival of the 107 witches' broom disease (Crinipellisperniciosa) in 1989 motivated the conversion of some of these traditional systems into pasture, local authorities and the scientific community used the International Cocoa Research Conference in Salvador de Bahia in 1996 to develop an image of tradition, culture, and environmental protection around the cabruca cocoa farms. The official recognition of their potential for biodiversity conservation and ecotourism represented a fundamental shift in political priorities in comparison to previous campaigns in Brazil and other cocoa-growing regions to thin these dense canopies of forest remnants in order to increase cocoa yields.

It exemplifies the dual character of cocoa agroforests in this region of the Brazilian Atlantic forest as an agent of conversion of natural forests into agricultural ecosystems and as one of the most biodiversity-friendly land use alternatives accessible to local farmers. Of course, all upland agriculture in the humid tropics must take place on forestland, and hence at the cost of the forest. A history of boom-and-bust cycles, along with the propensity of the principal cocoa-growing zones to wander from one location to another, has made the cocoa tree a key agent of the conversion of primary tropical forests throughout the previous four centuries, particularly in the twentieth century. Where these cycles began, they resulted in the formation of new forests, sometimes at breakneck speed. They left behind disease-infested groves of low production in a secondary forest habitat in the best situations, but typically merely poor fallows and pastures. These cycles were powered by cheap forestland and, in many cases, an immigrant work supply. Cocoa was grown in complex agro forests in regions such as Bahia, southern Cameroon, southwest Nigeria, eastern Ghana, and initially the Côte d'Ivoire; in other cases, such as most of the Côte d'Ivoire, western Ghana, Malaysia, and Sulawesi in Indonesia, cocoa was grown in plantations with little or no shade, often almost monocultures. It is clearly crucial for biodiversity whether forest is replaced by a tree crop monoculture or a complex agro forest with an understory of cocoa trees under the shade of ancient forest trees, both on the plot and on the landscape scale. What is more relevant for regional biodiversity is how different land use choices alter primary forest cover over time. The lifetime of a tree crop such as cocoa, as well as the ease of replanting it on the same site, are system features that are controlled by the degree of shadowing and, as we will see, may influence the long-term forest consumption by cocoa farms.

As efforts grow around the world to transform the cocoa tree's historical role as a consumer of tropical forests into an instrument to improve tropical farmers' livelihoods and conserve as much as possible of tropical forests and their biodiversity, it may be instructive to review the factors that determined whether this crop was grown in complex agroforests or monocultures, whether these systems were sustainable, and how they responded to social, environmental, and economic pressures. Although the Ecological Economics of Agroforestry article concentrates on cocoa, some of the results apply to other tropical tree crops that are both consumers of tropical forest and potential friends in the quest for sustainability in tropical forest environments [2].

The origin of the cocoa tree is most likely on the eastern equatorial slope of the Andes, and it is definitely in the Amazon basin. The crop's earliest true center of cultivation seems to have been Central America, where it has been cultivated for more than 2,000 years. Cocoa became an economically significant product once the Spanish learnt from the Amerindians how to turn it into a tasty drink. In 1525, Central American criollo cocoa trees were established in Venezuela and Trinidad; later, Jamaica, Haiti, and the Windward Islands became key producers. From that point forward, global cocoa output rose as new nations accepted the crop and former production hubs closed down. The continuous rise in global output throughout the ages has obscured a series of national and regional boom-and-bust cycles.

Central America was the first location to create a cocoa industry in the sixteenth century, before giving way to the Caribbean, particularly Jamaica and Venezuela. Venezuela was the world's leading producer of cocoa in the eighteenth century until declining in the early nineteenth century, when Ecuador took control and its port Guayaquil became the world's capital of cocoa export from the end of the nineteenth century until the 1920s. As cocoa output in Ecuador declined, production in Brazil and Ghana stepped in. Following that, Ilhéus and Salvador de Bahia in Brazil, Accra in Ghana, Lagos in Nigeria, and Abidjan in Côte d'Ivoire emerged as the world's main cocoa export ports, sending hundreds of thousands of tons of cocoa to Europe and North America. Malaysia monopolized the New York stock exchange's fax machines from 1980 to the early 1990s, but its cocoa cycle was one of the shortest in history; Indonesia, particularly the island of Sulawesi, took over practically quickly. Similar cycles on the subnational scale replicated these industrial changes from one country to the next.

The history of cocoa cultivation in Côte d'Ivoire, which is examined in depth in this chapter, and the more recent history of Sulawesi demonstrate cut-and-run cycles in early adopter zones that were later abandoned for new pioneer fronts. Descriptions of these changes in cocoa-growing areas from different continents and separated by four centuries sound eerily similar, highlighting a trait that defines most of cocoa history. The Sonocusco region (in Mexico) was famed for its opulence and success, heavily inhabited with Indians, and highly admired by Spaniard merchants for its vast chocolate output and the considerable commerce that resulted. There are relatively few Indians left. It is estimated that there are fewer than two thousand people, and the cocoa trade is relocating to another region, farther down the road to Guatemala Cocoa production in Côte d'Ivoire is uncommon today between Abidjan and Abengourou, the area where the cocoa business began. Over the previous 12 years, output in the Abengourou area has decreased from around 22,000 tonnes to 6,000 tonnes. There are abandoned farms all over the place. Production is moving to the interior, toward Dimbokro and Gagnoa, where virgin forest areas are being removed. (FAO 1957, 16-17) [3].

It should be noted that Dimbokro, the core of the Ivorian cocoa belt in the 1960s, had already completed its cocoa cycle by the early 1980s, when the crop had shifted farther west, mostly to Soubré. For the past four centuries, cocoa has spread across the globe, often at the price of tropical forests. Cheap labor and forestland: Ingredients of Cocoa Booms Most tree crop booms across the globe have been made feasible by a mix of migrations and destruction. Migrations are caused by the existence of big and mobile people close to sparsely populated forest. Such a mobile labor force was available in West Africa's savanna zone to supply the cocoa booms in Côte d'Ivoire from the 1960s to the 1980s, and in the densely populated southern section of Sulawesi and Bali to supply the cocoa boom in Sulawesi in the 1990s.

Cheap land in sparsely populated forest zones is a strong pull factor for poor farmers in the source areas of such migrations; for example, in Indonesia in the 1980s, a migrant could buy at least 10 ha of land suitable for cocoa planting in the forested plains of central Sulawesi by selling a quarter of a hectare of paddy terraces in his village in Bali. Migrants have easier access to virgin forest areas (and subsequent transport of agricultural produce to markets) when logging companies build roads and open tracks into the forest, especially if they are maintained by public investments (lack of these may have saved logged forests in parts of Cameroon from immigration. Government measures also had a significant impact on the rate of migration. Both Côte d'Ivoire and Cameroon produced around 100,000 metric tons of cocoa per year before to independence. Following independence, the two nations' diametrically opposed migration policies were the driving force behind Côte d'Ivoire's remarkable 1.2 million metric tons by the mid-1990s and Cameroon's seeming standstill around 110,000 metric tons.

In Indonesia, the cocoa boom in Sulawesi in the 1980s and 1990s, which had been launched by spontaneous bugis migrants from the southern part of the island's South Province, was involuntarily boosted by the government's transmigration program: although the program's intention was to resettle populations from the densely populated islands of Bali and Java in irrigated rice production schemes on Sulawesi, it took a new direction when the migrants copied the successful experience of the migrants. Planting a crop after removing primary forest may provide large economic benefits over planting it on previously utilized agricultural or fallow land, a factor that can be understood as "forest rent" and has contributed greatly to tropical forest conversion. Because of the difficulties in replanting cocoa in locations where the forest has vanished, this problem may be more essential for cocoa than for other tree crops. It helps to explain why cocoa has a strong inclination to follow the disappearing forest, with new plantations being created on cleared forestland rather than replanting old and disease-infested plantings on the same location. The difference in investment and production expenses for a metric ton of cocoa between a plantation developed after primary forest clearance and one established on fallow ground or by replanting an earlier cocoa plantation is characterized as the differential forest rent applied to cocoa. Planting on forestland usually always wins out over replanting. The reasons for this are related to the different efforts required for forest clearing and plantation maintenance, particularly weeding, differences in soil fertility and microclimatic conditions between forest and replanted sites, and biological factors such as pest and disease pressures, which all work together to determine production costs, yields, and tree mortality risks when establishing a new plantation. Cocoa benefits from minimal weed pressure, excellent soil fertility, and a microenvironment suitable to the establishment of these drought-sensitive understory trees when planted in virgin forest soil [4].

Replanting fallow ground or old plantations requires more weeding, slower development of new trees, and more mortality, particularly during the first dry seasons. Furthermore, when the forest disappears, lumber and game supplies become rare, raising house and living prices. Attempts to estimate forest rent in Côte d'Ivoire show a roughly doubling of investment costs for replanting after fallow (now commonly dominated by the aggressive invader Chromolaena odorata) or after an old, weed-infested cocoa plantation compared to planting after cleared forest. For the first year, the total effort for clearing, planting, and weed control was 168 working days per hectare for replanting and 86 days per another assessment of total labor expenditures until the cocoa began to yield placed the replanting effort at 260 days per hectare, compared to 74 days per hectare for after-forest planting. In the hills of Sulawesi, planting cocoa after fallow rather than forest results in higher labor costs, and most smallholders believe that cocoa requires more fertilizer when planted on grassland rather than forestland, with the total difference in production costs including net inputs such as fertilizers and labor costs amounting to approximately US$0.10 per kilogram of cocoa. This is a cautious estimate since net input costs are decreased by yields of food crops originally connected with cocoa, which are greater after forest than after grass land.

Furthermore, the depreciation of labor expenses during the juvenile period of cocoa plants disadvantages planting after grassland by delaying the initial cocoa harvests. As a result, although forest is still desired in the highlands and uplands, farmers on the lush alluvial plains are less concerned about the loss of forest rent. This forest rent and the availability of forestland has discouraged sustainable cocoa growth for decades. MacLeod, for example, documented the wasteful use of forest land in Sonocusco, Mexico, in the sixteenth century: excessive cutting and burning of woods and tall grasses produced erosion, leaching of top soil, and flash floods. On the cocoa coast, land was abundant in comparison to labor and money, and the Spaniards saw little incentive to preserve its quality and fertility. Even today, restoring eroded, leached soils for cocoa plantations is a time-consuming and challenging process. The Central Americans of the sixteenth and seventeenth centuries lacked the necessary technology and patience. Cattle and bush were often seen in the inferior pasture areas left behind by weary cocoa producers The Ecological Economics of Agroforestry.

The distinction is that, whereas rubber, coffee, and sugar cane are regularly replanted across the tropics today, transplanting old cocoa remains a challenging process in many locations, even for contemporary agronomists. This is particularly true when, during peak periods, soils unsuited for growing cocoa trees were utilized for planting, as has happened in several regions in western Côte d'Ivoire, Nigeria, and Sulawesi. The technical challenges of transplanting old cocoa are exacerbated by social and economic concerns. Replanting is typically not economically feasible for the first generation of cocoa farmers that arrive in a location, due to diminishing returns and increased expenses caused by plantation age. Furthermore, the life cycle of a tree interacts with that of its owner, his or her family, and the community. Migrants engaging in cocoa planting are frequently young, and since all planters in a single zone often came at the same time, they all age with their farms. When it comes time to replant, the farmers lack the requisite work force, particularly if their children have gone to school. As the yields from older plantations decrease, family size and consumption rise, limiting the capacity to invest in replanting even more. Conflicts between possible heirs often exacerbate agricultural deterioration by delaying investment choices. These problems may be exacerbated by ecological change, such as the introduction of new illnesses and shifting climate circumstances [5].

Eastern Ghana was the country's principal cocoa belt in the 1930s and was still prominent in the 1950s. However, as a result of the swollen shoot virus, soil exhaustion, and declining annual rainfalls, the region's cocoa economy collapsed, and the main center of cocoa production shifted to western Ghana's virgin forests, while the former cocoa belt became an oil palm and citrus belt. With this context in mind, we shall now analyze the cocoa history of the world's biggest cocoa producer, Côte d'Ivoire, before briefly considering two places where exceptionally complex cocoa agroforests have formed, Bahia and Cameroon. Migrants and the Côte d'Ivoire's Cocoa Boom The history of cocoa in Côte d'Ivoire started in the 1890s with a brief cocoa boom in the country's far southwest. Although economically insignificant, this local occurrence is informative because it demonstrates that early adoption arose as a result of indigenous processes rather than colonial initiatives. However, the modern Ivorian cocoa business was established in the eastern area after 1900. Cocoa expanded in this area and certain portions of the center-west from 1910 to the 1950s, mostly via micro-pioneer fronts. These early decades established the framework of migration because local farmers need labor. Many migrants might secure land and became cocoa smallholders after 3-10 years of solid service as employees. In turn, they requested family and laborers. Because of the poverty of nearby savannas of Côte d'Ivoire and Burkina Faso, there was a big and inexpensive work force waiting to be exploited.

The Ivorian president clearly realized the possibilities of uniting this immigrant work force with the huge Ivorian forest when the country gained independence in 1960. Migrations and the establishment of pioneer fronts were encouraged by measures that declassified forest reserves, disseminated knowledge, and opened borders to foreign workers. The movement into the woods was facilitated by logging firms and their paths. Between the mid-1960s and the early 1990s, the tropical forest was swept from east to west. The surge of migrants to the forest was intimately linked to the cheap costs of forestland. Some migrants in the southwest of the nation, where the last great cocoa pioneer front opened in the late 1970s, could still purchase 25 or even 50 hectares of primary forest for a bottle of gin, 12 bottles of beer, and one piece of fabric.

According to a 1998 survey of 1,000 cocoa farmers in the country, one-third were indigenous farmers, one-third Ivorian migrants (from the savanna in the center and north of Côte d'Ivoire), and one-third foreign migrants, mostly from Burkina Faso, with an average cocoa area of about 5.5 ha per household for all three groups. The high migrant component affected not just the pace with which cocoa expanded over Côte d'Ivoire's forest zone, but also the method cocoa was farmed. Until the 1960s, most cocoa growers did not, at least not all of them, take down the largest forest trees [6].

DISCUSSION

The vegetation was cleared and burnt, but some of the large trees were left standing and became part of the upper. Agroforestry canopy of cocoa agroforests: Ecological Economics. "Farms in the western cocoa growing areas are ordinarily well provided with primeval bush shade, as in the Gold Coast; but in the central and eastern districts, where the influence of the European planter is strongest, Because no chainsaws or even good axes were available, one important motivation for this agroforest cocoa growing strategy was to save labor by sparing especially trees with very hard wood or large buttresses, as described decades later for indigenous cocoa farmers in western Côte d'Ivoire . Of course, these forest people were aware of the many uses of their trees and kept some valuable species. Such densely forested cocoa agroforests can still be found in eastern Côte d'Ivoire, and pockets of this agroforest tradition have also survived in the center-west, in the region of Gagnoa, where a local revolt against the government's policy of encouraging immigrants in the 1970s discouraged further immigration.

The classic agroforest approach has the disadvantage of causing delayed returns since excessive shade delays the development of the tree crops. Shade, on the other hand, extends the productive life of the cocoa plantation. Furthermore, the fact that shading protects cocoa trees from insect pests has been known in West Africa at least since the early twentieth century, when attempts to increase cocoa yields on the islands of Fernando Pó and So Tomé resulted in crop failure. Moreover, the mostly unbroken root systems of the forest trees permitted for the forest's even tual renewal. Thirty years after the cocoa trees were planted, this system encouraged a strategy of abandoning the farm and allowing shade trees and forest regrowth to flourish. The previous cocoa plantation was subsequently transformed into a secondary forest, where successful replanting was nearly certain. This was nothing more than the shifting cultivation technique applied to a perennial crop, as recognized by Blank enbourg in the 1960s. It devoured forest at first, but once established for a certain population, it could potentially rotate on its own tree crop-fallow land without damaging the adjacent forest. If this form of rotating agroforestry method had spread across Côte d'Ivoire's forest belt, the landscape would look quite different today.

Why didn't this happen? The research and extension services that promoted zero-shading from the early 1970s to the late 1990s in Côte d'Ivoire, like in most other countries, had a crucial part in the subsequent modification of the cocoa-growing technique. Since the early to mid-1970s, the ancient amelonado cocoa types, locally known as cacao français, have been replaced by a new planting material, upper amazons and hybrids of upper amazons, locally known as cacao Ghana. With little or no shadow, the vitality of the new kinds seemed to be better displayed. The most major driver of modifying cocoa-growing practices, however, was demographic and societal change. Prior to the mid-1960s, the majority of cocoa farmers were indigenous forest people who used the same style of forest clearance they had learned through shifting agriculture on their tree crops. Before that period, there were relatively few migrants in the woodland zone. Rural populations in the forest zone where true booms were occurring, on the other hand, continued to rise at rates of 10-20 percent per year via immigration in the 1970s and 1980s.

This social land slide was followed by a technological one, the introduction of a labor-saving method to clear forest trees at the same time. The most energetic of the savanna people flooding into the forest, the Baoulé migrants, invented a method for destroying large trees by collecting undergrowth around them and setting them fire for a few days; the trees subsequently crumbled apart over the following several years. This was significantly less labor intensive and risky than chopping them with axes, frequently from a platform that enabled them to attack the stem above the buttresses, as had previously been done. Along with the cocoa trees, the migrants planted yams, which required heavy soil ploughing and limited the forest's ability to recover, rather than upland rice, which was produced by the indigenous and required minimal disturbance of the forest soil [7].

Instead of spending a lot of time cutting down the forest trees and cleaning the plot, the new technology of forest conversion served a strategy of immediately planting cocoa plants to designate land ownership. The intensive burning of biomass, soil tillage, and canopy opening also accelerated the initial growth of the cocoa trees and provided rapid financial returns: whereas the indigenous method took 5 years until the first cocoa yield and produced 500 kg of cocoa per hectare after 10 years, the tree crops started producing within 3 years and yielded close to 1 metric ton of cocoa per hectare at 6-7 years with the no-shade system. The migrants considered speedy planting and quick returns. Furthermore, the social and demographic pressures brought forth by immigration quickly eliminated any possibility of implementing the traditional, broad tree crop-fallow cycle. There was no room for cocoa fallows where cocoa was thriving, and leaving a plantation for 5-10 years would have resulted in land claims by indigenous people.

These characteristics explain why complex agroforests were not an option for migrants in Côte d'Ivoire when they began the cocoa cycle, as well as the low adoption rate. Chocolate Forests and Monocultures. After destroying most of the forest trees in the southwest of Côte d'Ivoire, a young cocoa plantation was built. Agroforestry rates are higher in most other places where migrants dominate the cocoa business. The conclusion of the Cycle The difficulty with the "Baoulé method" of forest conversion was that the forest rent had been eaten by the conclusion of the first cocoa cycle. When a cocoa farm reached the end of its life cycle, which happened more quickly in unshaded settings, it was difficult to execute the shifting cultivation concept, which allowed the creation of a forest vegetation where cocoa could be readily replanted after some time. Fewer woodland trees will be able to recover and develop again. With or without the effect of droughts and accidental fires, these historic cocoa plantations often became fallows dominated by the invasive shrub Chromolaena odorata, making cocoa replanting difficult and mortality high. Case studies of Baoulé communities in the country's center-west in the 1990s show the conclusion of a cocoa cycle. The cocoa boom began in this area surrounding Gagnoa in the mid- to late 1960s. The Baoulé migrants from the savanna lands of the center-north were correctly regarded the victors of the race for land and for est in the 1970s and early 1980s. Interviews with ten farmers in Petit Toumoudi, a community of Baoulé migrants, in 1995 reveal an image that is emblematic of the area. The majority of the farmers came just before 1970. They acquired 9.7 hectares of forest on average and planted more than 90% of it (8.9 ha) with cocoa combined with plantains. The severe death of cocoa plants started during the 1983 drought and persisted in the following years. They attempted to replant an average of 1.5 hectares, half of which died. After 25 years, they ended up with 5.3 hectares of low-yielding cocoa in 1995.

Their remarks were on soil exhaustion, as shown by the death of plantains, which foreshadowed the impending death of cocoa plants. They also reported lower and irregular rainfall, which they attributed to an increase in the length of the dry season rather than a drop in total annual rainfall, but also to the drier microclimate in the progressively deforested area. They also complained about weed and epiphyte invasion, as well as termites ruining the cocoa plants. Although they did not state their age, all were beyond the age of 55 and lacked the work force required for effective replanting. They lacked technique as well. Techniques that were very effective during the forest period have become outdated during the post forest era. Instead of effective forest clearing methods, a method to eradicate the weed shrub Chromolaena odorata, which had gradually taken over the previous forest area, was required. It was also becoming more difficult to manage weed pressure in both new and old crops. Furthermore, fire had become a growing hazard to plantations in various areas of the nation, including the old cocoa regions of Tanda and M'Bahiakro, which had practically become savanna [8].

Data from the Baoulé community of Konankouassikro, also in the Gagnoa region, reveal that rates of successful replanting remained very low in the 1990s when compared to planting rates after forest in the 1970s. The mentioned cocoa-growing system was very resource-intensive. As ancient cocoa farms were replanted and additional migrants came, technological advances arose in response to post forest circumstances. The three cases below are especially illuminating in this context since they potentially presented chances to embrace more sustainable techniques, including agroforestry, and maybe avoid some of the issues discussed before. However, since extension services lacked the requisite expertise and financial resources to participate in the essential dialog with farmers and promote more sustainable methods, the chances were lost, and farmers were forced to depend primarily on their own creativity and information channels. Primary woods for cocoa cultivation were more limited in the east and center-west areas of Côte d'Ivoire in the 1980s.

A decade or so later, the farmers devised their own solution to the "coffee crisis" by repurposing the mostly old and abandoned, mostly shaded coffee groves as alternative sites for planting cocoa, whose price was much higher than that of coffee (this technique was already mentioned in colonial reports from the Congo in the 1950s). It was normal practice to chop down the majority of the spontaneous forest trees that had developed on the abandoned farms, rehabilitate the coffee, and then plant cocoa seedlings under the coffee shade the following years. Once they were in place, the conversion was completed by removing the coffee trees. The earliest definite accounts of this technique's employment in Côte d'Ivoire come from the late 1970s to the early 1980s. Thousands of old and abandoned coffee estates that had virtually become secondary woods were transformed into cocoa plants in the 1980s. At the time, it was evident that the forest would not exist forever and that replanting cocoa on deforested places would be impossible.

This could have inspired farmers to develop a more permanent cocoa culture on these old plantation sites by retaining some of the shade trees and spontaneous regrowth, which could later be converted into secondary forest and then replanted, avoiding the difficulties associated with replanting in the monoculture system. Instead, with the cocoa sector dominated by recently arrived migrants, increasing population pressure, and an active land market, the conversion technique was adopted on a large scale by migrants, who purchased abandoned, forested coffee farms from indigenous farmers and transformed them into mostly unshaded cocoa plantation. The second breakthrough happened in the 1990s, when the Baoulé practically ceased migrating to the forest zone since there was little forest left for planting and rebuilding proved impossible. Young Burkinabé, on the other hand, continued to arrive in large numbers. They took labor at any cost since they were barely living in their own nation. At the time, it became evident that the future of cocoa in Côte d'Ivoire would be determined by smallholders' capacity to control the invasive shrub Chromolaena odorata, which infiltrated farms and controlled fallows created by forest clearance and cocoa aging [9].

In this circumstance, many Burkinabé purchased 1-2 ha of shrub fallows from indigenous people and replanted them, working three times as many hours per hectare as they did during the preceding forest period. The newly arrived young Burkinabé migrants were the most effective in replacing fallows with cocoa because they focused their work on a small area rather than spreading it over a broader field, as indigenous farmers and previous migrants did. Almost for the first time in the history of cocoa cultivation in Côte d'Ivoire, thousands of hectares of cocoa were planted after shrub fallows rather than primary and secondary forests. Simple associations of cocoa trees and plantains were employed by the farmers. Another, more complex but perhaps more permanent, shaded cocoa system would have been the use of tree fallows to control the C. odorata thick ets, which will be followed by cocoa trees.

Farmer in the Soubré area of Côte d'Ivoire's center-west in the 1990s. Because of its rocky soils, agronomists classed this area as unsuitable for cocoa cultivation as early as the 1960s. Migrants were unaware of this and would not have bothered. They poured into the area by the tens of thousands in the 1970s and 1980s, and by the late 1980s, it had replaced the Dimbokro-Bonguanou region to the east as the country's new cocoa belt. In the early 1990s, a large number of farmers found what agronoologists had predicted: production decreases and dramatic increases in tree mortality. Poor soils combined with enforced monoculture accelerated the local cocoa cycle, and 15-year-old cocoa trees in the eastern area resembled plants twice their age. Many cocoa plots have already vanished by the mid-1990s. The migrants had just two options: migrate to new woods farther west or develop a solution on the spot to prevent the demise of their cocoa fields. Because it is well recognized that shading decreases nutritional stress in cocoa plants, one may have anticipated using shade trees to enhance the nutritional quality of the cocoa trees and gradually transitioning to agroforestry methods. Instead, at a period when extension services were few, farmers discovered mineral fertilizers. Although the use of fertilizers did not maintain individual farms for decades, it did boost yields (perhaps by double them) and so provided farmers with an incentive to remain on their farms rather than relocate into new woods. This interim solution to the local cocoa dilemma may seem less environmentally friendly than the use of agroforestry technologies.

However, it had a critical role in postponing a further migration of cocoa producing regions, so contributing to the regional sustainability of cocoa cultivation. Are Ivorian Cocoa Farmers Willing to Adopt Agroforestry Practices? A journey across the former forest zone of Côte d'Ivoire with a focus on landscapes reveals a tendency of diminishing shade density in cocoa from east to west. Preliminary farm plot survey data from three villages show that big forest trees are present in cocoa plots at a density of around five trees per hectare in the east, two trees per hectare in the center-west, and fewer than one tree per hectare in the southwest. This decline in shade utilization from east to west reflects the rising dominance of migrants in the cocoa business, who utilize less shade than indigenous farmers. In the east, indigenous farmers kept immigration under check, but migrants make up 80-99 percent of the farmer population in the west. For both indigenous farmers and migrants, the majority of non-cocoa trees in farm plots are planted or spontaneous fruit trees rather than forest trees, with roughly 20 trees per hectare (compared to around 1,500 cocoa plants per hectare) [10].

The profits received from these fruit plants were only 5-10% of those earned from cocoa for both indigenous farmers and migrants in the study. The migrants' somewhat greater noncocoa revenues may be explained by better access to cola trade networks in their native nations of Burkina Faso and Mali, as well as a more commercially focused selection of noncocoa plants. These fruit trees are not ecologically equivalent to the big forest remnant trees that made up the over story of traditional cocoa agro forests. However, most Ivorian cocoa growers, particularly the younger generation, seem to have a negative attitude toward prolonged shadow from forest trees. In a 2002 survey of 65 farms focusing on the center-east and center-west regions, 70% of respondents found shade from forest trees useless to cocoa, and 20% found it useful only as temporary shade for plantation establishment, for which most farmers preferred plantains (at least on suitable soils). Shade trees were thought to aggravate not just illnesses but also pest issues in cocoa because they enabled insects to hide in the canopies and evade pesticides, reducing cocoa revenue (F. Ruf, unpublished data). Although farmers understand that shade extends the life of their cocoa fields, this is insufficient to halt the expansion of zero-shade plants.

This tendency is sometimes reinforced by a farm owner's generational change: when a newly arrived migrant acquires an old shaded cocoa plantation from an indigenous farmer, the first option is typically to remove the shade trees. Intergenerational transmission often results in the same behavior among indigenous populations. Many young cocoa growers want instant profits regardless of the long-term effect on the cocoa field. Because chainsaw crews are readily accessible, converting shade trees into revenue is simple. This sort of behavior is much more probable if a cocoa plantation is inherited jointly by numerous family members and ultimate ownership is unknown. Even in the most isolated migrant communities on the boundary of the country's biggest forest reserve, Ta National Park, it has been normal practice to chop down the enormous trees that are thought to offer home for insect pests (mirids) and are generally damaging to cocoa. Although more comprehensive studies of Ivorian cocoa farmers' attitudes toward shade and the factors that influence them are needed, evidence suggests that little has survived from an incipient tradition of cocoa growing in potentially sustainable but low-yielding rotational agroforests, with a 35-year longevity of the cocoa trees and a good chance of successful replanting after a forest-fallow period, after four decades of dominance of the sector by migrants.

Any initiatives to transition the Ivorian cocoa business to more sustainable methods must consider the experiences of other nations. This leads us back to the cacao trees of Bahia and southern Cameroon, where this tale started. These situations merit the attention of historians and agronomists since farmers in East Ghana and Bahia seem to have grasped the advantages of shaded systems, which may have lessons for the president. However, these instances of greater shade adoption in the twentieth century seem to be anomalies. Until the 1960s, the majority of cocoa was cultivated in the shade, but since the mid-1970s, the majority of cocoa has been produced in the open. Bahia, southern Cameroon, and southwest Nigeria are examples of places with complex and presumably viable cocoa agroforests.

Agroforest Estates in Bahia, Brazil For a second reason, Bahia is unique in the cocoa world: the majority of its cocoa is farmed on big estates. As a result, applying lessons from this case study directly to the smallholder farms that dominate the cocoa business in most other nations is challenging. Nonetheless, it is useful to note that, despite little data, attitudes about shade in this area contrast to some degree with those in Côte d'Ivoire. According to historical records, cocoa growth in Bahia in the nineteenth century was related with the usual fluctuations in local production zones. In 1820, the grains (beans) were spread over hot banks of fine sand to dry, then brought down in pirogues to the coastal ports, Ilhéos, Belmonte, Caravellas, and so on, a voyage of three to four days, according to Martius. This traffic has significantly decreased, owing to the railway's construction, but also to the progressive shift away from the river, which has resulted in the abandonment of the old fazendas; near Itabuna, all the way along the river, one frequently sees the now deserted buildings of these fazendas. In the early twentieth century, a structure of large estates was built in Bahia, and James described the practices of cocoa growing on these estates as follows: Plantation practices in Bahia are notably extensive and exploitative.

Once planted, the young trees are given almost no attention until they come of bearing age.... Following that, instead of cleaning away the brush and weeds every year, this kind of job is only done every four or five years. When yields fall, older plantations are abandoned and new ones are established on virgin soils. This is a speculative and destructive economy at its worst, providing Ilhéus and Salvador fleeting and unstable activity. In summary, the cacao zone capitalist elite views the land as something to be raped rather than adored like a bride. Ironically, the structure of enormous estates where these "notably extensive and exploitative" behaviors were witnessed aided the establishment of the cabruca system. Farmers on large estates, according to Alger and Caldas, tended to plant cocoa under native tree shade (i.e., in the cabruca system) and to invest in only a portion of their holdings, leaving the rest under forest, whereas small farmers were more likely to clear cut the forest on a larger portion of their property and plant bananas and other planted shade instead of native trees for their cocoa crop. Planting cocoa under the cabruca method required less investment per unit area than the clear cut approach and was better suited to the minimum management system used by absentee owners of vast estates. The cabruca method also allowed them to employ workers and enhance plantation management when cocoa prices were high and dismiss workers when prices were low.

With improved workers' rights in the late twentieth century, and since the outbreak of the witches' broom fungus, which necessitates continuous efforts to keep the disease in check, these former advantages (from the perspective of estate owners) of the cabruca system have been lost to some extent. Low cocoa prices coincided with the spread of the witches' broom disease in Bahia in the late 1980s and 1990s, encouraging some planters to (illegally) sell timber from residual forests reserved for future plantations and the cocoa agroforests themselves to compensate for low cocoa revenues. In addition, although some cocoa agroforests were abandoned, others were turned into grassland. In a November 1996 study, 30 farmers reported a loss of 70% of their work force and a corresponding decline in output. All planters cited neighboring tree removal and wood sales, and some planters predicted large-scale transfer of cocoa fields to other land uses, including grazing. However, the picture changes in 2003.

According to Brazilian agronomists and private cocoa pod counts and forecasters, the rate of tree felling and conversion of cabruca cocoa into pastures in the mid-to-late 1990s, although greater than before, did not surpass 10% in the last ten years. The majority of it happened in drier sections of the region, where cocoa plants had also been damaged by increasing drought frequency and irregularity of rainfall since 1982. These climatic occurrences seem to have strengthened Bahian cocoa growers' awareness of the ecological functions of shade trees, particularly soil moisture retention and cocoa tree microclimatic protection. In the mid-1990s, a research underlined the relevance of the shade canopy's biological functions in farmers' perceptions: shelter from the heat and conservation of soil moisture and fertility.

During the same time period, many farmers accused the extension service of misleading them in the 1980s by encouraging the removal of shade in old farms and the establishment of new farms with little or no shade, and they expressed their concerns about climate change, particularly more frequent drought, with some assigning drought the same. The relevance of the witches' broom illness in decreasing cocoa production. The first purpose of shade trees mentioned by Bahian cocoa producers in 2003 is drought prevention. Why this focus on the biological services of shade trees exists in Bahia but not in other places that have also suffered droughts, such as Côte d'Ivoire, is an unresolved subject that requires more investigation. It might be connected to shallow soils, but this theory has to be confirmed. One option to investigate how Bahian cocoa producers' experiences may give lessons for their colleagues in other cocoa-growing areas would be to encourage farmer exchanges and joint trips to their separate estates.

Cocoa Agroforests in Southern Cameroon Like cabruca cocoa in Brazil, the 50-year-old cocoa agroforests in southern Cameroon formed by natural forest trees are among the best examples in Africa of seemingly permanent agriculture that preserved a forest environment and some of its biodiversity. Satellite imaging cannot identify these cocoa agroforests apart from closed canopy forest. The fact that complex agroforests have arisen as the main type of cocoa cultivation in this area, as opposed to much of Côte d'Ivoire, is best explained by the predominance of indigenous farmers among southern Cameroon's cocoa producers. Other cocoa-producing areas in Cameroon, such as the M 'Bam and southwest regions, attracted more immigrants and followed more mono cultural cocoa-growing tendencies similar. Furthermore, both before and after independence, Cameroon's research and extension agencies preferred shade, and cocoa plantations constructed under forest tree shade in the 1950s have now grown into massive chocolate forests as the forest trees have waged by 50 years. Low yields, on the order of 300 kg of cocoa per hectare per year, are a disadvantage of excessive shadowing in these cocoa agroforests. Because excessive shading may aggravate pod rot (Phytophthoramegakarya), the most significant cocoa disease in this country, limiting shadow intensity may be part of integrated disease control plans. However, regulating the shade offered by such massive trees is impossible, unless they are chopped down and planked. The dense, permanent shade of forest trees creates its own set of replanting challenges: farmers attempting to regenerate their cocoa farms by under planting the agroforests with cocoa seedlings frequently discover that in the dense shade, the trees become tall and thin in their search for light, forming pods 2-3 m high, where they are difficult to harvest (and dis eased pods are difficult to remove).

As a result, farmers may decide to develop 6. Chocolate Forests and Monocultures 127 new cocoa plots in a different location, outside the plantation, where the shadow intensity may be more easily controlled. Ideally, this would be a previously planted patch of secondary forest, like in the old rotational system, although farmers sometimes utilize main forest if it is available. Historical evidence of this process may be seen in production changes at the village and regional levels. Between 1960 and 1963, the East province and the department of Dja et Lobo, where cocoa is mostly cultivated in agroforests, produced 8,000 and 9,000 metric tons of cocoa, respectively. Until 1984, yearly output had dropped to 5,300 metric tons per year, whereas cocoa production in the southwest province increased from 7,300 to 27,000 metric tons per year, and in the M 'Bam department increased from 6,200 to 10,900 metric tons per year.

Cocoa is grown mostly by migrants in weakly shaded systems in the later areas. In the Nyong et M 'foumou department, where cocoa is produced in ancient chocolate forests, the main cocoa production centers in the 1970s were the road from Akonolinga to Yaoundé and Endom in the south; by the late 1980s, cocoa production had moved to other districts such as Nwane Soo and Ayos Fang Biloun in the department's north. According to available statistics, noncocoa incomes from these agroforests are often inadequate to compensate farmers for lower cocoa revenues during periods of low cocoa prices. As a result, when cocoa prices fell in the 1990s, farmers turned to fresh forest clearance aimed at food crop production as a survival strategy. During the economic crisis, however, cocoa farmers near the Yaoundé urban market were successful in diversifying their farms by planting mandarin orange trees, often in places where cocoa trees had died and were difficult to replant, and this could indicate a way to further commercially oriented diversification of cocoa farms in other regions. Farmers in the Nyong et M 'foumou department mentioned the tree Voacangaafricana as a source of an exportable medicinal product in the 1980s, but this export trade has ceased, most likely due to a lack of certification and nonconformity to European market legislation. The African plum tree (Dacryodes edulis) is an intriguing species that, according to a study of 300 farmers in southern Cameroon, was planted on 83 percent of the respondents' cocoa fields. To summarize, although cocoa agroforests have effectively maintained a portion of southern Cameroon's forest environment, they have not been able to sustain farm profits during times of crisis, and however instances of successful eco nomic diversification of cocoa farms are developing. Replanting issues in agroforests vary from those in no-shade systems, although they exist and may have had a role, along with immigration into the southwest.

The cocoa agroforests have a fair chance of survival as long as population pressure in southern Cameroon stays low and migrants do not join the area via a possible land market. However, unless cocoa and noncocoa earnings from these agroforests can be enhanced, the model may be difficult to replicate if population pressure develops significantly. Cocoa has historically been a significant contributor of tropical deforestation, and it remains so now. At the same time, it is a crop on which many environmentalists and natural resource managers want to build an agriculture that not only provides a livelihood for tropical farmers but also contributes to the protection of biodiversity in tropical forest settings. A major concern is whether agroforestry methods can help stabilize cocoa producing systems and prevent the commodity from being moved to new forest frontiers while also providing a sustainable income to future generations of tropical farmers.

There are or were traditions of cultivating cocoa in agroforests in all three nations addressed in this chapter: Côte d'Ivoire, Brazil, and Cameroon. Obviously, this fact did not prevent deforestation by cocoa farmers, but it did help to slow down the process, at least in certain parts of these countries and at certain times, by extending the useful life of the cocoa tree and, critically, providing a foundation for replanting cocoa after a period of forest fall low and, thus, for more permanent cocoa systems. This foundation was substantially weakened when cocoa was grown in strict monoculture employing more harmful forest conversion practices, like in Côte d'Ivoire. These questions may only get preliminary responses. Complex cocoa agroforests have developed in response to unique technical, ecological, social, and historical circumstances. Such conventional structures may become unstable when their surroundings change, such as via immigration. As we saw in the case study of Côte d'Ivoire, numerous such changes might occur at the same time.

The necessity to cut labor expenses when establishing new plantations against a backdrop of poor technology and ample land has traditionally promoted the development of complex agroforests globally. Farmers saved time on forest cleaning and weed management by keeping a big portion of the forest trees. Important foundations of sophisticated cocoa agroforestry were lost when land became less plentiful due to immigration and more efficient forest clearance methods became accessible. The development of new cocoa cultivars that required less shade and had a faster initial 6 was a key element in the transition of the Ivorian and part of the Ghanaian cocoa economy toward zero-shade systems and monocultures.

Development, making intensive and labor-saving agroforestry approaches less appealing throughout the lengthy investment period. Furthermore, the use of pesticides and, subsequently, mineral fertilizers offered the monoculture system an instant advantage, and after these advances were implemented, there was even less motivation to embrace (or maintain) agroforestry methods. Despite the benefits of cocoa agroforests in terms of tree crop longevity and ease of replanting, the chances of traditional agroforestry practices using primary forest trees as shade and forest fallows to facilitate replanting are likely to be low in most regions, especially where demographic pressure increases, unless strong incentives develop or are created for the maintenance or adoption of such systems (e.g., markets for the timber from forest fallows, cedar forests, and cedar forests). In many locations, the most viable alternative for promoting cocoa agroforestry is likely to be rebuilding a new agroforestry tradition based on the planting of valuable lumber or other useful trees alongside cocoa rather than trying to maintain the ancient forest trees in the existing agroforests. The likelihood that these new agroforests will be adopted increases with their potential to give farmers with greater and more predictable revenue from both cocoa and noncocoa goods.

Cocoa income from agroforests may grow when clonal materials resistant to key cocoa diseases are introduced, as has recently begun in Bahia (witches' broom disease) and West Africa (Phy top hthora pod rot). Without markets for noncocoa goods, such as those in the Yaoundé region of southern Cameroon, stable earnings cannot be achieved, leading to the diversification of cocoa plantations with fruit plants. The expansion of urban markets in all tropical nations will stimulate this sort of diversification on the plot and farm size. The opening of the wood market to farmers in 1999, which legalizes the commercialization of timber and makes it less vulnerable to informal taxes, represents a promise for cocoa agroforestry in Côte d'Ivoire. If information about their new rights reaches cocoa smallholders, which has not yet happened, it should make maintaining trees on cocoa fields more appealing. The ability to exploit this potential to help develop more diverse and perhaps more sustainable cocoa systems will be very instructional for other African cocoa producing areas.

The important aspect in cocoa sustainability is not necessarily tree crop lifetime, but rather effective replanting. Replanting is expensive, thus it is critical that towards the conclusion of the cocoa tree's life cycle, there is funds available to pay replanting, which might be contributed by the trees. "As cocoa plantations should not live more than about twenty years, native people should be encouraged to intercrop cocoa with other trees, such as oil palms, colas, and avocados, which provide them with valuable produce when the main crop disappears. Whereas intercropping with oil palms and fruit trees may help diversify earnings from profitable cocoa groves, wood trees can accrue capital for replanting throughout the life of a plantation. Consider a pair of Côte d'Ivoire migrants in their twenties who began clearing forest and planted cocoa in 1968. Assume they sold a few iroko (Miliciaexcelsa) or frake (Terminalia superba) trees, or perhaps a sipo (Entandrophragma utile) trees between 1989 and 1993, during the height of the cocoa crisis. They could use the wood money to replant their cocoa grove, which was made possible by the presence of some giant trees and enough intermediate-sized trees to give the required shade. They may keep and care for these trees in the plantation as a retirement fund and an inheritance for their sons and daughters to fund the future transplanting.

Perhaps they planted some tree seedlings they found in a neighboring woodland or obtained from the extension agency. Their upkeep on the cocoa plantation, as well as the cocoa harvest, would be nearly free. It should be investigated how to stimulate such investments in sustainability via contracts and institutional arrangements between farmers and forestry services or wood processing enterprises. They must be accompanied by efforts to conserve remaining forests, sending a clear message to farmers that additional movements to the forest boundary are not an option. Whether cocoa farm diversification is based on timber, fruits, medicinal products, ecotourism, carbon credits, or payments for biodiversity conservation in a forest park buffer zone, what is most needed to make cocoa agroforests more sustainable is access to reliable and diverse markets for their products and services.

CONCLUSION

Governments and international organizations may play an important role in incentivizing forest protection in cocoa-growing areas. Financial aid, technical help, and legislative frameworks that promote sustainable cocoa production while conserving forests and fostering reforestation efforts are examples of such initiatives. To summarize, cocoa farming has traditionally led to tropical deforestation, but there is a rising awareness of the need to balance cocoa production with forest protection. It is feasible to encourage sustainable cocoa production while maintaining and restoring forest ecosystems via agroforestry systems, shade-grown cocoa, sustainable certification programs, deforestation-free pledges, landscape methods, and conservation incentives.

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CHAPTER 13

USING CONSERVATION CONCESSIONS TO SUPPLEMENT AGROFORESTRY FOR BIODIVERSITY CONSERVATION

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ABSTRACT:

Protection concessions may be an effective strategy for supplementing agroforestry methods in the protection of biodiversity. Conservation concessions include offering local communities, indigenous groups, or private entities long-term rights to manage and maintain natural resources within a defined region. Here's how conservation concessions may function in tandem with agroforestry to conserve biodiversity: Conservation concessions may be formed inside or next to existing protected areas to provide buffer zones or corridors that improve the biological connectedness of fragmented ecosystems. Agroforestry activities may be incorporated within these concessions, allowing for long-term land use practices that maintain biodiversity while also offering income possibilities.

KEYWORDS:

Agroforestry System, Biodiversity Conservation, Conservation Concession, Local Stakeholders, Sustainable Agroforestry.

INTRODUCTION

Agricultural commodity cultivation fosters habitat change and biodiversity loss across the tropics. Targeted interventions certainly have a role to play in slowing and mitigating the effects of this process, and in many circumstances, agroforestry is preferable than clear cuts and monocultures. Agroforestry systems, on the other hand, are a compromise rather than a solution in terms of conservation. Although agroforestry initiatives can create corridors or buffer zones in a patchwork of forest and production areas, they still disrupt the ecosystem; given a choice, biodiversity protection is better served by continuous intact habitat rather than the fragmentation inherent in a patchwork. Furthermore, agroforestry systems may or may not be viable in the medium to long term, creating uncertainty even when used as a conservation technique. Agroforestry is based on the idea that forests and natural resource bases must provide money via a flow of goods that benefits farmers [1].

Limiting revenue to that which can be derived through physical output flows restricts the scope for conservation interests to act and income prospects for local stakeholders. The hazard of just tying income to output is especially evident in places with poor economic prospects for agricultural commodity production, such as coffee-producing regions with low coffee prices (Sanchez 2002). In such cases, it is a lack of feasible departure choices for farmers that drives continuous habitat degradation, since many farmers living on tropical forest edges have little choice but to depend on harmful farming techniques for subsistence. Increased international willingness to pay for global biodiversity conservation opens up another land use option that does not rely on physical extraction; instead, local stakeholders can be financially rewarded for reducing their reliance on physical product flows from irreplaceable reservoirs of biodiversity, advancing both conservation and alternative income opportunities. The conservation concession approach developed by the Center for Applied Biodiversity Science (CABS) at Conservation International (CI) in collaboration with Hardner and Gullison Associates, LLC is one promising land use alternative that provides direct remuneration for conservation services. Conservation concessions may be used in a number of resource-based land use settings (such as wood extraction, perennial crop production, and animal grazing), but this chapter concentrates on their potential use as a supplement to agroforestry initiatives.

Following a broad description of the conservation concession concept, this chapter presents two scenarios for its use. The first is on coffee production in Colombia, and it describes how conservation concessions may be utilized to retire elderly coffee estates that are struggling due to bad economic circumstances. The second section discusses methods in which the conservation concession concept might strengthen agroforestry operations in Bahia, Brazil. Although these two scenarios do not cover all of the possible complexities and variances of conservation concessions or agroforestry, they do demonstrate that these two technologies may provide significant biodiversity benefits when used jointly.

The third part looks at several factors that might make the conservation concession strategy difficult to apply in practice. Agroforestry and Conservation Concessions Several authors to this collection explore how, from an ecological, agricultural, and economic standpoint, agroforestry might be superior to other land uses. Where habitat alteration has already happened, the ecological advantages of agroforestry systems over annual crops, cattle pasture, or monoculture plantings justify agroforestry promotion efforts. In cases where habitat conversion is unavoidable (or has already occurred), agroforestry systems can serve as corridors or buffer zones, with benefits including reduced agrochemical use, reduced soil erosion, less nutrient leaching and watershed degradation, and, depending on the species included in the system, enhanced nitrogen fixation and carbon sequestration. One of the most significant biodiversity benefits of some agroforestry approaches [2].

Under specific situations, the Ecological Economics of Agroforestry has the capacity to stabilize the geographical proliferation of production systems, therefore conserving forest boundaries. Any extent to which agroforestry may prevent or impede changing agricultural boundaries contributes significantly to biodiversity conservation. Deforestation is driven by agricultural commodity production as conventional techniques for a wide range of crops exhaust soil resources; under these techniques, declining productivity on aging plots leads growers to establish new plots in areas of intact habitat.

However, agroforestry land uses may also cause deforestation in a similar way, such as when diminishing cocoa tree production drives farmers to construct additional plots in virgin forests. Even if agroforestry supports more biodiversity than other cultivation systems, the greatest ecological benefits from agroforestry are obtained when production is concentrated on previously cleared lands; if forests are disturbed by the introduction of agroforestry, then alternatives that lead to more direct protection are warranted.

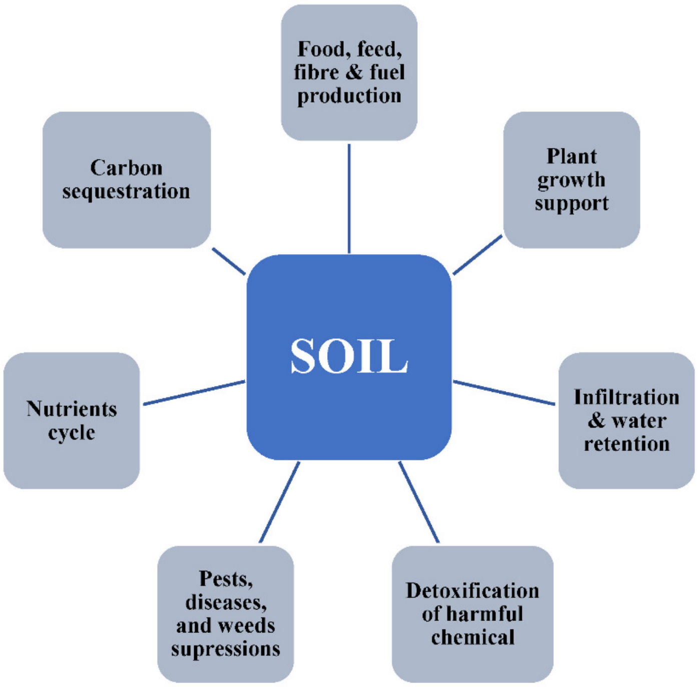

Figure 1: Soil system: Diagram showing the overview of the soil system (MDPI).

A conservation concession rewards local stakeholders and appropriate government agencies directly for delivering enhanced conservation services. Natural ecosystems are protected by national resource authorities and local resource users in exchange for a steady flow of structured investments under a negotiated agreement between local stakeholders, the host government, and investors such as environmental conservation organizations or private companies looking for environmental offset opportunities (Figure.1). A conservation concession, for example, may replace cultivation entirely, or the agreement may allocate some areas for agroforestry while reserving others solely for conservation. The level of payments, the period of payments, the investment portfolio to which these payments will be directed, and standards and procedures for monitoring and enforcing natural resource conservation are all negotiated parts of the agreement [3].

A conservation concession agreement is a long-term contract, often lasting between 25 and 40 years, that pays monthly payments from an endowed fund in exchange for the protection of a specific region. The payments represent, in part, the potential cost of not using the area's natural resources, addressing concerns such as lost employment, government income, and foreign currency capture. Payments may be negotiated to reflect additional considerations, such as government administrative and enforcement responsibilities associated with the concession, but the economic worth of exploitation foregone by protecting the land should be the foundation of any payment. Concessions include environmental costs and benefits, the economic value does not only equal exploitation earnings. Financial assessments may be altered to account for the concession's advantages, such as traditional usage and watershed preservation, as well as the payments' risk-free character. As a result, the amount of remuneration arises as a result of a negotiating process that involves these factors. The financial structure of conservation concession agreements may be quite appealing in comparison to other land uses.

Employment, income, foreign currency export profits, and governmental tax revenues are all potential economic advantages of logging, agriculture, and agroforestry. However, economic prospects for a wide variety of resource-based goods seem to be less than encouraging. Prices for coffee and cocoa have hit all-time lows in recent years, while cocoa prices rose significantly in 2002-2003 due to civil unrest in the world's biggest producer, Côte d'Ivoire. Low commodity prices might prompt desperate measures; for example, in 2000, prominent West African cocoa farmers revealed their intention to destroy 250,000 tons of cocoa, or around 8% of world production, in an attempt to boost prices. Agroforestry may lessen reliance on a single crop in certain situations, providing a hedge against poor price patterns. Nonetheless, revenue will continue to be volatile due to worldwide market circumstances and erratic weather patterns. Government income sources will continue to be fragile due to a limited ability to collect all taxes and levies. A conservation concession provides monthly, risk-free payments in stable foreign currency as long as the requirements of the agreement are followed [4].

Ideally, the payments are guaranteed by an endowed fund that lasts the length of the arrangement. The advantages of conservation concessions must exceed the profits from alternative uses of the target area. This is achieved, if appropriate, by investing pay mints in economic activity that will generate alternative employment and promote human wellbeing. A description of the portfolio of activities to which yearly payments will be allocated may be negotiated as part of the conditions of a conservation concession. Although the biodiversity investor's purpose is not to rigorously define host government public investment choices, economic gains from conservation payments should flow to individuals who may lose employment or other economic advantages as a result of conservation. The conservation investor might voluntarily supplement concession payments with health or education initiatives to assist local stakeholders, especially in rural places where government services are ineffective.

Salary enhancements, for example, may persuade instructors to serve in local schools in regions that are having difficulty recruiting skilled educators. Payments may also take the form of subsidies for medical products that would otherwise be too costly. Such investments contribute to the development of suitable compensation at the community level, as well as the development of trust and support for the concession among local stakeholders. The Ecological Economics of Agroforestry On the one side, the conservation concession strategy stresses compensation and social investments, and on the other, suitable enforcement and monitoring operations. The approach's fundamental point is to decouple revenue from habitat change and natural resource exploitation and instead connect economic advantages to effective conservation. The approach's most basic illustration is a conservation concession that pays local stakeholders to stop destroying forests and compensates them for monitoring and enforcing habitat preservation. In July 2002, CI reached an agreement with the government of Guyana to cover an area of about 81,000 acres in southern Guyana. Under the terms of the 30-year lease, CI pays the government annual acreage fees and royalties equal to those paid by timber concessionaires, totaling approximately US$30,000 and $11,000, respectively, and includes a voluntary annual investment of $10,000 in development projects benefiting three communities living near the concession (Guyana Chronicle 2002).

A conservation concession produces immediate, visible conservation advantages that are readily defined and assessed in geographical terms, demonstrating unambiguous conservation benefits to prospective biodiversity investors. Although there is a substantial and growing international willingness to pay for conservation, a growing trend emphasizes outcome-based rather than process-based indicators of conservation fund effectiveness; conservation investments must produce unambiguous, measurable results in terms of area and species protected. This tendency is immediately addressed by the tangible geographic foundation of conservation concessions, in which protection of a precisely defined region results from a negotiated commercial deal. The fundamental goal of a conservation concession is long-term habitat preservation. Nonetheless, the expiry of a concession's term gives a chance for a host government to reconsider the best use of the territory in issue [5].

Renegotiation and renewal of the agreement may be an appealing option: conservation concessions provide significant, stable income for the host government and local stakeholders while also being cost efficient from the standpoint of the worldwide conservation community. Most importantly, this mechanism allows conservation to pay for itself on a large scale, avoiding many of the challenges and complications that other conservation approaches face, such as high-maintenance integrated conservation and development projects and elusive sustainable extraction models. The simplicity of the conservation concession concept is part of its attraction. The model, however, must be adapted to unique. Conservation vary by nation, climate, primary natural resource, population density, ownership systems, and other factors. The approach's fundamental framework is easily adaptable to enormous swaths of unpopulated, state-owned land with negligible economic value. Greater the number of local resource users, the intensity of resource exploitation, and the complexity of tenure rights, the opportunity cost of conservation and the transactional cost of negotiating and implementing conservation concessions may all increase the opportunity cost of conservation. Although these factors may impact the price of a specific concession, they do not exclude the technique from being used in a given case as long as effective tenure rights are secure.

In many cases, the core principle of promoting conservation as a negotiated economic transaction between resource users, governments, and international conservation investors retains promise. Conservation concessions and sustainable agroforestry initiatives may work in tandem to conserve biodiversity and generate revenue. First, when sustainable agroforestry encounters challenges, conservation concessions provide farmers who would otherwise have few options. Second, although agroforestry does not guarantee a stable forest front tier, conservation concessions combined with sustainable agroforestry initiatives might raise the likelihood of maintaining a stable spatial equilibrium. Conservation concession payments may be used to promote agroforestry initiatives rather than more damaging agricultural land uses on land allocated for production in exchange for pledges to strengthen preservation of remaining natural habitat in such circumstances.

When used to land set-asides and retirement programs, a conservation concession may expedite the area's transition to permanent protected status. The sections that follow illustrate two situations in which conservation concessions might help to conserve biodiversity in agroforestry land uses. Retiring Coffee Farms in Colombia (FAO 2001) Coffee growing occupies over 12 million acres of land in almost 80 countries across the tropics. Nineteen of the twenty-five worldwide biodiversity hotspots identified by CI as conservation priority are important coffee-growing areas. This overlap arises from the fact that agro climatic conditions conducive to coffee cultivation also sustain ecosystems of high conservation significance. Sustainable coffee farming is an effort to alleviate the resulting tension between coffee agriculture and biodiversity, aided by the abundance of certified "green" coffees on the market. However, although shade coffee provides a lower conservation risk than other alternative land uses, it is not a replacement for natural habitat. Furthermore, certified coffee represents less than 1% of global coffee markets, limiting the possibility for sustainable agro.

The Ecological Economics of Agroforestry needs must impact change on a large enough scale to avoid a worldwide conflict between coffee and biodiversity. Colombia, a long-time coffee producer, has over 750,000 hectares under coffee cultivation, many of which correlate with biodiversity hotspot zones. Surviving ecosystems in the country's most intense coffee-growing regions support up to 15% of the world's terrestrial biodiversity, making biodiversity conservation critical. Colombia, in particular, has the largest diversity of birds and amphibians in the world, with 1,815 bird species, at least 142 of which are endemic, and 600 amphibian species, more than half of which are endemic. Furthermore, nearly one-third of Colombia's estimated 45,000 higher-order plant species are considered to be endemic, placing the nation second only to Brazil in this respect, although having a significantly smaller geographical area. Colombia also ranks first in orchid diversity and third in butterfly diversity. The determination of Colombia's National Federation of Coffee Growers to "producing specialty coffee all over the country, even in places where you would least imagine it" threatens this extraordinary ecological diversity. Coffee export prices in constant US dollars fell to a seven-year low in 2001 [6].

Colombia's coffee-growing areas and ecological hotspots. Level since 1900, much lower than during the 1930s Great Depression. The worldwide price of coffee beans fell by 60% between 1999 and 2001, to little over $1 per kilogram. Colombian coffee producers are particularly vulnerable at a time when global coffee prices are deplorably low due to high labor expenses. In this setting of extensive coffee planting, low market prices, high production costs, and high biodiversity levels, there are several prospects for conservation. Coffee farmers, many of whom operate at a loss and remain in the coffee business due to a lack of alternative natives, may be willing to retire their shade coffee farms for restoration to forest land or set aside intact forests as private reserves in exchange for monetary compensation that would allow them to pursue alternatives. Colombia encourages private reserve construction by offering tax breaks to landowners and legal acknowledgement of their land's reserve status. In these circumstances, plans to reward producers for permanently maintaining nearby forests or retiring shade coffee fields via a mix of public and private funding may benefit both farmers and consumers.

A policy of purchasing or leasing low-yielding coffee plantations and retiring them, backed up by compensation systems for farm owners and employees, might stimulate private reserve development and directly reward local stakeholders for conservation. Landowners and labor would profit from predictable revenue streams, and biodiversity protection would no longer be contingent on striking an elusive balance between agriculture and conservation. Such agreements might be reached with individual landowners who control big estates with great conservation value. Another possibility, particularly in the context of agroforestry, would be for a community of smallholder farmers to set aside fragments of intact forest and retire aged farms for conservation in exchange for access to pro-conservation coffee markets or other communitywide benefits such as education or health care. Such arrangements might have far-reaching social and environmental advantages if more struggling coffee producers choose an appealing land use option and better connection is made across remaining habitat parts.

Cocoa Farm Set-Asides in Bahia, Brazil Cocoa growing is critical to the extension of agricultural frontiers across the tropics. Cocoa plantation claims around 8 million acres globally, mostly in biodiversity hotspot regions of West Africa, Brazil, and Indonesia. Stabilizing cocoa production areas has been challenging because to economic concerns that discourage private. Agroforestry proprietors benefit by replanting and maintaining aging cocoa orchards; also, the financial benefits of growing cocoa on virgin soils make cocoa growers a constant danger to intact forests on the agricultural border. The Atlantic Forest of Bahia, Brazil, is exceptionally rich in biodiversity and one of the world's most endangered woods. A joint study there by the New York Botanical Garden and the Brazilian government commission CEPLAC discovered the world's second-highest tree diversity. The area also has a plethora of unique fauna: the Atlantic Forest is home to 80 percent of the 22 primate species, 45 percent of the 77 rodent species, and 37 percent of all known marsupials. Only around 5-7 percent of the original forest cover survives, and it is made up of many tiny pieces [7].

Much of the forest in the region consists of tiny sections on private holdings divided by agricultural, ranching, and other commercial activity. Because tiny, isolated sections of forest cannot maintain genetically viable populations of unique species, fragmentation presents a serious danger to biodiversity in the region. Many of Bahia's natural forest pieces are linked by Cabruca cocoa estates that retain a part of the canopy vegetation. Since 1989, when international cocoa prices fell due to a surplu, the Brazilian cocoa industry has suffered. As earnings fell, Bahian cocoa production fell by 60-70 percent. Some landowners have resorted to damaging and financially risky alternatives like livestock grazing or robusta coffee production. Others have abandoned their farms or even encouraged subsistence farmers to occupy property in order to speed up negotiations and secure more generous compensation packages under the agrarian reform program. Small-scale subsistence farmers, on the other hand, rely on annual crops and use slash-and-burn methods, which accelerate forest loss, fragmentation, and isolation. Finally, many landowners are attempting to entirely dispose or combine properties in order to acquire funds for further agricultural investment. A conservation corridor in which cocoa agroforestry systems act as biological linkages between protected natural forest pieces is one component of initiatives to safeguard Bahia's biodiversity (CABS and IESB 2000). Even the most diverse cocoa farms, like shade coffee plantations, do not have the same amount of biodiversity as natural forest. Furthermore, since the understory is constantly disturbed by weeding and other activities, the canopy maintained by cabruca may be ephemeral, limiting long-term biodiversity benefits. As a result, efforts to maintain remnant forest fragments and stimulate forest regeneration where possible are critical components of conservation strategy.

Brazilian law mandates landowners to keep at least 20% of their property in natural forest. Although this legislation is often disregarded in reality, members of the southern Bahia farmer cooperative for organic goods are expected to follow it and keep set-asides as reserves in order to get organic certification. The promise of organic premiums, along with non-government and government initiatives to teach farmers, give market access, and assist the adoption of organic agricultural practices, provides a financial incentive to keep set-asides in place. Organic price premiums, like conventional cocoa prices, are subject to market changes. Conservation concession payments may directly compensate farmers for setting aside sections of their land as a sort of insurance against market changes, such that remuneration is focused on conservation services rather than the indirect route of markets for certified goods.

DISCUSSION

Conservation concessions might push the organic cabruca cocoa program even farther by compensating farmers for putting aside more than the minimal requirement of 20%. This would increase the program's attractiveness to those who would otherwise be unable to forego the potential revenue from resource exploitation, expand farmers' freedom to determine their optimal composition of income from cultivation and conservation, and make set-asides a financially viable means of consolidating. Agroforestry conservation corridors' Ecological Economics. Thus, the conservation concession concept may help to complete Bahia's sustainable agroforestry initiatives. The two scenarios shown so far imply that the search for solutions in regions where agroforestry and biodiversity may intersect might benefit from instruments to fund set-asides and retirement of cultivated plots as a conservation service [8].

Particularly in locations where economic prospects for cultivation are bleak, such instruments might provide welcome relief to local stakeholders while also being cost efficient from a conservation standpoint. In essence, set-asides and retirement are direct rewards for choosing conservation over agriculture. The conservation concession strategy provides a conceptual framework for developing such compensation systems. Conservation Concessions in Practice: Issues and Considerations Biodiversity is under threat from a variety of activities around the world, and it would be unrealistic to expect agroforestry, conservation concessions, or any other single tool to address them all. The conservation concession strategy should not compete with agroforestry, but rather be used in conjunction with it, especially in regions where sustainable agroforestry is not viable due to institutional or budgetary constraints. Conservation concessions may support the transition from cultivation to biodiversity preservation in locations where farming may be a sunset sector by subsidizing the retirement of cultivated lands. Finally, in areas where agroforestry or other productive system interventions are deemed necessary, the two approaches can work in tandem: a conservation concession can help to stabilize the agricultural frontier by designating set-asides for protection in exchange for social investments in changes in agricultural practices in remaining areas.

Agroforestry is still the second-best choice for biodiversity conservation. Though possibly less harmful than other types of land use, agroforestry systems cause environmental disruption that may not always result in a stable spatial equilibrium. The long-term resilience of agroforestry systems in the face of changing agro climatic and economic circumstances is an unanswered subject. Because discount rates are high and foreign markets for green-labeled goods are restricted, market forces cannot be depended on to drive the adoption of sustainable agroforestry systems. Furthermore, as sustainable agroforestry becomes more financially appealing, the greater the incentives to convert remaining natural habitat increase.

Fundamentally, agroforestry compensates farmers for increasing physical demands on ecosystems, possibly less so than other types of land use, but definitely in comparison to natural habitat protection. By combining conservation concession payments with sustainable agroforestry initiatives. A conservation concession is an attempt to reach a mutually agreed-upon degree of habitat preservation by giving adequate compensation. If any of the parties to the agreement fails to comply with the conditions of the concession, payments stop, therefore the problem is to develop compensation systems that give all parties with a vested interest in compliance. Nonetheless, a focus on monitoring and enforcement must be maintained in order to verify and assure agreement compliance, which often necessitates capacity development. Given that alternative employment for local stakeholders is often required for concession acceptance and success, capacity development might take the form of hiring stakeholders as monitoring and enforcement agents, fulfilling many goals. Another problem is the possible hazard of merely relocating populations from one habitat region to another [9].

A farmer participating in a conservation concession arrangement, for example, may spend resources freed up by the inability to clear a certain area (and the pay for doing so) in clearing another area that is not covered by the agreement. However, in terms of retirement and set-asides of productive plots, the conservation concession method will first target regions with a low opportunity cost of conservation, i.e., places with poor cultivation prospects. Payments provide farmers a route out of a terrible situation in Colombia; conservation concessions in this context provide an exit option, not a complement to continuing initiatives. Coffee's poor economic performance is exactly what makes retirement through the conservation concession model appealing to both environmentalists and farmers. The issue of displacement may seem relevant if farming might be diverted to completely new sections of the nation that provide better chances for the same or a different crop. However, regions with a high opportunity cost of conservation, meaning a high profit potential from conversion, are threatened regardless of where conservation concessions are applied. Furthermore, this dynamic is not specific to conservation concessions; every attempt to conserve habitat means that activities that may have occurred in the target area may now occur elsewhere. Only thorough stakeholder research can identify whether beneficiaries of a conservation concessions retirement scheme are likely to seek other rural jobs in the region, create new plots elsewhere, relocate to metropolitan areas, or explore other options. However, one of the conservation concession approach's strengths is the explicit focus on alternative job prospects as an investment aim.

Such possibilities, as an intrinsic component of the mechanism, are part of the remuneration for conservation. The Ecological Economics of Agroforestry Services and moderate the inclination to shift environmentally unfavorable operations elsewhere. Alternatively, creating a strong border suggested by an effective conservation concession may encourage intensification on remaining productive land, perhaps with negative environmental implications. A conservation concession in an agroforestry context, for example, may motivate a farmer to remove shade trees or use more agrochemicals on productive plots when barred from extending to other regions. The previously reported Bahian scenario would result in increased protection for forest pieces but decreased connectivity between them, with equivocal net benefits to biodiversity. This potential dynamic demonstrates the need of properly managing connections between sustainable agroforestry programs and conservation concessions in order to achieve desired results.

Stakeholder analysis, agreement design, and compensation negotiation must be structured in the context of a long-term, system wide perspective, with the system boundaries defined broadly enough to capture the full intertemporal and spatial impacts of both agroforestry efforts and conservation concessions. Another issue emerges when ownership over new for est lands is readily established, as in enormous expanses of the Amazon. When a precedent of compensating private landowners for conservation services is established, there may be an incentive to claim places only for the purpose of leveraging them as possible conservation concessions. However, since the lands in issue did not attract ownership claims or investment in the absence of conservation payments, the inference is that saving them would have a very low opportunity cost. This dynamic might therefore permit long-term, cost-effective protection of enormous regions formerly unavailable due to ill-defined tenure by clarifying ownership regimes and compensating new owners for the opportunity cost of conservation. More crucially, such a mechanism may require governments to weigh the advantages of obtaining long-term conservation commitments over such places. The conservation concession technique is especially appropriate for huge regions managed by a single organization, such as the government or big landowners [10].

The approach's viability in places not under government or private control is dependent on the ownership structure in place. Agroforestry systems are managed via a range of ownership regimes, ranging from tiny, privately held plots to huge plantations to community property allocated by traditional chiefs. The complexity of tenure arrangements effects the identification and connections of stakeholders, which include local, regional, and national governments, traditional authorities, landowners, land renters, sharecroppers, hired labor, farmer groups, and others. This characteristic of agroforestry systems presents two considerations for the conservation concession strategy. First, a critical mass (in terms of the number of participants and the spatial configuration of plots) is typically required for an effective conservation program. Second, the number of farmers and their degree of organization in cooperatives or collectives influence the costs of negotiating and transacting an agreement. Transaction costs associated in establishing a conservation agreement are often cheaper, per hectare, for large regions with few parties. The extent to which transaction costs rise in situations like the ones discussed before, with many farmers on tiny plots, remains to be seen. In any event, compensation payments dominate the overall expenses of a conservation concession in the long run. Because payments reflect opportunity costs, farmers in agroforestry systems who are struggling to break even may benefit from extremely cost-effective conservation possibilities such as set-asides or plot retirement. Furthermore, conservation concessions in places with questionable economic prospects may give potential chances for co-financing and collaboration with government and non-government development organizations' income assistance and poverty alleviation activities.

The foregoing discussion implies that the implementation of conservation concessions in every particular setting will be accompanied by a variety of challenges, some foreseeable and others unexpected. Globally, the usefulness of the conservation concession concept is determined by financial concerns and conservation objectives. In certain locations, the strategy is excessively costly, while in others, the opportunity cost of conservation is cheap but biodiversity assets are restricted. The structure of stakeholders and property rights is also an important indicator of a target area's appropriateness for the method. Ultimately, the right design of a conservation concession's compensation, monitoring, and enforcement components is based on a detailed consideration of stakeholder demands and interests, ranging from local communities to regional authorities and national governments. However, the framework's intrinsic flexibility invites creative modification of the model to locally unique situations. In many cases where improved protection necessitates collaboration with local communities to investigate alternative cultivation forms, the combination of conservation concessions and sustainable agroforestry programs may yield a powerful response to the economic, social, and institutional forces that threaten biodiversity around the world.

CONCLUSION

Conservation concessions may target biodiversity hotspots, which are locations with high levels of species richness and endemism. Concessions may emphasize the conservation of key habitats and endemic species while supporting agroforestry methods that help to habitat restoration and connectivity by concentrating on these regions.Conservation concessions may foster cooperation and partnerships among a variety of stakeholders, including local populations, non-governmental organizations (NGOs), government agencies, and academics. Collaborations of this kind may offer technical skills, financial resources, and information exchange to assist in the adoption of agroforestry methods and biodiversity conservation activities inside concessions. It is feasible to accomplish both sustainable agricultural production and biodiversity conservation goals by combining the advantages of agroforestry with the protective mechanisms of conservation concessions. To support long-term biodiversity conservation, this integrated strategy emphasizes the need of involving local people, recovering ecosystems, and sustaining ecological connections.

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CHAPTER 14

SHIFTING CULTIVATION LANDSCAPES' BIODIVERSITY AND CONSERVATION POTENTIAL

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ABSTRACT:

Shifting cultivation is an agricultural method in which land is cleared, farmed for a few years, and then left fallow to regenerate. It is also known as slash-and-burn agriculture or swidden farming. While shifting agriculture has been linked to detrimental consequences on biodiversity in certain circumstances, it also has the ability to conserve biodiversity in particular environments.We discussed about the biodiversity and conservation potential of shifting cultivation landscapes in this chapter.

KEYWORDS:

Altering Agriculture, Biodiversity Conservation, Forest Dependent, Shifting Cultivation, Shifting Agriculture.

INTRODUCTION

The most frequent definitions of shifting cultivation are based on Conklin's work and describe it as any agricultural system in which fields are cleared and farmed for shorter periods than those during which they are fallowed. In more recent works, a more dynamic approach has emerged, with McGrath defining shifting cultivation as "a resource management strategy in which fields are shifted in order to exploit the energy and nutrient capital of the vegetation-soil complex of the future site." Watters summarizes the main characteristics that define shifting cultivation as it is practiced in the tropics: the shift between fields rather than between crops on the same field. The alternating of crops and fallow vegetation dominated by woody plants on the same site allows shifting cultivation to be defined as an agroforestry land use (Figure.1). Shifting agriculture produces one-of-a-kind landscapes made up of a dynamic patchwork of crop fields, fallows of varying ages, secondary forest formed from fallows, and remains of the original flora. Crop fields and ancient secondary forests are well-defined communities, however fallows may be seen differently by scientists from various disciplines [1].

Fallow communities are seen as secondary vegetation in a system of dynamic connections between vegetation types, focusing on main or old-growth vegetation. FAO defines "forest fallow systems" as "complexes of woody vegetation deriving from the clearing of forest for 153 agriculture" and mosaics of "various reconstitution phases." However, we emphasize that fallows are primarily components of an agricultural land use system, and their ecological or forestry status as secondary vegetation or phases in the "reconstitution" of forest in this content Fallows are components of an integrated agricultural system in which numerous goals for farmers' lives must be addressed. They occur for a variety of ecological and social reasons, including soil fertility restoration, erosion reduction, weed control, and chances to harvest items for home maintenance. In terms of forest "reconstitution," fallows in many tropical locations may never grow into a community like the original one of the site, even if they are not disturbed further.

As a result, we agree with Burgers et al. in defining fallow communities as the vegetation and associated fauna that occupy land that has been cleared for cultivation but is no longer in use, despite the fact that the community may have multiple other uses, such as the provision of firewood or non-timber forest products. The vegetation component of the community normally consists of plants that regenerate naturally when the land is left fallow (we follow authors such as Spencer and Smith et al. In not using the term abandonment, with its negative connotations, in reference to the transition from crop to fallow). It also contains valuable plants that the farmer saves, whether planted or naturally regenerated (jungle rubber production techniques are an exception; see Chapter 10, this book), as well as agricultural crop residues and weeds. Professional and public perspectives on shifting cultivation differ. It is one of humanity's major agricultural systems, is ancient in origin and in the context of certain levels of available technology, capital, and population density, and is widely regarded as a sophisticated and sustainable land use. However, because shifting cultivation results in the replacement of natural communities with anthropogenic communities, it is frequently identified as a major cause of habitat destruction and biodiversity loss in the tropic, though other perspectives have recently emerged [2].

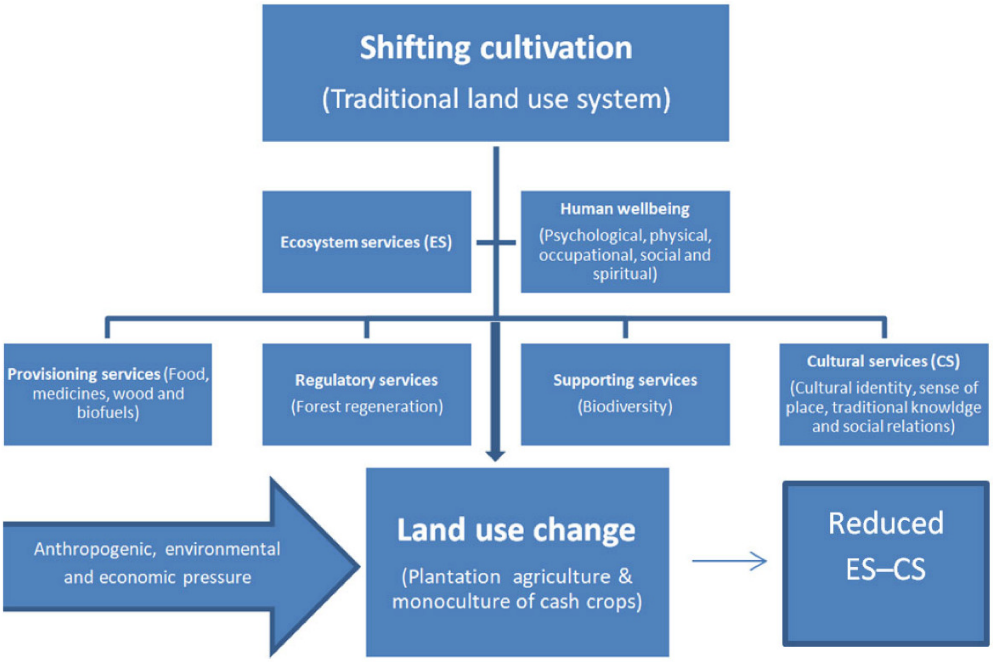

Figure 1: Shifting Cultivation: Diagram showing the overview of the Shifting Cultivation (MDPI).

The growing consensus that tropical biodiversity conservation must include action in all land use types across landscapes and regions necessitates an examination of shifting cultivation in the context of the current book. From a variety of perspectives, including biodiversity maintenance and generation, it is critical to distinguish between shifting cultivators who have lived in a region for a long time and recent immigrant shifting cultivators pioneer shifting cultivation as defined by Conklin. Traditional shifting agriculture is itinerant, so impermanent on any specific plot of land, and is strongly but not unanimously supported. Agroforestry system biodiversity is entirely reliant on the presence of huge expanses of undisturbed forest. Land conversion by agricultural settlers or cattle ranchers in many modern agricultural frontiers is characterized by higher degrees of permanence, though similarities to traditional systems can be found even when modern colonizers lack knowledge of traditional shifting cultivators. However, in the second case, forest areas converted to alternative uses are 20-50 times larger in area than those impacted by nomadic slash-and-burn agriculture.

Soil fertility recovery and pest and weed management are well-established among the principal agricultural purposes of the fallow season. Although weeds developed during the cropping season have also been demonstrated to help to the decrease of nitrogen losses, most biophysical research on fallows has concentrated on these ecological roles. The fact that fallows are, by definition, to be converted to cropland may have contributed to a lack of interest in fallows as systems for studying forest succession or as potential routes for the restoration of tropical forests and the goods and services they provide, including, of course, biodiversity conservation. This lack of interest is exemplified by recent collections of papers on tropical forest restoration, which focus either on the "catalytic" role of forest plantations in the process or on forest restoration through natural succession on pastures [3].

Shifting agriculture is the most common kind of land use in non-irrigated areas of northern Thailand, as well as neighboring Laos, Cambodia, and Vietnam. In Laos, shifting agriculture employs up to 1 million people and accounts for 40% of the land area allocated to the country's main crop, rice, with 200,000 hectares under cultivation in any given year. It is also the preferred land use in less densely populated areas of Indonesia, such as Kalimantan, and the Philippines. Fallows occupy a large portion of the land area in swidden environments, and for this and other reasons, they are critical to the maintenance of forest biodiversity in these settings. Alen car et al. Discovered that fallow vegetation in three distinct developmental stages occupied around 50 percent of the total area in a 137,800-ha municipality in eastern Pará State, Brazilian Amazon, and cropland occupied only 8-11 percent of the area. In contrast to the vast amount of fallow, residual primary forest covered around 15% of the land, the majority of which was in riparian strips. Vieira et al. conducted a similar analysis in another Pará State town and discovered 18, 17, and 5% of the 156 III. Agroforestry System Biodiversity 47,700 hectares were evaluated in juvenile (3- to 10-year), intermediate (ca. 20-year), and mature (40- to 70-year) fallow and secondary vegetation, respectively. Taking into consideration the 12 percent of land area covered by primary forest, which is mostly riparian, total forest cover in this municipality approaches 50 percent if a wide definition of forest is used (explained later in this chapter), despite more than a century of agricultural settlement.

The Lawa people of Ban Tung in northern Thailand farm around 30 hectares each year for an available fal low area of 800 ha. Petit found that in a drier savanna setting, the percentage of village land under different forms of fal low was 34.5 percent for the Senufo people of northern Côte d'Ivoire and 64 percent for the Musey people of northern Cameroon. Aside from the obvious relevance of fallows, it is worth noting that secondary woods or ancient fallows play a vital and sometimes ignored role in altering agriculture systems. The percentage of new agricultural fields created in primary forests is just 5% for ethnic groups in south Cameroon, 13% for Sarawak's Kenyah, 24% for French Guyana's Palikur, and 31% for Borneo's Kantu. Overall, it is obvious that changing agriculture in general, and fallows in particular, are defining aspects of many tropical landscapes, and hence are critical to the prospects for biodiversity conservation in such settings. The temporal dimension of the examination of changing cultivation and biodiversity at the landscape scale is as essential as the spatial. Tropical agricultural landscapes are dynamic at several temporal and geographical dimensions, and these dynamics must be understood in order to understand the potential of shifting agriculture to generate and sustain biodiversity. Traditional shifting cultivation land use dynamics vary from those imposed by current colonization operations. Modern deforestation is associated with agricultural frontier advancement and development, a process for which various writers have presented models. Henkel hypothesized, for example, that initially wooded terrain goes through four phases following the arrival of the first colonists. This model may be stated as follows, using similarities with [4]

A pioneer fringe (Richards' early pioneer stage) advances into the forest, with deforested areas eventually evolving into the commercial core of the fron tier, a stage in which farmers benefit from improved infrastructure and access to markets; Richards refers to this as the stage of the emerging market economy. This commercial core may degrade into a degradation zone as agriculture. Production drops, farmers depart land, and some may return to the pioneer fringe; land is consolidated in the hands of fewer property owners. The degradation zone is then revived by combining small plots for animal production or introducing higher-technology agriculture. The latter two phases of Henkel's model correspond to Richards' closing frontier, which he defines as limited or zero availability of forest area for future colonization and further improvements in infrastructure and farmer integration with markets. These basic models help to explain the geographical zonation of agricultural boundaries at any moment, as well as the changes that occur throughout time at any specific location. At some point in the shifting cultivation cycle, changes in the percentage of the landscape accompany stages in the development of agricultural boundaries. They estimate that, excluding cow ranches, around 50 percent of an area's initial primary forest cover is lost between the pioneer and EM phases, when their data are interpreted as points in the temporal history of a single frontier. At any one moment, half of cleared land in EM is fallow, and this percentage rises to over 60% in CF as residual primary forest cover declines. Despite the significant loss in residual forest cover between the two phases, the net decline in total forest cover as the border develops is small because primary vegetation is replaced by secondary (including fallow) vegetation.

CF still has 40% forest cover, including 23% secondary forest and 17% primary forest. However, the increased cow ranching in CF implies that the loss of original forest cover, as well as the net total decline in forest cover, including secondary vegetation, is larger when the whole land scape is examined. A last point on Smith et al.'s research is that whether net change in total forest cover is restricted throughout the evolution of widen landscapes is, of course, dependent on the definition of forest utilized. Net change is certainly restricted if the definition includes young fallow plants. However, in the context of this chapter, it is important to understand that fallow vegetation and secondary forest are extremely different in terms of biodiversity from primary forest. Agricultural borders may be dynamic, as we've seen, yet shifting cultivation can be a stable land use in both traditional and contemporary settings. It most likely started about 3500 BC in Mesoamerica's Maya Zone and is being performed there today.

The extent of land used and the size of the dependent population undoubtedly fluctuated over time for many reasons, including the widely cited hypothesis that land degradation was a factor in the decline of Maya civilization. The ecological, social, economic, and political settings in which altering cultivation persists across time are intriguing study topics. De Wachter investigated the traditional swidden agricultural technique utilized by the Badjwe people on the outskirts of Cameroon's Dja Reserve. Mod eling suggests that under this land use system, the current population density of 4.2 inhabitants per square kilometer of arable land could increase to up to 38 inhabitants per square kilometer while still maintaining a landscape mosaic with 50 percent of the land under shifting cultivation, 43 percent under primary forests (including 26 percent swamp forests), and 7 percent of pure Raphia palm stands after more than 50 years and within 5 kilometers of roads. Under a scenario of increased cash crop-oriented activities (cocoa, plantain), the population drops to 18 people per square kilometer, and it takes roughly 35 years to maintain a comparable mosaic within 5 kilometers of the road. The Shortening of Fallow Periods: Causes and Consequences The length of fallow periods is a key factor in the amount of biodiversity that accumulates on individual patches in swidden landscapes and the amount of biodiversity that landscapes as a whole maintain; in many ways, the longer the fallow, the better. This basic guideline leads us to one of the biggest problems about biodiversity in shifting agriculture landscapes [5].

The basic Bose up model achieved agricultural improvements via land expansion, more labor, and, most importantly from our perspective, shorter fallow periods. Many recent studies suggest a tropics-wide trend toward shorter fallows in shifting agriculture, and this is one of the well-documented elements of the issue from both an ecological and an agronomic view-point. It was examine the variables behind farmers' reduction of fallow times in recent talks. Farmers, they observe, establish fallow times by considering the costs and advantages of various fallow durations. Longer fallows have the potential for higher crop yields, lower labor costs for weed control during that period (one of the most important functions of the fallow), and more opportunities for harvesting the products of unplanned biodiversity during the fallow.

As soil fertility recovers, the time required to suppress specific weeds in the patch rises. Under some conditions, fallow duration may increase. Among the costs associated with longer fallow lengths is the need to achieve a larger area of land under the shifting cultivation cycle to maintain a given quantity of agricultural produce, as well as the possibility that this larger land area must be obtained through labor-intensive cutting of more primary forest. When it becomes impossible to cut additional primary forest, land area under cultivation can only be increased as a reaction to diminishing agricultural yields or a growing population to be sustained by the land by reducing fallow time. Fallows are considerably more often shortened than they are lengthened. Thiele states that typical fall low durations in seasonal habitats of lowland Bolivia were 6-12 years but had dropped significantly by the 1980s, with a median length of 4 years. Fallow durations in northeastern India have dropped to a range of 3-10 years in the 1990s, from a customary norm of 60 years.

Traditional fallow durations in the Ta woodland area of Côte d'Ivoire were 14-30 years, but by the end of the twentieth century, they had been reduced to 6-10 years. Shortening fallow periods might worsen agricultural production declines, increase weed issues, and hence manpower requirements during cultivation. Short fallows, for example, resulted in a 72 percent rise in weed biomass during cropping seasons in Côte d 'Ivoir. Farmers and the research and development community have sought alternate technologies as a reasonable reaction to these inclinations. Permanent agriculture, as advocated by the Lao government to replace shifting cropping, which is deemed ecologically unfavorable, is one option. Another major focus of work is improved (planted) fallows. Improved fallows are designed to fulfill the agro-ecological function of the fall low in a short period of time (perhaps 3 years or less) and may increase labor needs, though examples of their spontaneous development and widespread adoption by farmers have been documented. To summarize, one of the most significant elements in the potential of changing agriculture landscapes for biodiversity conservation, as mentioned later in this chapter, is the link between fallow time and the floral and faunal features of the community. The trend for shorter fallows and the development of strategies for fallow "improvement" are significant constraints on its potential. Because of their generally monospecific composition and short lifetime, improved fallows seem to be of limited benefit for forest biodiversity conservation and will not be evaluated for 160 III. Agroforestry System Biodiversity there. Fallow duration is obviously an essential problem in the management of changing cultivated landscapes for biodiversity conservation purposes, apart from its agronomic value. Plant Regeneration Mechanisms in Fallows In general, plants can regenerate in fallows from seed already present in the soil seed bank, seed dispersed onto the site after it has been left fallow, or sprouting from cut but living plant parts, either above ground or as root sucker. The regeneration of fallow vegetation shortly after cultivation is mostly vegetative. Almost all trees, shrubs, vines, and large herbaceous perennials, as well as the majority of grasses, regenerate from stumps, roots, or rhizomes. Burning and weeding during the cropping time, as well as the short lifespan of certain species' seeds, are factors that restrict seed regeneration in trees and shrubs. Burning at the start of the cropping season and regular weeding help destroy tree and shrub seedlings, the majority of which have just recently germinated. All of these variables deplete the soil's seed bank and diminish seed regeneration's contribution to the reestablishment of tree cover during the fallow season [6].

Few studies have explicitly addressed sprouting's role as a regeneration process in tropical secondary vegetation. Although overall successional pathways in fallows may resemble those that follow other types of human land use in structural and floristic terms, the importance of reports as a regeneration mechanism is arguably one of the defining ecological characteristics of fallow vegetation and secondary for Est derived from it. Hull shown experimentally that frequent weeding during cultivation may lower sprout density in fallows. However, in practice, the brief periods of low-intensity cultivation that define shifting agriculture are unlikely to appreciably impair the regeneration ability of tree stumps and root pieces that report when land is left fallow. Grasp plant regeneration, and hence plant community composition and variety in fallows, requires a grasp of species individuality. For example, the relative relevance of reports and seed as post disturbance regeneration strategies varies across species in populations prone to natural disturbance. Although experimental investigations are necessary to prove whether tree species recover from sprouts, descriptive study offers a convincing indication of the presence of patterns. Kammesheidt demonstrated that 28 of the 58 tree species he documented in tiny plots in fallows at his Paraguayan research site were regenerated via both processes, whereas 7 were only found as resprouts and 23 were regenerated 8. Only from seed, The Biodiversity and Conservation Potential of Shifting Cultivation Landscapes 161 was discovered. Vismia spp. is a typical genus of neo-tropical short-lived pioneer trees.

Work on slash-and-burn practices in subtropical Australia and Indonesia has also shown species differences in regeneration processes. The richness and variety of tree species with restricted regeneration via sprouting rely on the existence of seed trees and dispersal mechanisms in dynamic agriculture landscapes. Most Macaranga species, which are typical short-lived pioneers in Africa and Asia, seldom resprout and rely mostly on soil seed banks and seed rain for regeneration. The proportional relevance of resprouts in the establishment of fallow vegetation may change across agricultural boundaries of varying ages or landscapes with varying amounts of remaining primary vegetation. In Kamme- sheidt's Paraguayan subtropical moist forest study site, sprouts were the most important sources of woody regeneration in 2- to 5-year-old vegetation on low-fertility oxisols, but their relative importance declined with age, and trees regenerated from seed were more important in 10- to 15-year-old stands. The results of 5- to 20-year-old fallows on identical soils in the Brazilian Amazon's Bragantina district in eastern Pará State were strikingly different. Throughout the range of stand ages evaluated, resprouts provided the largest percentage of both stems and species 5 cm or more in diameter at breast height (130 cm) [7].

There may be explanations for such intersite variances in the relevance of resprouts as a regeneration mechanism. The dominance of resprouts over lengthy time periods in Bragantina seems to be due to the significantly longer time since settlement than in Paraguay. It is reasonable to hypothesize that on-site seed production by many tree species must be reduced or nonexistent in shifting cultivation landscapes such as those of Bragantina simply because stems barely or never reach reproductive status. The loss of primary forest habitat and its role as a seed supply may aggravate any changes in the amount and variety of the seed rain produced by the previous variables. Furthermore, if the majority of the surviving primary forest is riparian or swamp vegetation, some of the plant species that comprise it are likely to have limited capacities to colonize dryland locations, particularly in conflict with the pioneer’s characteristic of such sites.

Although the great diversity of life forms and dispersion techniques across the tree species of changing agricultural land scopes makes any generalization regarding the relative relevance of dispersal mechanisms problematic, our data appear to confirm our hypothesis. Recent studies show that trees in geotropically pastures facilitate succession by providing habitat for seed-dispersing vertebrates, an interaction that has long been recognized in many successional environments. However, as with dispersion processes, the little study on seed dispersal in fluctuating cultivated landscapes does not offer a similarly solid foundation for generalization. Ferguson saw no indication that the Attala cohune palms widespread on his shifting cultivation sites provided such a purpose and proposed.

To summarize, it is clear that a significant proportion of individuals of woody plant species in any shifting cultivation landscape have regenerated by reporting, and it appears highly likely that the agricultural cycle exerts strong selection for species capable of reporting after cutting, burning, and weeding. Nonetheless, these are pioneer plant-dominated ecosystems. If the lack of seed sources means that reporting is the main, if not the only, mechanism of regeneration for many forest-dependent tree species in shifting cultivation landscapes, then the chances of recovering a diverse forest with at least some of the original vegetation on shifting cultivation land are slim. The vigorous regeneration from root sprouts of exceptionally valuable multiple-use species such as Platonia insignis appears to have contributed to some authors' optimistic view of secondary succession's potential for production and forest restoration in shifting cultivation landscapes.

Denich, on the other hand, believes that fallows should be seen as a new, entirely anthropogenic vegetation form rather than a step in the restoration of primary forest. If this is the case, it does not preclude farmers from managing fallows for specific crops as they did in the past, but it is a sobering thought in the context of biological conservation. Successional Dynamics of Fallows and the Factors That Underpin Successional Change Fallows and secondary forests derived from them have been studied in moist forests of Mesoamerica (Mexico, Guatemala, Panama), the Amazon basin, the Guianas, and the South American subtropics, and show successional sequences broadly similar to those in Africa and Asia. The number of successional phases identified by reviewers within this overarching framework of similarity varies, and the identification of stages in an essentially continuous process is mostly for convenience. Finnegan outlined three phases of neo tropical lowland rainforest succession throughout the first century of the process in broad terms. Pioneer plants, shrubs, and climbers are often followed by phases dominated by short-lived and subsequently long-lived pioneer trees [8].

Agroforestry System Biodiversity, with dominance by this latter group possibly lasting many decades. In as little as two decades, forest structural traits such as canopy height and basal area may approach primary forest levels. Individuals that colonize the site soon after its abandonment or assignment to fallow control it for decades, and succession occurs due, in large part, to the varied life cycles and degrees of shadow tolerance of this group of species. Similar successional processes occur in Africa's tropical and subtropical areas and Asia's tropical and subtropical regions. Botanical species, rather than tree functional categories, differ between continents. It is critical to move beyond fundamental generic descriptions of successions and describe and comprehend the wide range of successional processes seen in practice. Only under ideal circumstances can tropical secondary successions occur as detailed in the preceding paragraph. These conditions include little or no degradation of site conditions, a well-stocked seed bank, seed trees within dispersal range with functional seed dispersal processes, viable tree stumps and root systems for resprouting, and minimal additional disturbance to the site once succession begins. Common sense suggests that these characteristics are most likely to be realized in tiny regions with little or no agricultural usage, contained in matrix with substantial proportions of primary or ancient secondary forest.

Such requirements are unlikely to be satisfied in the majority of secondary succession scenarios that will occur in the tropics in the future years. Successional processes over broad expanses, such as many abandoned pastures in the mainland nootropics, are likely to be more complicated than in the best situation, resulting in slower growth, poorer variety, and lower production in successional communities. This is particularly probable when a broad area is accompanied by a set of site features that function as obstacles to the commencement of succession. Concerning succession on shifting cultivation plots, it is vital to note that these are limited habitat patches established by a land use system intended with the primary purpose of maintaining site productivity for agriculture. In theory, this condition is conducive for the establishment of fallow vegetation—for secondary succession. On the other hand, these are habitat patches that have a high frequency of drastic disturbance (even traditional fallow lengths should be considered short time periods in relation to the recovery of many forest characteristics), and they are embedded in a landscape where fallow vegetation of intermediate value as a seed source is most likely the most important single land use.

Fallow vegetation is also chronically prone to disruption by uncontrolled fire in seasonal contexts, and long-term losses in site productivity induced by repeated cropping cycles and ever-shorter fallows are inevitable. All of these variables, in various ways, inhibit the establishment of secondary vegetation. The Biodiversity and Conservation Potential of Shifting Cultivation Landscapes 165 stations may be particularly harmful to forest-dependent plant species. In any event, they have a low proportionate abundance in secondary successions for many decades, while under favorable circumstances they may accumulate in secondary forest understories. However, conditions in altering agriculture landscapes are far from ideal, and are particularly hostile to this group of species, making conservation intervention a priority. The discussion of variables that restrict successional growth leads to significant particular examples of divergence from the model offered at the start of this section [9].

Weighting is especially critical for agricultural communities and landscapes. This is due to the fact that species richness may be high in such environments. As we shall see, the biodiversity of agroforestry systems plays an essential role in the use value of a community or landscape to people as well as the conservation of ecological services in it. However, no matter how varied a community is, if it is mostly made of species adapted to human disturbance, its relevance in the context of biodiversity conservation will be minimal. Our analysis of biodiversity and conservation in altering agriculture landscapes focuses on forest-dependent plant and animal species. Crop Field Biodiversity in Shifting Cultivation The field in all shifting cultivation methods is made up of multiple layers of vegetation. It fills a three-dimensional area and provides the impression of vegetal disarray at first glance.

The first is that genetic loss is unavoidable, hence ex situ conservation is the answer. The second is that farmers are hesitant to quit their landraces or agricultural operations for new varieties or new procedures for a variety of reasons (including site adaptation, risk aversion, and culture). Traditional farmers have minimal value in the first perspective after landraces have been maintained ex situ; in the later view, in situ conservation continues to make distinctive contributions even in a modernized environment. For the most part, the "ex situ conservation only" paradigm is giving way to a new, more balanced "ex situ and in situ" paradigm.

Farmers' tree planting seems to be more connected to complex agroforests than to traditional shifting farming. However, boundaries are not always clear, and the Krissa people of Papua New Guinea practice shifting cultivation by nurturing or planting trees (Gnetumgnemon) and palms (Areca catechu, Cocos nucifera, Metroxylonsagu) as major crops in their shifting cultivation gardens. In a Krissa garden, a casual survey identified 11 distinct trees, two palms and two bam boo species planted, and seven trees and two palms grown from the 8. The Conservation Potential of Shifting Cultivation Landscapes 169 regrowth. Thus, the primary role of gardening seems to be the spread of valuable trees rather than the immediate and direct production of food, creating a hazy boundary between forest and gar dens, wild and cultivated. When carried out over millennia, as in this instance, such an activity has clearly substantial repercussions for the structure, composition, and biodiversity of the forest. Jungle rubber is another example of a production method that blurs the distinction between shifting agriculture and other forms of agroforestry.

As previously stated, "Weeds," which can simply be defined as all non-crop species present in crop fields, are one of the primary reasons why crop fields are left fallow in the tropics. They contribute to the diversity of species but, by definition, do not contribute to the total conservation value of altering agriculture landscapes. They may, however, play a role in the maintenance of ecological services. Many common weeds are also potential sources of medicinal and food goods, and they are the pioneer species of the succession that starts when land is left fallow, according to forest ecologists. First, as with many organisms connected with human disturbance, this flora is distinguished by a large number of species with diverse geographic ranges, some of which are known to be the result of human introduction and others of which are pantropical. The herbaceous weed flora associated with shifting cultivation has no conservation value based on the geographic distribution criteria commonly used in conservation priority-setting exercises and their abundance in anthropogenic communities [10].

Weed floras, on the other hand, may be rather varied. Although weeds are better known as one of the main agro ecological bases for the use of fallows, they may contribute to ecosystem nutrient retention in the cropping stage of some shifting cultivation systems, and the quality and magnitude of this contribution to the maintenance of ecosystem function may be related to the local diversity of weed communities. The description of weeds as noncore species, with no expressly negative connotations, is suitable due to the use of many such species to rural populations. Weeds, especially herbaceous species, have the potential to be major non-timber product sources in altering agriculture landscapes. Indeed, multiple studies have demonstrated that disturbed neo-tropical plant communities include more individuals of more valuable species than undisturbed forests and create a wider range of goods known and consumed by rural people. The regeneration of certain valued light-demanding tree species is an essential aspect of crop field and fallow weed community consideration. Examples of such plants that farmers may actively nurture include Platonia insignis, which is beneficial for fruits, and the multipurpose Inga spp., as well as wood trees including the widely distributed Jacaranda copaia and the western Amazonian Guazumacrinita (Smith et al. A thorough examination of this topic is beyond the scope of this chapter, but the potentially high utilitarian benefit of taxonomy.

Weed functional diversity in crop fields and young fallows should not detract from the reality that their significance in terms of taxonomic bio diversity conservation is relatively low. All discussion of the utilitarian or conservation significance of non-crop plant species in the context of shifting agriculture must inevitably return to the reality that a weed is, by definition, a plant that the farmer dislikes. The degree to which weed control is attempted during crop growth varies and may be low, but this activity appears bound to limit species diversity during the cropping phase, especially when accompanied by burning after harvests during that phase. Plant Biodiversity of Fallows under Shifting Cultivation Fallows and the secondary forest that grows from them have many traits with secondary vegetation that grows in other conditions in terms of taxonomic and functional composition of woody species. A limited representation of forest-dependent plant species, other than those protected by farmers for various reasons, is a general feature of fallows and hence a significant limitation on their conservation importance. Numerous genera and species of pioneer trees, the first to dominate fallows, are extensively dispersed in secondary lowland tropical wet vegetation.

In general, the species richness and diversity of fallows are initially low but higher than in crop fields, and they increase over time as the vegetation develops; in small sample plots, several decades may elapse before these parameters approach values similar to those of primary forest. Even in secondary forest, which is sometimes derived from fallow, the long period of vegetation dominance by long-lived pioneer tree species, combined with a low representation of forest-dependent species due to the previously discussed factors, ensures that recovery of the compositional characteristics of mature forests will most likely take centuries, even if forest-dependent species are colonizing the site, which they may not be. Pioneer trees' shade and root competition probably hinder the expansion of species richness and variety. In Africa, Leroy-Devaland Kahn demonstrated that early in succession, Macaranga huriifolia (a short-lived pioneer species) and Aucoumeaklaineana (a long-lived pioneer species) established root grafts, increasing the species' competitive power and allowing the establishment of pure stands. Despite a lack of species richness in the early phases of fallow growth, changing agriculture landscapes may be highly varied when the species of fallows of various ages are combined together. Christanty et al., for example, stated that the kebun-talun system of Java comprised 112 plant species, owing primarily to a lengthy period of perennial production in a controlled fallow. It is also clear that the species richness of fallows grows considerably when compared to cultivated areas. According to Hart and Ewel , such systems may be developed as analogs of natural forest systems since they tend to replicate successional phases of the forest in structure and, presumably, function. On the other hand, the growing propensity of very dominant species such as Chromolaena odorata (mentioned previously) to invade fallows represents a trend toward greater decreases in fallow plant species diversity.

The contribution of fallows to the regeneration of local-scale (alpha) variety of vegetation and the compositional properties of primary forest is limited, as shown by this and the previous subsections. This is due to the brevity of fallow periods and the dominance of resprouts and, in the case of seed regeneration, widespread short-lived pioneer tree species. Plant diversity in fallow landscapes may be considerable, but it is very improbable that species counts grow with area at the same pace as in primary vegetation. The presence of forest-dependent species in landscapes seems to be primarily determined by the extent of remaining primary forest. Fallow Animal Biodiversity in Shifting Cultivation Shifting cultivation landscapes offer a spatially and temporally varied habitat for vertebrates, to varying degrees that are likely impacted by the scales at which various species detect such environmental fluctuation. Research on vertebrates, like that on plant species and communities, has focused on variations in species richness and composition across various habitat types in the landscape.

Researchers have attempted to link this variance to variables such aas vegetation and landscape structure, distinctive habitat characteristics, resource availability, and hunting pressure. However, there is less evidence available on vertebrates than on plants (Shankar Raman et al. 1998). The ages of fallow or secondary forest analyzed in published research vary, as do the features of the surrounding terrain, such as the overall area of primary forest. The importance of the surrounding environment is recognized by writers such as Shankar Raman et al. For shifting cultivation and by Saunders et al. As a general concept, but is not quantified in most shifting cultivation research. Nonetheless, data show that variations in vertebrate richness and composition between fallow stands and landscapes on the one hand and primary forest on the other are not always as clear-cut as they are for plants. This variation is caused by variables such as vertebrate migration and the supply of resources such as food in plant communities with widely different structural and compositional properties. Six-year-old fallows of 0.9-2.9 ha in a primary rainforest matrix in lowland Chiapas, Mexico, had the same species richness of small and medium-sized animals as primary forest. Although there were variations in relative abundances across habitats, all of the mammal species documented in traps were present in both.

Two monkey species were identified as obligate arbo-reals that were missing from the fallows. Shankar Raman discovered that two mostly canopy-dwelling squirrel species were missing from fallows less than 25 years old in northeastern India's tropical wet forest setting. Cow-lishaw and Dun don, focusing on monkeys, remark that extensive tracts of woody vegetation that endure in altering agriculture landscapes may provide enough habitat for several species of this group. Tropical studies frequently reveal no differences in primate richness and composition between fallow and secondary forest vegetation and primary forest, and some primates are more abundant in anthropogenic vegetation than in "natural" communities in Asia and Africa. Nonetheless, Shankar Raman and Medelln and Equiha present evidence that, as with birds (discussed later in this chapter), the species composition of mammal assemblages exploiting fallow vegetation would alter over time, at least in certain circumstances.

All of these writers, like the previous authors, employed a Chrono sequence method to sampling, working concurrently in fallows of varying ages and presuming that any variations between them indicate trends through time in a single habitat patch. These studies do not reveal a single, distinct pattern of bird species richness and diversity; we shall discuss compositional trends later in this chapter. Terborgh and Weske and Andrade and Rubio-Torgler found no differences in species diversity per 100 individuals between habitats in understory mist net captures, despite the fact that total numbers of species observed by all methods differed between habitats in the former study and were lowest in second growth and a cocoa plantation. Vieira et al. captured fewer species in 10-year and 20-year fallows than in their main forest section, adding to the evidence that bird species richness may be lower in fallow vegetation than in primary forest.

They also discovered more forest bird species in the 20-year fallow than in the 10-year fallow, and in both the African and Asian studies noted, bird species richness rose considerably with increasing age. Fallow, on the other hand, was the most species-rich environment in Johns' location. Anderson showed that the quantity and diversity of raptors rose with increasing structural heterogeneity given to the landscape through changing farming, with primary forest being the least structurally complex habitat. As the number of disturbed-habitat species increases, such a relationship is likely to be recognized on many various scales in many different groups of creatures. The biodiversity and conservation potential of Shifting Cultivation Landscapes 175 as a result of human alteration of a portion of the habitat is more than the number of forest species lost as a result of the same cause.

DISCUSSION

Compositional trends in bird communities in shifting agriculture landscapes may be clearer than those in species richness and diversity, particularly in regard to feeding guild composition. Even when many species are common to all habitats in a landscape, as was the case in many of the studies cited here, variations in their relative abundances mean that compositional similarity at the community level tends to be greatest between sites with the most similar vegetation (e.g., primary forest and old fallows) and least between sites at opposite ends of the disturbance gradient. The degree of isolation of manmade habitat patches probably influences compositional trends in bird groups, however this is little unknown. Stiles and Skutch , for example, note that four of the five most numerous species documented by Vieira et al. utilize shady environments, such as cocoa plantations and older secondary forest, when they are next to primary forest. On the same subject, Shankar Raman et al. Emphasize the importance of habitat around patches of fallow and secondary forest in affecting the abundance, composition, and variety of vertebrate assemblages seen in those patches. They do note, however, that the bird assemblages of duplicate areas of fallow vegetation separated by many kilometers in certain age groups were more comparable to one other than to those of neighboring habitats. These findings support the idea that the composition and structure of a specific patch have significant roles in shaping the features of bir assemblages found in that patch, regardless of the habitat type next to it. Although some writers have reported abundance trends across disturbance gradients for individual species, patterns at the guild level are likely a more realistic indication of the key ecological processes driving bird community features. Several studies have shown that terrestrial forest birds, especially insectivores, are less frequent and species rich in fallows and agricultural fields than in primary forest. Overall, the available data support the basic conclusion that forest fauna components that require habitat structural elements or kinds that are missing or unusual in regions altered by shifting agriculture are likely to be less plentiful in those places than in forest. Habitat characteristics linked with changing farming, on the other hand, will draw species suited to those traits into the population. Depending on the features of the vertebrate guild or species involved, these connections will work at various geographical scales. The features of vertebrate populations in dynamic cultivation landscapes are extremely likely to be influenced by spatial and temporal patterns in food availability.

Phayre's leaf-monkey (Presbytis phayrei), on the other hand, is a folivore that feeds on a variety of early and mid-successional trees and was not seen in the primary forest. Typically, studies of neo-tropical birds reveal many feeding guilds, some of which have previously been noted. Guilds are defined by the preferred food type and the precise habitat component employed during foraging (from broad categories like "canopy" and "understory" to more specific ones like "bark"), as well as whether activity is diurnal or nocturnal. The current writers referenced Robinson and Terborgh for the most complete taxonomy of feeding guilds, which identified 22 guilds. Species in these guilds may also be classified as generalists or specialists, or grouped according to the size of food items consumed. The above mentioned studies of birds in altering agriculture landscapes include numerous theories tying the observed community- and species-level trends to food availability. In certain circumstances, the loss of forest bird populations may be connected to the reduction or unavailability of preferred food supplies in shifting agriculture landscapes compared to forest. The limited number of terrestrial forest insectivores that accompany army ant swarms demonstrates how trophic connections may break down in human-influenced settings. Studies in fragmented forests show that these birds must follow many ant swarms at the same time, therefore they may vanish if forest fragments are too small to accommodate the requisite number of swarms.

Although the reduction of understory and terrestrial insectivores in disturbed habitats has previously been highlighted, it needs to be shown if similar causal linkages to ant swarms apply in altering agriculture landscapes. For example, Johns thought that the frequency of army ant swarms did not vary depending on the habitat types he studied. It is also possible that certain terrestrial forest birds may incur physiological stress in the microclimates of second-growth vegetation, and that this factor, rather than a pattern in food supply, may be responsible for bird communities' reactions to habitat disturbance. When foraging, a number of forest bird species or guilds clearly utilize or prefer anthropogenic habitat areas in altering agriculture landscapes. The insectivore-nectarivore guild, which includes hummingbirds (Trochilidae) in the neo-tropics, usually maintains or increases its presence in fallow vegetation due to the availability of both floral and invertebrate resources.

The impacts of microclimatic variation across tropical forest habitats with varying degrees of disturbance on plant populations and communities are well known and have been the topic of various reviews over the years. Shifting agricultural clearings are extensive in the setting of tropical forest canopy gaps, and their microclimates will undoubtedly range significantly from those of the forest understory and forest treefall gaps. However, in large clearings, plant regeneration may swiftly buffer microclimatic change, and it is unfortunate that there seem to be no published comparison studies of microclimate in various aged fallows and primary forest. In many dynamic cultivated landscapes, hunting, rather than habitat shape and quality, is likely to be a significant role in shaping certain vertebrate population traits. The apparent higher impact of shifting agriculture on monkeys found in neo-tropical locations compared to those found in Africa and Asia might be due to historical or contemporaneous hunting rather than environmental concerns. Even under substantial hunting pressure, the high biomass of small and medium-sized animals in African shifting agriculture landscapes is maintained, but if big species are missing. The Biodiversity of Agroforestry Systems the land is most likely due to human activities that have evicted or extirpated them. Finally, when the vertebrate assemblages reported in fallows and agricultural fields are compared to those observed in primary forest, changes in diversity and composition may be discovered.

Anthropogenic change of forest habitat is expected to enhance the variety of the associated fauna at several spatial scales, as shown in Anderson's raptor community at the landscape scale. Diversity gains are often caused by species from disturbed habitats entering regions following disturbance and should be regarded as neutral from a conservation viewpoint. Changes in vertebrate assemblage features are likely to be connected to changes in habitat structure, spatial and temporal patterns in food availability, and even microclimatic variation. The kind and extent of changes detected at the community level are influenced by the features of the terrain in which the observations are made. Managing Shifting Cultivation Landscapes for Increased Biodiversity and Conservation Value In many tropical landscapes, the patchwork of phases of the shifting cultivation cycle is the dominating single land use. This land use, as well as how it interacts with remnant regions of primary communities and other human land uses, must therefore become a core focus of biodiversity-oriented study, development, and management in such settings.

To maintain as much biodiversity (human-made and wild) in the landscape as is compatible with the satisfaction of other human needs in a sustainable way, though not necessarily to maximize biodiversity in each patch within the landscape. To contribute to regional efforts to conserve forest-dependent plant and animal species such objectives could be integrated with planning and ac we feel that for biodiversity protection, the landscape scale should be the major management emphasis. Action at the landscape size would be supplemented by control at the patch level. This is due to the fact that there does not seem to be much opportunity for increasing the biodiversity conservation value of specific habitat patches in changing agriculture landscapes. Farmers are hesitant to forgo one of their most ecologically unfriendly management techniques, fire, in order to acquire the nutrients contained in fallow biomass. The fallows must be cut in any circumstance. Because vertebrates are mobile and may utilize multiple habitat patches to satisfy their requirements, it may be simpler to preserve forest vertebrates than forest plants in altering agriculture landscapes.

Two such concepts stand out, none of which is unique to this sort of environment. Conserve as much of the remaining primary forest as feasible in landscapes. Justification for such a measure does not seem to be essential, but if it is, signs that the quantity of "native vegetation" in the landscape is the best single correlate of animal species diversity reported in certain studies of forest plantations are more than enough. In such a case, primary forest remnants potentially become keystone habitat patches in the landscape, acting similarly to keystone species in that they have a disproportionate influence on biodiversity in the landscape. A "coarse-filter" approach know found in many precautionary frameworks for biodiversity conservation in human-impacted ecosystems such as forests managed for timber production would ideally include forest in each of the major physical environments of the landscape. Maintain connection between patches of habitat that are critical for the survival of forest-dependent organism populations. However, an essential component of a precautionary approach to connection supply would be to strive to protect the physical continuity of the landscape's most critical and least widespread habitats: mature forest and older secondary forest. Building on the concepts of Smith et al., it is arguably self-evident that all of the previous proposals for biodiversity-focused landscape management would be best applied during the early phases of agricultural frontier development, when considerable amounts of primary forest still exist.

The immensity of the problem of managing landscapes at various phases of landscape development is self-evident. Aside from action specific to primary and old secondary forest habitats, the preservation of biodiversity in general, and forest-dependent species in particular, might be assessed and managed in connection to overall landscape structure and variety. At the scale of patch types in the landscape, shifting agricultural landscapes are varied. Biodiversity in changing agriculture landscapes is therefore heavily reliant on human populations, with fallows being the most significant in terms of area. Rapid turnover of community types on specific patches of land scape is a distinguishing feature of changing agriculture landscapes, and it is of critical ecological value. The relative shares of land allocated to various uses fluctuate between phases of agricultural frontier evolution, with old-growth forest declining, fallows growing, and non-shifting cultivation land uses increasing in more advanced stages of frontier development.

Mature and perhaps ancient secondary forests are likely keystone communities, important for creatures that are forest reliant in some manner, such as those that employ a variety of landscape patch types but need well-developed forest for at least part of the conditions and supplies necessary for existence. Some community-level traits for example, the proportions of plants regenerated from re-sprouts vs those regenerated from seed, or the existence of forest-dependent animals in anthropogenic settings are likely to be influenced by the structure and composition of the landscape around the community. Affects the species variety of creatures with coarse-grained perceptions of habitat, such as diurnal raptors, and has an undeniable impact on species-level diversity in general. Intuition tells us that trends in landscape structure and diversity that are detrimental to biodiversity and are associated with the trend toward shorter fallows include greater dominance of the landscape by younger fallow habitats and increases in the mean areas of patches of anthropogenic vegetation. Specific management goals to counteract these tendencies might include maintaining or increasing the extent of older fallow vegetation and maintaining a high degree of inter-spersedness of distinct patch types. More extensive quantitative assessments of altering agriculture landscapes than those already available could give further hints to technically acceptable management goals.

The landscape-scale effects of improved (i.e., planted) or managed fallows would be determined by how this modification changes the relative acreage and spatial arrangement of natural fallow vegetation and other patch types in the landscape, which is currently hard to measure. It is obvious that improved, planted fallows, which are generally brief (less than 3 years) and often include a single planted species as a main component, have lower patch size variety than wild fallows. Finally, in accordance with ecological principles relating to fragmented communities, patch size and shape, the type of community or communities bordering a given patch, and distances to similar patch types must all influence biodiversity in any given patch. There seems to be no published data on this element of biodiversity and its dynamics in transforming agricultural environments.

Community-Level Management contains a summary of our review of aspects of biodiversity in the communities that comprise shifting cultivation landscapes, upon which we base the following recommendations for biodiversity management at the level of individual communities or patch types within such landscapes. Fallow vegetation and crop fields are anthropogenic communities whose traits are predominantly influenced by dramatic, high-frequency disturbances. As a result, they are unfriendly to forest-dependent plant species, and the existence of forest-dependent animals in them is likely to be contingent on the presence of older secondary or mature forest in the landscape. The anthropogenic character and antagonism of forest species to patch-scale biodiversity is likely to be more pronounced in planted fallows. Because mobile animals and birds move throughout a number of patches within the landscape, analysis and management at the patch size are perhaps most relevant from the perspective of plants. However, aspects of fallow and secondary forest vegetation composition and structure could be manipulated to increase the number of animal and bird species using specific habitat patches, thereby increasing the total habitat area in a land scape suitable for at least some of the needs of animal and bird species.

Options for biodiversity-conscious management of plant communities may focus on two related, specific goals: increasing the length of fallow periods so that more species accumulate and (a point not addressed in case studies) a greater number of individuals reach reproductive maturity, and increasing the rate of plant diversity accumulation so that more diversity accumulates for a given fallow length. The former goal could be achieved by promoting fallow uses other than weed control and soil fertility recovery, ones that entail longer periods of vegetation development, another significant challenge in the context of general tendencies toward shortening fallows and adopting the planted fallow. Fallow management for wood and non-timber forest products is one possible method here. The second goal might be followed by thinning to favor longer-lived or forest-dependent plant species over pioneers, with a particular emphasis on minimizing the degree and duration of domination of the vegetation by low-diversity assemblages of short- or long-lived pioneer species. The regrowth of the preferred species is a fundamental premise here and cannot be guaranteed.

In an ideal world, managers would assess regeneration using silvi-cultural diagnosis techniques, as Finegan and Delgado proposed in the context of forest restoration through secondary succession on abandoned neo tropical pastures, and may conclude that planting is required for biodiversity conservation objectives. However, there is little or no experience in this form of silvi-cultural intervention in the neo tropics, despite advancements in temperate zones. In the case of vertebrates, two major areas of action emerge: control of vegetation structure, composition, and microclimates, and management of hunting. Data from other settings indicate that conserving more original forest trees of a broader variety of species would make a significant contribution to the animal and bird richness of changing agriculture communities. The efficiency of different spatial arrangements of con served trees in this setting may vary. Given that changing cultivated land is regularly burnt, and that most tropical forest tree species are particularly sensitive to mortality even from ground fires, trees would most likely have to be protected in strips between fields, with careful burning. Riparian forests may also play an important role in habitat management due to their fire resilience.

Tree conservation is another measure that would obviously be more effective if implemented during the early stages of frontier development; however, it is important to note that this is a temporary measure because once they are gone, primary forest trees will not be replaced in the landscape. Individual fallow and secondary forest areas' vegetation structure might be advantageously varied to support vertebrate diversity. The conservation of forest trees, as well as the favoring of some individuals of fast-growing pioneers regenerating from seed, would contribute to the diversification of vegetation structure, all with the goal of broadening foliage height profiles and increasing vertical and horizontal structural diversity. Vine tangles, continuous tree canopy cover at all feasible levels in habitat patches, and moribund or dead trees are among the more specific habitat traits listed in this chapter as crucial to vertebrates and should be protected.

Many pioneer plants supply food to frugivorous or omnivorous animals, and because of their nature, these plants may need minimal management effort to continue this role. Management interventions meant to improve stand diversity or favor forest-dependent plant species in older vegetation, on the other hand, might increase the frequency and size of fruit yields if they include canopy opening. Diversification of stand vertical structure might be integrated with the conservation of species that provide fruits to vertebrates, given that certain vertebrate fruit eaters have foraging height preferences. Any alteration of habitat features would have to follow the fundamental guideline of avoiding a return to early-successional microclimates and their associated species.

Shifting cultivation debates tend to become politicized, with the practice portrayed as either the destiny or the future of tropical forests and their biodiversity over large regions of the tropics. However, polarization is based on basic misconceptions of the nature of shifting agriculture and its consequences on biodiversity, as well as a gross simplification of an agricultural production system that, in reality, comprises of a number of methods used under a variety of situations. Because of differences in agricultural systems, sociocultural organizations, external factors, and site biological circumstances, the effects on biodiversity will vary greatly from place to place. This cultivar must be examined before any reasonable conclusion can be formed on shifting cultivation and biological conservation. This chapter is an effort to start such an investigation. Conservationists or foresters claim that shifting agriculture in general is a primary driver of deforestation or forest degradation, and hence of biodiversity loss.

Too frequently, new migrants clearing land by fire are incorporated into historic traditional shifting farming systems. There has not been enough emphasis placed on the fact that shifting cultivation is the sole food production strategy used by traditional forest people. It is usually supplemented by hunting and gathering, home gardens, and, in certain cases, elaborate agroforests. Overall, as this chapter has stressed, changing agriculture often creates landscapes that preserve high levels of biodiversity in general, in which certain components of forest bio diversity, particularly vertebrates, are likely to be maintained. It is critical to differentiate between biodiversity in general and forest-dependent species in particular when analyzing the potential contribution changing agriculture landscapes might contribute to tropical biodiversity conservation. This contrast has been emphasized throughout this chapter. Biodiversity is a fundamental element of current methods to agriculture and natural resource management. Natural forest ecosystems and the species that rely on them, on the other hand, are the focus for conservation work in the humid tropics. Many observers, especially social scientists, perceive biodiversity as too simplistic in this setting.

Crop fields and fallows are examples of anthropogenic communities that may sustain or contribute to biodiversity at the species and genetic levels. However, most of tropical variety existed long before human impact on tropical forest characteristics became significant. Tropical forests are the most biodiverse terrestrial ecosystems for reasons that are not completely understood, and the desire to understand how variety is created and maintained is an important component of tropical forest study. Much biodiversity's "forest-dependence" should be self-evident, as should its vulnerability to the high-frequency drastic disturbance inherent in shifting cultivation and to modern tendencies toward shorter fallows and, as a result, greater areas of crop fields and young fallow vegetation in landscapes. Finally, it is obvious that changing cultivation systems may play a beneficial role in biodiversity conservation, particularly—though we have not highlighted this point—much more positively than any current intensive agricultural system.

People are increasingly shaping modern tropical landscapes, and shifting farming is therefore a reasonably biodiversity-friendly land use in the face of this fact. Its contribution to ecological conservation, however, will be significant only provided altering agriculture landscapes do not become just temporary phases of border growth, as is often the case now. Population growth, economic policy, and governance are all aspects. Relocation programs are essential factors that may boost the transience of altering agriculture landscapes, according to the Biodiversity of Agroforestry Systems. Furthermore, fallow seasons are decreasing throughout most of the humid tropics, and the relative extents of crop fields and young fallow vegetation are growing rapidly. These tendencies have far-reaching consequences for the sustained agricultural productivity of shifting cultivation systems, as well as for the preservation of biodiversity in the landscape as a whole. Planted fallows are an essential answer to the agricultural production issue, but they are not helpful to biodiversity unless they are complemented with actions to maintain or expand cover of ancient secondary and primary forest in the landscape. Management of changing agricultural landscapes for biodiversity, along the lines we've outlined and prioritizing forest-dependent species, has the potential to boost their contribution to biological conservation, but it confronts significant implementation obstacles.

CONCLUSION

With its mosaic of land cover types, shifting agriculture landscapes may contribute to landscape connectivity. The availability of several habitat patches across the landscape may promote migration and gene flow for many species, preserving genetic diversity and promoting population sustainability. However, it is crucial to highlight that the biodiversity and conservation potential of changing agriculture landscapes may vary based on a variety of characteristics such as cultivation intensity and duration, land use scale, and surrounding landscape context. Short fallow seasons, heavy burning, or development into vulnerable ecosystems may all have a detrimental influence on biodiversity. Working closely with local populations, including traditional knowledge and practices, promoting sustainable land management strategies, and ensuring the preservation of vital habitats and species are all required to maximize the conservation potential of changing agriculture landscapes. Balancing community agricultural demands with conservation goals may result in more sustainable and biodiversity-friendly shifting farming systems.

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CHAPTER 15

TROPICAL TRI TROPHIC INTERACTIONS: HORRIBLE HOSTS AND PERVASIVE CASCADES

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ABSTRACT:

Tropical tri trophic interactions relate to the complex connections that exist in tropical ecosystems between plants, herbivores, and their natural enemies (such as predators, parasites, and diseases). While these interactions may be varied and complex, two particular elements that are often mentioned are "horrible hosts" and "pervasive cascades." The existence of dreadful hosts may have ecological consequences. It has the potential to impact community structure and relationships, as well as herbivore population dynamics and distribution. Herbivores may focus on these susceptible plant species, resulting in localized herbivory patterns and possible changes in plant community composition.

KEYWORDS:

Trophic Cascades, Tropical System, Terrestrial Systems, Tropical Forests, Tropical Communities.

INTRODUCTION

The vast variety of organisms at all trophic levels in the tropics, along with heightened chemical defense and predation intensity, provide perfect conditions for intriguing community ecology study. Trophic cascades and coevolution are two especially relevant topics in the field of tropical tri trophic interactions, and significant hypotheses developed by these principles should continue to give direction to empirical research in tropical communities. Trophic cascades and co evolutionary interactions are predicted to be different in tropical ecosystems simply because most species at all trophic levels are more diverse. However, many of the assumptions regarding how tropical communities vary from temperate groups have not been well investigated and may be erroneous. As a result, one of the primary goals of studying tropical tri trophic interactions is to extensively record latitudinal variations in community features such as consumer specialization, plant chemical defense, and predation intensity [1].

Due to a lack of concentrated research initiatives, there are no appropriate syntheses of trophic cascades and co-evolutionary theories for the tropics. Tropical ecologists should concentrate on model systems and use phylogenetic data in conjunction with innovative experimental, correlational, observational, and modeling methodologies to explicitly evaluate these ideas. Given the richness and significance of ant plants in most tropical communities, myrmecophytes are excellent candidates as model systems for such a synthetic approach. Tri trophic connections in tropical communities are often part of a larger complicated web with highly varying interaction strengths; nevertheless, with the correct methodologies and research systems, we may discover which interactions are the most powerful for certain species and environments.

Myrmecophytes and its accompanying arthropods interact in ways that are possibly the most uniquely tropical of all recorded tri trophic associations. These diverse tropical plants, which have evolved in over 100 genera, are most likely the result of millions of years of strong tri trophic interactions, and are just one of many genres of intricate tritrophic stories that have yet to be thoroughly investigated. Tropical ant plants have supplied a solid yes response to the core issue of tritrophic research: whether or if natural enemy influence on herbivores imposes strong enough selection pressure to affect plant features. In fact, a thorough research program that uses a tropical myrmecophyte as a model system should yield advances for major issues in tritrophic interactions, such as trophic cascades, evolution of specialization, multi trophic mutualism.

Specialization is a key concept in tropical community ecology, and co-evolutionary interactions could potentially generate a large percentage of the great diversity of plants and animals in tropical communities. However, after 40 years of theoretical progress and hundreds of empirical investigations, no complete theoretical framework has been developed, and as a consequence, there are no unified research techniques, particularly for tropical species. Evolutionary theory, in particular, has seldom explored the roles of additional selection factors that might change or improve coevolution, such as herbivore predators and parasitoids. Are tropical forest or agricultural tritrophic interactions experimentally distinct from temperate tritrophic interactions? Trophic cascades and co-evolutionary interactions are predicted to be different in tropical communities simply because most species at all trophic levels are more diverse. Diversity at a given trophic level can weaken the effect of consumption on lower trophic levels due to increases in interference competition (including intra-guild predation), diet shifts, omnivory, and other buffering mechanisms facilitated by greater complexity. Because of increased exploitation competition, lower host availability for specialists, and changes in chemical defenses, increased diversity may also lessen the influence of resource availability on higher trophic levels [1].

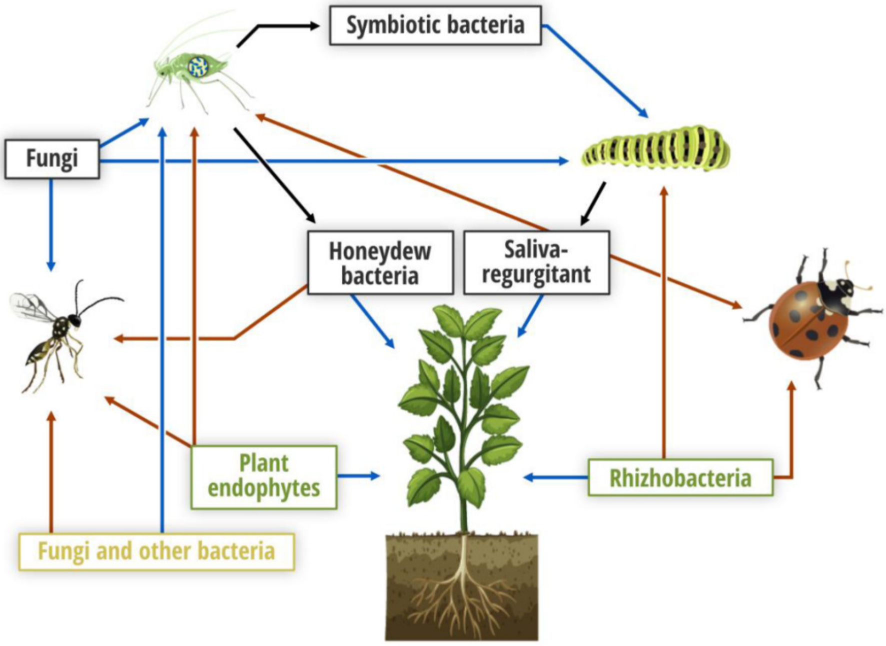

Figure 1: Symbiotic relationship: Diagram showing the overview of the Symbiotic relationship (MDPI).

If true, these ecological changes may reduce the likelihood of coevolution since top-down and bottom-up selection pressures may be decreased by the same mechanisms that degrade cascades. There are several more tropical community-specific characteristics that lead to divergent expectations regarding selection pressures across trophic levels and related indirect consequences. But how many of these other characteristics have been properly established, and how many are merely folklore? Before delving into coevolution and trophic cascades in the tropics, basic assumptions regarding how tropical communities vary from temperate counterparts should be reviewed.

Many assumptions remain unproven at the core of all multi trophic concerns in tropical community ecology. Apart from obvious correlates of increased diversity, such as more reticulate food webs, the most prominent hypotheses for tropical communities are tropical consumers are more specialized predation is more intense in the tropics. Chemical defenses are more abundant and toxic in the tropics and multi trophic mutualism. The gradient in species richness may seem to be the sole tenable generalization concerning latitudinal gradients in community ecology, but a detailed examination of complicated trophic relationships should uncover additional significant gradients (Figure.1). The initial task for tropical ecologists is to identify the species, habitats, and environmental variables that support the tropical paradigms of specialization, severe predation, poisonous food, and indirect mutualism. This is required before addressing any concerns about tritrophic interactions, such as assumptions about the development of specialization and trophic cascades. The easiest approach to do this is to make enhanced natural history a priority in all tropical tritrophic interactions research [2].

There are also complicated patterns of tritrophic interactions within the tropics. Altitudinal gradients, for example, generate close-knit ecosystems with severe disparities in total diversity, productivity, and ant abundance, all of which decrease with altitude. However, in the tropics, altitudinal variations in ecological interactions have not been thoroughly investigated. The most dramatic pattern of interactions within the tropics may be found along the climatic gradient from dry deciduous to moist evergreen forests. Tropical forests have higher plant diversity as total annual rainfall increases and climatic variability decreases, higher primary productivity and stem turnover, and lower seasonal production of new foliage and reproductive parts. Furthermore, plants that live in wetter tropical forests seem to be better guarded against herbivores because their leaves are harder, have larger concentrations of secondary chemicals, and have a lower nutritional value. These variations in plant traits along tropical rainfall gradients are expected to have a significant impact on tritrophic interactions. For example, it is likely that as rainfall and climatic variability rise, so would the top-down influence of natural enemies and the bottom-up effect of plant defenses, resulting in lower annual herbivore numbers in wetter tropical forests.

To demonstrate such a relationship between climate and herbivory based on differences between tropical dry and wet forests, three general hypotheses should be tested in dry forests, herbivore populations are limited by the bottom-up effect of plant availability (because leaves are largely deciduous and absent during the dry season) and direct abiotic effects of the severe dry season parasitoids, predators, and plant secondary compounds have a negative effect on herbivore populations; Tropical community ecologists have failed to offer enough evidence for generalizations regarding differences between tropical and temperate communities, and no hypotheses concerning tritrophic trends in tropical forests have been tested. There are many reasons why proper studies have not been performed, the most important of which is a lack of resources to support the essential research. Assuming that funding is available in the future for such research, rigorous evaluations of hypotheses examining the development of specialization and trophic cascades will generate data that will aid in establishing the strength of these hypothesized patterns and the relative relevance of underlying processes.

The coevolution paradigm, according to which the evolution of dietary specialization is a result of increasingly specialized adaptations for secondary metabolites in one plant taxon, influences most current studies on tritrophic interactions directly or indirectly. This hypothesis was preceded by an explicitly tritrophic idea that specialized diets represent enemy free space for her bevors, because monophagous insects are better able to defend against predators and parasitoids by utilizing chemical, morphological, and phonological attributes of their host plants. Multiple writers have presented the hypothesis that herbivore diet breadth is shaped by plant availability/appetency and pressure from enemies. If herbivores are indeed trapped in tropical wet forests by more poisonous plants and greater rates of predation and parasitism, it seems probable that herbivore specialization arose in response to one or both of these powerful factors and is perpetuated by one or both. The challenge is determining the proportional roles of these selecting factors [3].

Did specialization arise for a certain herbivore clade when herbivores developed techniques to improve plant availability (e.g., bypassing chemical defenses through specialized enzymes) and then enemies maintained that specialization, or vice versa. The high concordance between the phylogeny of the chrysomelid genus Phyllo brotica and that of its host plants implies parallel diversification, as predicted by the co evolutionary scenario, but is it possible that enemies were an additional selective force that kept these beetles special? Feeding specialization research focuses on an animal's "realized niche" diet - the set of resources that it is known to eat under natural settings. Feeding efficiency is a component of specialized consumption (at any trophic level), and consumers that can efficiently eat just a limited range of resources are referred to be "functional" specialists. Many ecologists believe that functional specialization is positively connected to the small diet breadths found in nature. However, this assumption is incorrect since improved feeding performance may evolve irrespective of dietary specialization. Furthermore, Fox and Morrow discovered that some insects efficiently digest plant compounds that they seldom utilize in nature.

When herbivores concentrate on plants with protections that reduce feeding efficiency (bad for the herbivore) while simultaneously repelling adversaries (good for the herbivore), the contradiction between ecological specialization and functional specialization becomes more apparent. Despite being a specialist, the herbivore does not function better (physiologically) on its preferred diet, although it may have decreased mortality. In such cases, traditional laboratory and field rearing experiments designed to detect trade-offs between feeding performance and diet fail to detect negative genetic correlations because herbivores are not functional specialists - that is, there are no genotypes that perform better on one diet versus another, but they are still limited to one diet due to enemy pressure.

Explicit tests of the co-evolutionary (bottom-up) scenario for dietary specialization in herbivores have been conducted primarily with temperate taxa (e.g., at the time of writing, only 23 of 750 studies citing Ehrlich and Raven's 1964 paper are focused on tropical taxa). The well-documented synchronized evolution of Blepharida beetles and their host plants, Bursera spp., is one notable example. Becerra and Venable are two examples. In this interaction, the leaf beetles have evolved a broad range of behavioral and physiological methods to evade each new defense of the host plants, including squirting resins and complex terpene combinations. There is no reason to believe that this and other well-documented examples of strong coevolution between host plant and herbivore are the norm in tropical communities, particularly given that several studies have found low congruence between plant and herbivore phylogenies.

More testing of parallel phylogenies following the examples of previous work that comprise just a few clades are needed to develop a robust co evolutionary theory for tropical systems. The top-down approach described above, as well as by Singer and Stireman, has been tested in the tropics with predators and parasiteoids. The findings for predators paralleled temperate research, with specialists outperforming generalists in predator protection. However, parasitism patterns vary greatly. Gentry and Dyer discovered that tropical specialists were no better protected than generalists, and that some parasitoid taxa prefer specialists and chemically defended caterpillars, possibly because these hosts represent enemy free space, because chemically defended specialists are avoided by many distinct guilds of predators. This is in contrast to studies in temperate systems that show anti-parasitoid defensive value of sequestered secondary compounds, and it provides evidence against the "nasty host hypothesis", which contends that parasitic hymenopterans are less diverse in the tropics because their hosts have high levels of chemical defense [4].

A major issue with comparing specialist versus generalist herbivore defenses against their enemies in all of these studies is that the original selective advantages of specializing may be lost, especially for anti-parasitoid mechanisms, because parasitoids may evolve mechanisms that allow them to overcome chemical defenses sequestered by herbivores. A phylogenetic approach should be used wherever possible to investigate the evolution of diet breadth in conjunction with modifications that enable the utilization of phytochemicals as anti-predator and anti-parasitoid defenses. Temporal scalee from more than 100 million years ago to current communities The tropical patterns of parasitism on lepidopterans with varying diet breadths are potentially compatible with the view that enemies contributed to patterns of specialization, because parasitoids are relatively new in comparison to the long histories of specialized plant-herbivore relationships. The Tachinidae, for example, is thought to be 20-40 million years old, and this family is often the leading cause of lepidopteran mortality. In contrast, certain plant and herbivore taxa have been associated for about 100 million years.

Singer and colleagues used an unusual technique to determining the diet breadth of generalist arctiids. A mixed diet delivers advantages of improved development owing to adding a high quality plant in the diet and higher defense due to including a poisonous plant in the diet for two general ist arctiids. The benefit of opponent free area outweighs the value of improved larval performance owing to higher food quality for both of these arctiids. Regardless of how specialization originated and whether it is adaptive, limited consumer diet width should affect its ecological function in a community. Specialist herbivores are far more likely than individual species of generalists to present a consistent regulatory force on plants, and specialist parasitoids are traditionally thought to be more effective herbivore regulators than generalist predators.

Because many hypotheses about the origin and maintenance of tropical diversity make assumptions about the prevalence and consequences of consumer specialization, putting diet breadth into a coherent ecological context should be an important goal for tropical community ecologists. The term "trophic cascades" has been defined in a variety of ways, which has caused confusion, but the most restrictive definition is: a measurable increase in primary productivity due to predators' negative effects on herbivore biomass. Hairston et al. presented the trophic cascade concept, popularly known as the "green world hypothesis".

There are many other types of trophic cascade hypotheses that are potentially important forces in terrestrial systems and they fall under a more general definition provided in theoretical and empirical studies. This includes indirect impacts among individual species or whole trophic levels, with the consequences operating on community metrics such as species richness. Two further cascade ideas that I address here are the "trait-mediated cascade" and the "diversity cascade," both of which may be crucial in tropical populations. A trait-mediated trophic cascade is a shift in plant biomass induced by changes in herbivore feeding behavior when predators are present. A diversity cascade is the result of variety at one trophic level having an indirect influence on another trophic level. In a tropical environment, no trophic cascade concept has been thoroughly investigated [5].

DISCUSSION

The ecosystem exploitation hypothesis (EEH) incorporates variation in primary productivity and generalizes predictions for even and odd numbers of trophic levels that may result along a productivity gradient. Hairston et al. presented the trophic cascade concept, popularly known as the "green world hypothesis". There are many other types of trophic cascade hypotheses that are potentially important forces in terrestrial systems and they fall under a more general definition provided in theoretical and empirical studies. This includes indirect impacts among individual species or whole trophic levels, with the consequences operating on community metrics such as species richness. Two further cascade ideas that I address here are the "trait-mediated cascade" and the "diversity cascade," both of which may be crucial in tropical populations. A trait-mediated trophic cascade is a shift in plant biomass induced by changes in herbivore feeding behavior when predators are present. A diversity cascade is the result of variety at one trophic level having an indirect influence on another trophic level. In a tropical environment, no trophic cascade concept has been thoroughly investigated. The ecosystem exploitation hypothesis (EEH) incorporates variation in primary productivity and generalizes predictions for even and odd numbers of trophic levels that may result along a productivity gradient. Most tropical communities have HSS and EEH ecological systems as a result of predators' significant top-down impacts. According to Strong and Polis, trophic cascades should be predicted only in systems with limited within-trophic level variety, simple food webs, isolated habitats, and little geographical variation. These authors contend that complex ecosystems feature "species cascades," in which the indirect positive impact of predators is proved only for one plant species, not for the whole community.

Predation, according to this viewpoint, may be crucial in different communities for certain embedded food chains, but trophic cascades are not expected to be important for a whole complex community. Because the mechanism of trophic cascades is likely to be trait-mediated rather than density-mediated, a distinction between trait-mediated and density-mediated indirect interactions has been made. In DMII, the cascade is mediated by a change in the abundance of the intervening species or trophic level, but in TMII, the indirect impact is mediated by a change in the intervening species' behavior or defensive traits. DMII and TMII are not mutually exclusive; in fact, trait-mediated interactions are likely to be the most significant mechanistic reason for substantial indirect effects on density in trophic cascades. Gastreich researched spiders, ants, and caterpillars connected with the ant plant Piper obliquum and found the finest tropical example of a trait-mediated trophic cascade. Theridiid spiders influenced the foraging of mutualist Pheidolebicornis ants, increasing caterpillar herbivory while maintaining ant populations. Gastreich and Gentry argue that spiders are generally useful predators for examining DMII versus TMII because they are ubiquitous enemies and have been shown to alter the density and behavior of their prey in many contexts e.g., MacKay 1982, Diversity cascades Diversity cascades are a complex set of interactions that are particularly relevant to tropical systems. This bottom-up cascade hypothesis is a subset of the major hypotheses explaining the latitudinal gradient in species diversity, and it has been well tested, with results indicating that plant diversity usually explains a measurable portion of consumer diversity for many different ecosystems. Diversity indices, species richness, abundance, or any other statistic linked to diversity may be used as response variables in diversity cascades [6].

The simplest diversity cascade incorporates the indirect influence of plant variety on total consumer diversity via increased herbivore richness and abundance. This bottom-up cascade hypothesis is a subset of the major hypotheses explaining the latitudinal gradient in species diversity, and it has been well tested, with results indicating that plant diversity usually explains a measurable portion of consumer diversity for many different ecosystems; however, the existing evidence is weak and easily criticized. The exceptions, in which a considerable proportion of individuals at an upper trophic level are removed, frequently result in significant indirect consequences. Terborgh et al. observed one such example, in which islands generated by hydropower impoundments in Venezuela were devoid of vertebrate predators. Herbivory levels on these islands were 10 to 100 times higher than in comparable regions on the mainland, with corresponding decreases in plant seedlings and saplings. However, important enemies of invertebrates were not excluded in this example of "ecological melt down"; perhaps such an additional exclusion would result in "ecological catastrophe," or the first convincing demonstration that trophic cascades are very strong stabilizing forces in tropical forests.

All trophic cascade and trophic interaction syntheses point to a lack of precise knowledge of food webs as a fundamental constraint in evaluating theories. As a result, some authors argue that future research should document additional data regarding species affiliations, the strength of links between species, and other fundamental natural history of food webs. Because natural history is often scarce in tropical systems, the issue is worsened. The fact that true trophic levels of predators or parasitoids are unknown is a classic illustration of this lack of knowledge. In reality, several writers admit to combining fourth and third trophic levels for studies, resulting in a reduced impact size for cascades. In the meta-analysis conducted by Schmitz et al., practically all of the 60 research analyzed were conducted for just one season using individual plants or extremely tiny plots (0.1-0.5 m2).

Surprisingly, the length of the research had no influence on the amplitude of the trophic cascade. Valid tests of indirect predator regulation of plant populations would necessitate decades, if not centuries, of research, but even tests that simply demonstrate density effects consistent with regulation or control may necessitate a significant amount of time. The known experimental spatial scales are further skewed toward demonstrating no classic trophic cascade, since none of the extremely small-scale modifications that are often carried out could possibly generate a change in ecosystem production. Furthermore, the tendency to explore primarily smaller geographical scales is unlikely to result in a comprehensive knowledge of tritrophic community dynamics. A simple tabulation of all the literature included in recent meta-analyses that test comparable hypotheses enables one to assess the percent overlap of papers used in pairs of meta-analyses. The mean literature overlap amongst contemporary paired meta-analysis papers is 5.7 1.8%, indicating that each study excluded the majority of the studies regarded relevant by other authors.

Furthermore, most meta-analyses do not limit the number of studies utilized from single articles in order to minimize effect size biases, resulting in exaggerated effect sizes for studies reporting more findings. Because several findings from a single research are utilized as independent observations in generating the effect size statistic, this method fits the requirements given by Hurl bert for pseudo replication, raising the relative contribution and related biases of the chosen studies. Many more detailed empirical research at appropriate geographical and temporal scales are required before meta-analysts create the entire, well replicated quantitative summary, particularly in tropical systems where they are missing. Many authors have concluded that trophic cascades are insignificant in more diverse terrestrial systems, and Halaj and Wise concluded that this particular independent effect is simply a trickle in most terrestrial systems. Many ecologists currently believe that only the simplest communities - aquatic versus terrestrial systems, grasslands vs forests, agricultural versus wild systems, and temperate versus tropical systems - are likely to exhibit cascades [7].

While this paradigm has some limited support, trophic cascades, diversity cascades, trait-mediated indirect effects, and species cascades cannot be dismissed as key influences driving diversity, primary production, and the number of trophic levels in tropical ecosystems. Indeed, the trophic cascade is one of the most valuable theoretical frameworks for evaluating hypotheses on herbivore population management. Ecologists will find the extent to which trophic cascades are weaker in more diversified terrestrial ecosystems by testing these and similar ideas, and they are likely to discover key community processes. Tropical interactions research is still in its infancy. One issue that might stymie major progress is a tendency to bounce from one hot subject to another. Indeed, it has become fashionable to proclaim hypotheses "dead" in the absence of a suitable armory of tests. This creates an illusion of progress. The emphasis for tritrophic interactions in the tropics should be on combining the best available approaches to build a larger synthesis and a better understanding of essential processes behind trophic cascades and co-evolutionary interactions. For example, Irschick et al. use a variety of modern methodologies to examine works on the development of specialization and present a sound foundation for future research.

Ecologists, on the other hand, should resist the desire to perform short-term experiments at large geographical scales that fail to thoroughly test important hypotheses, are often contradictory, and offer little theoretical advancements. In this paper, I suggest theories on coevolution and trophic cascades. It also provide recommendations on how to test these and related ideas. Because interaction strengths and accompanying statistics may vary greatly, distinguishing between strong and weak impacts within a community is important. According to Halaj and Wise, trophic cascades are really "trickles," or modest impacts as measured by meta-analyses. Wootton and Emmerson give useful suggestions on how to find "strong" relationships in a community using experimental, correlational, and modeling methods. I use the term "strong effects" to describe situations in which persistent additions or deletions of a population cause statistically significant and biologically significant changes in major community parameters such as productivity, diversity, the number of functional trophic levels, and the presence or absence of keystone species. Strong effects in quantitative summaries of empirical data would include all those that are technically equal to "large" meta-analysis effect sizes [8], [9].

CONCLUSION

Pervasive cascades may occur in tropical tritrophic interactions when disruptions or alterations in one component of the system have far-reaching consequences. For example, natural enemies (such as predators or parasitoids) may reduce herbivore pressure, resulting in greater plant survival and development. This may have an effect on the variety and abundance of higher trophic levels, such as predators and birds that depend on those plants for food or refuge. Understanding terrible hosts and ubiquitous cascades in tropical tritrophic interactions is critical for understanding the complexities of tropical biological groups. Plant evolution, herbivore behavior, natural enemy dynamics, and ecosystem functioning may all be affected by these dynamics. The study of these interactions contributes to a better understanding of the complicated web of links and mechanisms that influence biodiversity and ecological processes in tropical climates.

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CHAPTER 16

CONSERVATION OF BIODIVERSITY IN NEOTROPICAL PLANTATIONS

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ABSTRACT:

The incorporation of native plant species into plantations, as well as the restoration of degraded ecosystems inside or next to plantations, may help to conserve biodiversity. Native plants offer habitat and food for native species, as well as assistance for pollinators and general ecosystem resilience. Restoring riparian zones, building buffer strips, and creating tiny wetlands inside plantations may help increase ecosystem connectivity and water quality. Designating small areas within plantations as protected areas or nature reserves may offer habitat for native species and help to conserve biodiversity. These places may be set aside to protect key ecosystems, endangered species, or to conduct ecological research and monitoring.

KEYWORDS:

Biodiversity Conservation, Coffee Plantation, Coffee Farms, Shade Canopy, Shaded Coffee.

INTRODUCTION

Scientists are focusing on biodiversity conservation in man-made landscapes and agroecosystems due to the very high rate of loss of natural forests and other natural ecosystems. Agroforestry systems stand out as prospective biodiversity conservation techniques due to their high tree species richness and varied vegetation structure. Shaded coffee and chocolate (Theobroma cacao) plantations, home gardens, rubber and fruit tree agroforests, grazed dry scrubs and woodlands, and lengthy fallows are all well-known examples. Shaded coffee farms have been singled out in recent years for their capacity to support varied and plentiful wildlife. Shaded coffee plantations have a high potential to retain biodiversity and may play critical roles in regional conservation efforts.

Because coffee is important economically in more than 50 countries, employing 20-25 million people and covering 11 million ha of land, it has the potential to influence biodiversity conservation across large areas. In most coffee-growing locations, the landscape has been so badly deforested and changed that the only surviving tree cover is that found in coffee plantations; for example, in El Salvador, the majority of so-called forest cover is really shade-grown coffee. Coffee is farmed mostly in ecologically varied locations such as Mexico, Ecuador, Peru, Brazil, Colombia, Côte d'Ivoire, Tanzania, India's Western Ghats, Sri Lanka, Papua New Guinea, and New Caledonia. Colombia, for example, is not only one of the world's most significant coffee producers, but it also contains the world's greatest variety of birds and amphibians [1].

Individual nations' coffee producing zones may overlap with conservation priority areas containing a high number of species or endemics. 14 of the 155 conservation priority zones in Mexico, for example, are in or near traditional coffee-growing areas. As a result, actions promoting biodiversity protection in coffee farms may have an influence at both the national and regional levels. Shaded coffee plantations in the neo tropics also provide as critical habitat for migratory birds, having a significant impact on biodiversity conservation at supra regional scales. We begin with a historical account of the use of shade in coffee plantations, followed by a review of the literature on vegetation structural types of coffee plantations; plant diversity in shade canopies and ground cover, including genetic diversity of the coffee crop itself; diversity of other vegetation, including shade canopy and ground cover plants; and diversity of fauna and microorganisms including coffee pests, diseases, and aphids.

The emphasis is on geotropically coffee plantations, with the exception of a worldwide historical overview and a review of pests, diseases, and their natural enemy complexes, which have been investigated mostly in India. The Structure of Coffee Agroecosystems for as long as coffee has been farmed, the question of whether it should be grown under a shadow canopy has been disputed. Several studies discuss the benefits and drawbacks of shade in coffee. Because of historical processes, pedo climatic variations across coffee-growing locations, and socioeconomic considerations, a diverse range of structural forms of coffee agroecosystems with varying degrees of biodiversity have emerged in various parts of the tropics. Coffee (Coffea arabica) was found in Ethiopia about AD 850 and was first farmed in the Arabian colony of Harar, an Ethiopian region.

The typica cultivar's agro-ecological needs are typical of the Ethiopian hillsides where it originated, at 6°-9° north and 1,300-2,000 m altitude: moderate temperatures (lower and upper extremes of 4° and 31°C, respectively, and means of 20° to 25°C, with hot days and cool nights), 1,500-1,800 mm of annual precipitation with a well-defined dry season of 4-5 months, and a photoperiod of 10.5 to Ethiopian coffee plants grow in the wild beneath a canopy of natural or modified forests on slopes and along riverbanks. Coffee had to be planted in shade when it was brought into Yemen (fourteenth and fifteenth centuries), at the extreme south of the Arabian Peninsula, with a drier climate and sandier soils than in Ethiopia. Coffee use and cultivation spread south across Asia's humid tropics in the sixteenth and seventeenth centuries, with the spread of Islamic civilization[2].

Coffee was grown in household gardens and thinned woodlands in the shade. During the eighteenth and nineteenth centuries, the Dutch and subsequently the British encouraged heavy coffee cultivation in India and Ceylon under full sun. From the end of the seventeenth century onwards, coffee farming grew throughout the Indonesian archipelago under the colonial Dutch administration, with coffee being planted under shade on tiny peasant farms. There were three kinds of coffee systems in the mid-eighteenth century: the colonial model in high places where forests were cut and lines of coffee bushes and shade trees were planted, coffee plantations placed as hedges, and coffee plantations below natural forest. Small farmers favored the final two methods because they allowed for the simultaneous cultivation of food crops.

Coffee cultivation in the Americas started in the nineteenth century in the Caribbean on plantations of varied sizes and degrees of production intensity, using slave labor. The predominant plantation type in Saint Domingue was an intensively farmed plantation with little shade but trees placed in field boundaries or in widely separated lines throughout the plantations as windbreaks. This Antillean coffee plantation model (with little or no shade, intensive cultivation with high labor inputs, and wet processing of coffee beans, which greatly increased the cup quality of the coffee) was brought to Cuba by French emigrants following the Haitian revolution and abolition of slavery at the end of the eighteenth century. Cuba sent seeds and coffee technology to the rest of the Spanish territories in Central and South America.

Coffee was grown in Spanish Puerto Rico beneath a planted and maintained canopy of Inga spp., with densities varying with plantation height. In the British Caribbean, which was more specialized in sugar production, coffee plantations evolved from intensive production without nutrient replenishment and high soil erosion rates using slave labor to less intensive systems with shade and other crops grown between the coffee plants. The kind of coffee production system in South America differed depending on whether it was situated on the Atlantic or Pacific Andean slope. For example, in the Guyanas throughout the eighteenth and early nineteenth centuries, coffee was grown in broad sun and was connected with heavy land usage and slave labor. Both the genetic material and the habit of growing coffee in full sun seem to have been spread to Suriname and the north of Brazil, then to the state of Rio de Janeiro, and finally to So Paulo. Bananas (Musa spp.) were employed as temporary shade on peasant farms and huge haciendas in Colombia and Venezuela, while legume trees supplied permanent shade. Coffee polycultures were widely used on small peasant farms, with shade densities lower in high, cold zones than in warm, dry zones. In Central America, the utilization of shade in coffee farms varied from area to region and even from time to period within the same region.

Costa Rica, for example, followed the French Antillean model of farming coffee in full sun or minimum shade between the end of the eighteenth century and 1870. Shade was introduced into the plantations when production dropped due to plantation age and increasingly severe insect infestation, to the degree that in the latter third of the nineteenth century, the use of shade was popular across the nation. Coffee has usually produced beneath a shade canopy on Central America's arid and hot Pacific coast. The technological intensification of coffee production advanced in numerous regions of the globe in the twentieth century, at variable speeds and with significant differences across nations and different kinds of plantations and farmers [3]. After the mid-twentieth century, a number of places saw the introduction of new, shorter coffee kinds; smaller coffee bushes allowed for greater planting densities, improving self-shading and minimizing the requirement for shade trees. These new types increased yields while also necessitating a larger usage of agrochemicals. In many locations, shade management was simplified and limited to the use of just a few species, mostly fast-growing leguminous trees that quickly re-sprouted after crown pruning, fixed nitrogen, and were readily propagated and maintained. Shade was completely eradicated and then returned in numerous coffee producing zones.

Shade cannot be adjusted in these polyculture systems to meet the demands of solely the coffee plants (for example, cutting fruit trees to increase fruit output may not be the best approach to regulate shade for the coffee underneath), which may diminish coffee yields. Coffee Plantation Structures Coffee plantations range in complexity from very basic to highly sophisticate. The following structural categories may be recognized schematically. Open sun monocultures (no shadow canopy). Coffee plantations with lateral shade from linear tree plantings on field boundaries and along roadways that block wind, limit excessive shadowing, allow air flow, and decrease pathogen infestation in humid, overcast settings. Monolayer shade canopies: coffee farms having a single shade stratum and, in most cases, a single shade species, such as a service tree planted for conservation. Vertical constructions and floral compositions in coffee plantations that are idealized. Shading and soil improvement or a second commercial crop (e.g., bananas, oranges, Macadamia spp., cinnamon, clove, or avocados). The species richness in these systems is modest, the vertical structure is basic, and management is intensive. Two-layered shade canopies, such as those seen in mid-elevation Costa Rica's Erythrina poeppigiana-Cordia alliodora coffee systems. The E. To assist shade control, the poeppigiana shadow layer is maintained short by extensive pollarding; the timber layer (C. alliodora, either planted or chosen from natural regeneration) is let to grow unregulated, but tree density is carefully managed to minimize excessive shading. Replace the service tree with bananas or other perennial crops (coffee banana-timber or coffee-oranges-timber) or replace the timber tree with a tall service legume tree (non-pollarded Inga or Erythrina species) and underplant with bananas or other perennial crops (coffee banana-Inga). Multistory coffee polycultures with three or four vertical layers and three or more species. Typically, the shade canopy is dominated by a planted shade species and enriched by the planting of a mixture of fruit trees, useful palms, timber trees (often chosen from abundant natural regeneration), and, in some cases, trees remnant of the original natural forest. All remaining species are preserved at modest densities under the shade canopy, with the exception of the backbone species, which are frequently planted at 50-300 trees ha-1 depending on the pollarding and pruning regime.

Rustic coffee plantations, in which the natural forest's understory is cut to grow coffee bushes, but the forest canopy is trimmed (to minimize shadow) and enhanced by the planting (or favoring) of valuable species. Rustic coffee systems are densely forested and have a structure similar to the natural forest; yet, coffee yields are poor. Coffee Genetic Diversity Coffees originated in Africa. They are grouped into two Rubi aceae family genera, Coffea and Psilanthus, with each genus divided into two subgenera. More than 80 species in the subgenus Coffea have been identified, and recent collections of numerous new taxa in Cameroon and Congo show that the inventory is far from comprehensive. Commercial coffee production is primarily based on two species: Coffea arabica (66 percent of global output) and Coffea canephora (34%). C is related with higher cup quality. arabica, which has its principal center of diversity in the East African highlands; C. The Congo River basin lowlands are the principal center of diversification for canephora. C. Other Coffea species are diploid ($2n = 2x = 22$) and typically self-incompatible. Existing C. has genetic variety. Because of substantial decreases in both genetic diversity and polymorphism during domestication, a process promoted by its self-fertility, arabica plantations globally are quite low. The majority of commercial cultivars planted today (Caturra, Catuai, and Mondo novo) were chosen from two small genetic base populations that expanded in the early eighteenth century and were known as Typica and Bourbon cultivars [4].

Both cultivars show low polymorphism (Anthony et al. 2002) and are vulnerable to a variety of severe diseases, including coffee rust (Hemileiavastatrix). Genes from other diploid species (Coffea and certain Psilanthus) may fortunately be introduced into C. arabica by controlled hybridization (Couturon et al. 1998), and this has been a focus for commercial coffee genetic improvement (Carvalho 1988; Lashermes et al. 2000). Many current coffee farms rely heavily on a few introgression lines derived from natural interspecific hybrids: the Timor hybrid (C. arabica x C. cane phora) in Latin America and (C. arabica x C. liberica) in India. In Central America, selected lines include Costa Rica 95 and IHCAFE 90, as well as Variedad Colom 9. Conservation of Biodiversity in Neotropical Coffee Plantations 205 bia in Colombia, IAPAR 59 and Icatu in Brazil, Riuru 11 in Kenya, and Sln 12 in India.

The species employed in coffee shade canopies varies by country. Bananas, for example, are abundant in Nicaraguan coffee fields (various species and kinds of Musa, 60-240 stems per hectare), but less so in El Salvador and Costa Rica (10-37 stems per hectare). In Costa Rica and El Salvador, poeppigiana and various Inga species dominate the shade canopies. The majority of the species had less than five trees per hectare. Mexico has had similar effects. Inga species are routinely utilized in the shade layers of neo tropical coffee farms; in certain places (e.g., Honduras and El Salvador), most shade canopies feature a variety of three to six Inga species. Fruit, firewood, and ecological services such as water and nutrient management are provided by Inga species 9. Plant Diversity in Coffee Shade Canopies Farmers (especially smallholders) have long managed coffee shade canopies to diversify production, cope with unexpected family needs and pest outbreaks, buffer themselves against persistent low coffee prices, and reduce both weed competition and the need for expensive inorganic fertilizers. There is a wealth of literature on the design and management of helpful plants in coffee shadow canopies (for example, from India, Kenya, and Central and South America). For example, species valued only for shade account for 54% of all stems in Costa Rica but fewer than 12% in El Salvador and Nicaragua. Bananas are particularly significant in Nicaragua (50-57 percent of all stems), but not in El Salvador (only 5 percent of all stems); timber production is essential in all Central American nations, although firewood is not relevant in certain regions of Costa Rica [5].

The most prevalent motive for planting Inga spp. is for firewood. Provides shade on Salvadorian coffee fields, and wood trees are seen as a savings account that may be utilized when coffee prices are low or unforeseen family needs occur. Shade canopy products may be key sources of revenue for small coffee holders. In Peru and Guatemala, for example, goods from the shade canopy may account for 28 percent and 19 percent of the total value coming from the coffee crop, respectively. Firewood for family use (52%) and fruit sold (19%) or eaten by the family (15%) accounted for a large portion of the overall value gained from coffee plantations; firewood for sale (8%) and lumber for family use (5%) or sale (1%) are less significant. The majority of the fruit output is lost (53%), 28% is sold, and 19% is eaten by the family. Biodiversity Conservation in Neotropical Coffee Plantations. Relative abundance (stems per use group as a percentage of total stems at a location) and number of beneficial plant species (in parenthesis) under the shadow canopy of Central American coffee plantations

DISCUSSION

Ecotourism and rehabilitation are important components of tropical rainforest conservation. Reforestation and restoration are popular procedures in certain locations to attempt to enhance the density of tropical rainforests. Conservationists may learn more about how to effectively concentrate their efforts by engaging with the local people who live in and around the jungle. Rainforests are critical to global sustainability and biodiversity preservation. Despite differences in geography and plant and animal species, they are nevertheless significant globally for their wealth of natural resources and ecological services [6]. In order to correctly apply conservation measures, it is essential to examine the many species and biodiversity that occur throughout different rainforest types.

Ecotourism is the practice of leading tours of a particular location in order to educate the public about sometimes vulnerable habitats. It is a method that is one of the most important ways to save endangered habitat. Tourists and tour guides alike often give considerable contributions to conservation projects in the locations they visit, which contributes significantly to the preservation of the Amazon rainforest. Ecotourism and its effects on neighboring ecosystems are often discussed by experts with environmentalists, policymakers, and local politicians and leaders. Ecotourism may help to conserve and preserve biodiversity in tropical rainforests.

The Amazon rainforest in South America is one of the world's biggest and most thick jungles. Rainforests are vanishing all around the globe, but especially in Brazil. More than 153,000 square miles of Amazonian rainforest have been lost to deforestation since the 1980s. With freshly cleared land, Brazil has helped feed the world's expanding need for soybeans and meat. The Amazon is certainly one of the worlds largest and most biodiverse natural reserves, once a lush, green, and diverse basin that has since been cleared for soy crops and cattle ranches in many regions. Brazil has recently managed to significantly halt the loss of its rainforests, lowering the pace of deforestation by more than 80% [7].

Deforestation has been delayed to some extent by tougher land use rules and the establishment of protected areas. One of the major drivers to climate change in the Amazon area is greenhouse gas emissions, which are mostly the result of worrying rates of rainforest deforestation. Brazil's national government promotes greater social and economic planning in sectors that have major parallels with national programs. Brazil recognized this concern and accepted the challenge to cut its carbon emissions by 36-38 percent by 2020 in order to limit the quantity of gases spewed into the atmosphere. Carbon credits are another way that conservation has become the most economically advantageous alternative. Under the Kyoto Protocol, nations must cut carbon dioxide emissions by 5% below 1990 levels by 2012. Countries may satisfy their statutory emission reduction targets by offsetting part of their emissions in other ways. Countries may obtain credits for rainforest protection or replanting.

Some global corporations have openly announced that they would not buy items sourced from newly removed rainforest regions. Beef is often sourced from ranches situated on terrain that was formerly home to rainforests. It is important to protect the rainforest since it provides numerous resources for daily commodities such as rubber for tires and spices such as cinnamon, among other things. The rainforest is critical to the survival of life on Earth because the trees absorb carbon dioxide to produce oxygen. Deforestation and rainforest degradation account for almost a quarter of global greenhouse gas emissions [8]–[10].

CONCLUSION

Plantation owners, researchers, conservation groups, and local populations must work together to effectively conserve biodiversity in neo tropical plantations. Sharing information, best practices, and experiences may result in the creation and implementation of new conservation initiatives customized to local situations. Conserving biodiversity in neo tropical plantations requires a multifaceted strategy that takes into account ecological, social, and economic factors. It is feasible to offset the negative consequences of plantation agriculture and contribute to the conservation of biodiversity in these key tropical environments by applying sustainable practices, fostering habitat restoration, and implementing landscape-level planning.

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CHAPTER 17

POTENTIAL ROLE OF COMPLEX AGROFORESTS IN LANDSCAPE CONSERVATION

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ABSTRACT:

Multistate agroforestry systems, often known as complex agroforests, play an important role in landscape conservation. In these systems, numerous layers of trees, bushes, and crops are deliberately integrated into a diversified agroecosystem. Complex agroforests may support a diverse variety of plant and animal species. These systems' varied structure and composition provide niches and resources that promote biodiversity. Various tree species may offer nesting locations, food supplies, and shelter for animals such as birds, insects, and small mammals. Complex agroforests help to the protection of local species and the enhancement of overall biodiversity by establishing a mosaic of habitat types within the landscape.

KEYWORDS:

Cocoa Agroforests, Complex Agroforests, Natural Forests, Slash Bum, Tree Crops.

INTRODUCTION

Complex agroforests (or simply agroforests) are defined here as a type of agroforestry system with a forest-like structure and significant plant diversity in which useful tree and tree crop species achieve significantly greater density than in natural forests through planting, selection, and management of useful species from spontaneous regeneration. Agroforests are the most forest-like of all agroforestry systems in structure and appearance, and some of them may be mistaken for natural forests from a distance. Agroforests may be found in all tropical climates and are made up of a variety of tree crop types. Shade-tolerant subcanopy species such as cocoa (Theobroma cacao), tea (Camellia sinensis), and coffee or canopy species such as rubber (Hevea brasiliensis), damar (Shoreajavanica, a resin-producing dipterocarp species), or durian (Durio zibethinus, a highly valued fruit species of Southeast Asia) [1].

Species from both categories are often found in the same system. Of course, tree crops grown in complex agroforests can also be grown in other systems of varying complexity and diversity, ranging from monocultures like unshaded and clean-weeded plantations to simple associations of a few tree crops and shade trees (simple multi strata systems) to complex agroforests and extractively used natural forests. Subcanopy agroforests are often formed by selectively removing natural forest and under planting it with tree crops. Agroforests based on canopy trees, on the other hand, frequently depart from a clear-felled, slash-and-burn plot into which tree crops and food crops are planted together; these agroforests develop their forest structure through the association of different 227 tree crop species and selective tolerance of spontaneous regrowth, particularly of useful species. Thus, complex agroforests are the outcome of an increase in the density of already extant important species as well as the introduction of new value species into the framework of damaged primary or recovering secondary forests.

Agroforests differ from extractively utilized natural forests by having a much greater density of beneficial tree species and, as a result, restoring the original vegetation. The boundaries between "pure" extractivism, as practiced in natural forests, and complex agroforest production, on the other hand, are fluid. With the exception of oligarchic forests, which develop under specific conditions and may have a high value for extractivism, the typically high plant diversity of tropical forests implies that most species, including those sought by extractivists, usually occur at low densities. Extractivism includes efforts to promote the number and growth of these beneficial plant species in natural forests. In the Amazon forest, for example, extractively used natural rubber groves have traditionally been enriched through planting of rubber seeds or seedlings to counteract decline, and regeneration management appears to be an essential feature of the formation of Brazil nut (Bertholletiaexcelsa) groves. Enriching natural forests with useful tree species, particularly palms, in groves near campsites was the first form of agriculture in various forest places, including the northeastern Amazon and Indonesia, implying.

Relationships between distinct forms of multi strata agroforestry systems on schematic gradients of planned and unplanned variety, as well as the types of management that may be used to turn one system type into another. Extensification may entail a period of temporary abandonment. In certain areas, this sort of agroforest has traditionally predated slash-and-burn agriculture. Some tree-dominated home gardens have a large variety of plant species and a multilayered structure with agroforests. Home gardens are generally tiny, near to the house, and intensely kept. The association of various valuable trees, palms, shrubs, and herbaceous plants that occupy varied canopy locations results in their multilayered structure and tremendous variety. Their great variety of planted and domesticated species (planned diversity) and typically intense maintenance contrast with the large diversity of wild species (unplanned diversity) in typical agro forests, which results from wide management or even temporary abandonment. However, the line between home gardens and agroforests is not apparent; in fact, home gardens (or forest gardens if farther away from the home) might be seen as a possible endpoint of an agroforest intensification and domestication trajectory [2].

Complex agroforests are typically of exceptional significance for the conservation management of tropical forest landscapes due to their dominating tree cover, significant plant variety, structural complexity, and substantial management. Not only do they have a high diversity of plant and animal species on-site, but they also frequently border forest areas, buffering them from more intensively used agricultural surroundings and providing effective wildlife corridors. We explore the current and prospective contributions of complex agroforests to tropical biodiversity conservation in this chapter, including information on their geographic distribution, spatiotemporal relationship with other land uses, structural features, and species composition. We concentrate on cocoa and rubber agroforests since they have the greatest information. Agroforests play an essential role in tropical landscapes and farming systems, occupying enormous expanses of land and providing substantial sources of revenue for local people.

Because the importance of agroforests for the ecology of tropical landscapes and the livelihoods of their inhabitants has only recently been recognized, and because agroforests are often difficult to distinguish from secondary forest on aerial photographs and satellite images, quantitative data on their extent are only available for a few regions. The jungle rubber systems of Sumatra and Borneo's lowlands comprise 2.5-3 million acres, with rubber trees cultivated in a secondary forest habitat, whilst fruit-dominated forest gardens occupy hundreds of thousands of hectares. On Sumatra, complex agroforests occupy 229 hectares while damargardens cover around 50,000 hectares. These agroforests provide around 80% of the rubber, 95% of the fruits, and 80% of the dipterocarp resins produced in Indonesia, as well as significant quantities of bamboo, rattan, firewood, and medicinal. Rubber-based agroforests are estimated to employ at least 5 million people in Indonesia. However, more intense land use forms are putting strain on these wide land use systems; for example, rubber agroforests in lowland Sumatra are being replaced by monoculture plantations of oil palm and rubber.

In southern Cameroon, cocoa agro forests encompass 300,000 to 400,000 hectares, and 400,000 families rely on them for income and food. According to Somarriba et al., shade-grown coffee accounts for about 80% of the remaining forest cover in El Salvador. Later in this chapter, we will look at the distribution of cocoa agroforests in Bahia, Brazil (see also Figure 10.8). Agroforests may be important land uses in other regions of the globe, although statistics on their number and distribution are lacking. The earliest forms of agroforests, at least in some areas, appear to have been patches where the forest was enriched with useful tree species through the transfer of seeds and vegetative material from surrounding areas to places close to camp sites, resulting in islands of increased productivity in a forested landscape [3].

Agroforests are now typically found in more heavily human-modified landscapes, where they coexist with annual cropping systems such as lowland rice or upland slash-and-burn plots, home gardens, pastures, fallows, perennial crop plantations, and often remnants of primary and secondary forest. Agroforests are often seen in landscapes as a transitional zone between intensively exploited agricultural land and natural forest. Tree-based systems often occupy slope sites that are not appropriate for rice farming, as is common in Southeast Asia, where lowland rice is the major food crop. This gradient has also been described in the Lake Maninjau region of western Sumatra. The permanent soil cover provided by agroforests on mountain slopes is especially significant in this volcanic area for safeguarding settlements from landslides, to which these soils are particularly vulnerable.

Agroforests covered 22-63 percent of the agricultural area in three communities and provided for 26-80 percent of agricultural product revenue. In mountain settlements in northern Thailand, where miang tea for chewing is historically cultivated in an enormous "jungle tea" system, a comparable land use gradient has been documented. This strategy is based on the enrichment of hill evergreen forests with tea plants, which may be accompanied by other crops and, in certain cases, cat tle. As with earlier cases, a belt of jungle tea develops between valleys, where communities and home gardens are located, while natural forest grows at higher altitudes. Because tea is often grown inside the forest, and because some jungle tea regions return to forest when they are abandoned due to labor shortages, the shift from agroforests to natural forests is slow. In other situations, agroforests and other land uses coexist in a patchwork pattern. Land use mosaic of slash-and-burn plots and old (more than 50 years) rubber agroforests on the margins and slope of a plateau near the Tapajós River, a significant southern tributary of the Amazon.

This small-scale land use mosaic emerged on the plateau edge, which is defined by a thin strip of humus-rich soils between the plateau's ferralitic soils on one side and the riverbank's sandy soils on the other. Rubber agroforestry is also a prominent land use on sandy riverbanks where few other tree crops can be produced effectively. Cocoa agroforests occur as part of a patchwork of forest fragments, small plantations of banana and plantain, rice and maize fields, and pastures in the Talamancan region of Costa Rica, with individual cocoa plots averaging less than 2 ha and occupying a small percentage of the overall landscape but representing important sources of income for indigenous people. The value of agroforests ranges from lowlands to slopes (less than 300 m). The valleys' land is mostly devoted to bananas and plantains, with some agroforests and residual forest areas existent. Cocoa agroforests, on the other hand, are prevalent on the slopes and are often mixed with secondary woods, pastures, areas of forest regrowth, and annual crop fields. In Bahia, Brazil, a similar land use mosaic with cocoa agroforests occurs. The geographical relationship of agroforests with other land use types shows their appropriateness for the corresponding site circumstances (e.g., agroforests on slopes and lowland rice on valley bottoms), as well as their complementary function in the prevalent agricultural systems (Dove 1993). Slash-and-burn agriculture and agroforests offer the majority of basic foods such as rice, maize, or cassava, while the former provides financial revenue (e.g., coffee, cocoa, and rubber), fruits, timber, firewood, and medicinal goods. The role of agroforests in delivering such items is determined by their composition, the availability of alternative sources of wood and non-timber forest products, such as fallows and natural forest, and household demands [4].

In the Tapajós region, for example, leaves of the understory palm Attaleaspectabilis (curuá) used for roofs are an important byproduct of certain rubber agroforests, and the agroforests further away from villages are also used for hunting by many farmers. Trees with medicinal properties, such as Brazil nut (whose bark has medicinal properties), Himatan thus sucuuba, a common tree in rubber agroforests on sandy soils at the Tapa jós, or Alstoniaboonei and Voacangaafricana in Cameroon, may be retained or specifically planted. Plantains and palm fruits, such as peach palm (Bactris gasipaes) in Latin America and oil palm (Elaeisguineensis) in West Africa, may also be found in agroforests. They may function as investments; for example, in Sumatra, lumber or cinnamon trees may be harvested on occasion to generate higher quantities of cash. Agroforests, particularly in extensively over logged environments, may include important trees of species that have become uncommon in neighboring forests.

Because of low cocoa prices, Cedrela odorata and Cedrela odorata from cocoa agroforests in Bahia, Brazil, were recently sold for lumber, and the same has happened in Côte d'Ivoire (see Chapter 6, this book). Many farmers in Talamanca, Costa Rica, keep Cordia alliodora trees in their cocoa agro forests to supply lumber for home building. The relationship between agroforests and annual cropping systems is often not just geographical, but also temporal. In many situations, the creation of an agroforest follows a successional process, beginning with food crops and short-lived perennials and eventually replacing them with longer-lived trees. Food crops serve a variety of ecological and economic functions in this process, including sustaining the farmer during the first years when the tree crops are not yet producing, providing an early return on investment for clearing and weeding the plot, covering the soil, using the nutrients released by burning and clearing, and reducing weed growth. Rice, the major staple food crop in Indonesian jungle rubber systems, has the benefit of not being sensitive to fungal root rots, which helps to clean the ground.

Food crops, such as bananas and taro on West African and Central American cocoa and coffee estates, may also provide temporary shade for delicate tree crop seedlings. Although most agroforests are established following clearcutting or selective clearing of the original forest vegetation, some are, in principle, permanent systems that are continuously renovated in a small-scale pattern of replanting and spontaneous regeneration, whereas others undergo cycles of distinct management phases, including periodic replanting, which frequently involves a slash-and-burn phase. In cycle systems, replanting is often followed by a period of intensive management or abandonment, during which the productivity of the aged agroforest has declined but the land is not urgently required or resources for replanting (particularly labor) are in short supply. Such intensively maintained or abandoned agroforests ultimately transform into secondary forests, which may then be clear cut or replanted with tree crops. Thus, there are parallels between cyclic agroforests with tree crops and shifting cultivation systems based on annual crops in that phases of establishment, more intensive management, and extensive management or fallowing alternate on the same site (though in the case of agroforests, this can occur over several decades) and form mosaics of different land use phases within a landscape.

Annual and semi perennial food crops are easily incorporated into the regeneration phase of agroforests, and in certain situations, the current cyclic agroforest system originated from a shifting agriculture system by including tree crops into the conventional fallow. The Biodiversity of Agroforestry Systems cycle Agroforests the agroforest phase in certain cycle agroforests is a sort of long-term, environmentally enhanced fallow that alternates with slash-and-burn periods on the same plot of land. This sort of system is particularly developed in Indonesia, with the jungle rubber system serving as its most prominent. After the introduction of rubber about 1910, farmers in Sumatra and Borneo incorporated rubber trees into their fallow cycles, resulting in the jungle rubber system. Rubber seedlings are planted quickly after rice is sown in slash-and-burn fields. They grow alongside food crops and forest regrowth and may be tapped at about 10 years old, around 3 years later than rubber trees in weeded plantations [5].

Under the effect of intense competition, the density of rubber trees typically decreases from around 1,500-2,000 seedlings per hectare during planting time to 500-600 when tapping starts. With year-round tapping, strong pressure from fungal infections of the tapping panel, and root rots, their density gradually falls over the next several decades, however dead trees are partially replenished by spontaneous regeneration. When the number of productive trees in a plot no longer produces enough latex, the plot may be abandoned for a variable amount of time before being clear cut, burnt, and replanted to begin a new cycle. According to Gouyon et al., the density of rubber trees declined to roughly 200 trees after 40 years, at which time tapping became unprofitable; however, the age of replanting varies widely, and in certain situations the cycle may go up to 80 years.

The renovation period, during which there is no income from the rubber trees, is especially difficult for poor farmers who own only a small rubber area; therefore, farmers can extend the productive life of their agroforests by transplanting rubber seedlings into gaps that have formed due to the mortality of older trees, a technique known locally as sisipan. With this method, a complete transition from a cyclic to a permanent system is hampered by the light-demanding nature of rubber trees and, as a result, slow growth of seedlings under the canopy of an existing stand (Vincent et al. in press), so most stands are eventually renovated by slashing and burning. Another long-term kind of rubber agroforest has been documented from the middle Amazon area of the lower TapajósRiver. These agroforests are likewise produced by a slash-and-burn phase, following which rubber seeds or seedlings are put into the first annual crop, commonly cassava (Manihot esculenta), and grow into agroforests after 10 years. Some years, farmers limit weeding to circulation pathways between the rubber plants and allow forest regrowth to occur in the other regions. These systems are similar to Indonesian jungle rubber in many ways; however, they are not meant to be rotational and are considered as permanent by many farmers, despite the fact that their actual lifespan may be limited by the numerous dry season fires.

Indeed, 50-year-old trees are often still in excellent health, and some have been productive for three generations of rubber tappers and may be almost a century old. The often better health of old rubber trees at Tapajós compared to those in Indonesian jungle rubber systems is due to a tradition of abandoning the groves during times of low rubber prices (which means that few if any agroforests have been tapped for their entire life), lower pressure from fungal root rots, and a specific tapping technique that protects the trees from fungal infection. Little is known about the regeneration of these systems, but for the reasons stated above, it is probable that they should be regarded long-term cyclic rather than permanent systems. Unfortunately, no comparative studies of the biomass, structural complexity, and diversity of various age Amazonian and Indonesian rubber agroforests are available to assess the consequences of these regional and management variables [6].

Benzoin (Styrax paralleloneurum) agroforests are an unusual kind of cyclical canopy tree-based agroforest that does not undergo a slash-and-burn phase. They are found in the highlands of North Sumatra, where Garca-Fernández et al. evaluated silvicultural practices and related levels of plant variety in this environment. The establishment process begins with the removal of small to medium-sized trees in secondary or primary forest, followed by the planting of 400 benzoin seedlings per hectare in the understory. Big canopy trees are girdled two years later to eliminate shadow. Tapping of benzoin trees begins at the age of seven years, and by the age of twelve, all trees have been tapped. A plot is generally abandoned after roughly 50 years of tapping because to decreased yield and progressively reverts to forest. These benzoin agroforests are only found in very recent settlements (four to eight generations) in northern Sumatra, and the system itself is likely to be less than 150 years old.

Early Dutch colonial accounts describe benzoin cultivation in the Palembang region of southern Sumatra and the northern Sumatran lowlands. Benzoin (possibly Styrax benzoin, a distinct species considered to be less shade tolerant) was introduced following land clearance and rice cultivation at the time, in a manner similar to how rubber trees are established now in rubber agroforests. In the 1920s and 1930s, rubber mostly supplanted benzoin farming in Sumatra's lowlands, although S. In North Sumatra, between 500 and 800 meters above sea level, benzoin is still farmed intermittently in combination with rubber and sometimes cocoa. Some benzoin (S. paralleloneurum) gar is found at higher altitudes. Because benzoin resin costs were low in the 1970s, coffee- and cinnamon-based systems substituted dens in the Biodiversity of Agroforestry Systems. The instance of Sumatra's benzoin gardens exemplifies the dynamic character of agroforests based on globally traded commodities, which may be abandoned or transformed into alternative land uses in reaction to swings in worldwide market values.

Cyclic agroforests were also the traditional method of cocoa cultivation used by indigenous forest producers in Côte d'Ivoire. Cocoa trees were planted alongside food crops in thinned forest and cultivated extensively under the dense shade of forest remnant trees for approximately 35 years, after which the groves were abandoned and reverted to forest, where cocoa could be conveniently replanted with the same method after some years. This approach was essentially a kind of shifting cultivation tailored to the requirements of a perennial crop that was easy to replace in a forest setting. It was gradually displaced in Côte d'Ivoire from the 1960s by more intensive, sometimes practically monoculture practices, however shaded cocoa agroforests may still be found in this nation today. Other nations have established and continue to practice more permanent kinds of cocoa farming in complex agro forests, such Cameroon, Nigeria, and Bahia, Brazil.

Permanent Agroforests as previously noted, certain cyclic agroforest types may live for many decades before being rebuilt, particularly if land demand is low and resources for replanting are few (e.g., during periods of low commodity prices). As a result, the distinction between permanent and cyclic agroforest types must take into account the method of regeneration, which in permanent agroforests is a continuous, small-scale process based on either planting or natural regeneration in gaps rather than a distinct (though rare) replanting campaign that entails disruption of the system on a large (plot) scale. The damar gardens of southern Sumatra, which are similarly formed on slash-and-burn fields by planting damar seedlings alongside fruit trees into a rice crop interpolated with coffee and pepper, are an excellent example of permanent agroforests. These agroforests are continuously renewed, mostly by natural regeneration with little interruption to the forest canopy.

Another example from Sumatra shows how farmers may select between several crop-growing alternatives and the factors that might contribute to the formation of permanent agroforests. Farmers cultivate cinnamon in a variety of agroforestry systems in the Kerinci-Seblat National Park area, some of which are basic cycle systems and may not be legitimately described as agroforests, while others of which are permanent agroforests. The primary method is cyclic, with annual harvests cultivated for around two years between new or resprouting (coppiced) coffee plants. Following the yearly cropping period, cinnamon trees are placed into the system, allowing for two or three coffee harvests before their canopy closes. During this stage, the plots are overrun by spontaneous vegetation, which mostly comprises of common weeds rather than forest species. Cinnamon trees are typically harvested every 6-12 years, and the cycle begins again (Burgers and William 2000). Farmers with enough acreage often choose a longer development period for cinnamon trees (up to 25 years) since bark quality rises with tree age, and therefore manage a collection of plots of varying ages [7].

Aside from this basic cycle system, permanent cinnamon agroforests may be found in the immediate vicinity of Lake Kerinci, where irrigated rice fields are sparse and arable hill lands are constrained by the steep topography. Many indigenous fruit trees and wood species are grown in these agroforests alongside cinnamon, coffee, and rubber. Their structural complexity and accompanying plant variety vary, but are much greater than in the cyclic system: in a single hamlet, a hundred valuable woody and herbaceous plant species have been found. Permanent agroforests are said to have arisen in reaction to land scarcity; beyond a certain amount of arable land, lowering the rotation cycle or plot size is no longer sustainable, and permanent agroforests seem to be a better alternative.

The diminished productivity of the cinnamon under shade is compensated for in these systems by the production of the surrounding fruit and wood trees. Although all agroforests, by definition, include several vegetation strata and a number of planted or spontaneous tree and other plant species, their structure and plant species composition differ significantly from one type of agroforest to the next, determining their value as habitat and biological corridors for various types of wildlife and their ability to physically protect and buffer forested areas. In this section, we discuss the factors that influence the vegetation structure and composition of floral and faunal communities in a variety of agroforests, with a focus on the crop and tree species planted, the method of establishment and subsequent management, and (to a lesser extent) their position in the landscape. In terms of vegetation form and management, a major contrast in agroforests is made between those based on canopy trees, such as rubber, damar, and durian, and those based on understory tree crops, such as cocoa, coffee, and tea.

The Floral Composition of Agroforests Based on Canopy Trees Studies in Sumatra show that the vegetation structure of old jungle rubber is very similar to that of secondary forest, with a closed canopy 20-25 m high dominated by rubber trees and a dense understory of shrubs and small trees, including many canopy tree seedlings. Rubber plants have taken the place of pioneer trees in these agroforests. In productive rubber agroforests, tree species richness may reach 70 species per hectare for trees larger than 10 cm in stem diameter at breast height. Because of the dominance of rubber trees in agroforests, this is likely smaller than the species richness of secondary forests of same age. Several studies suggest that the diversity of tree species in rubber agroforests is adversely linked with the density of rubber trees, indicating competition for light and soil resources between the dominating rubber trees and other species. Rubber dominance, however, reduces as the plots age and rubber trees die, enabling other plant species to sprout and develop into the top layers [8].

The tendency of increased species richness with rising age and decreasing density of rubber trees in the understory of rubber agroforests has also been shown. As a result, while the conservation value of rubber agroforests increases with age, rubber production decreases, increasing the likelihood that the plot will be converted into a less diverse land use (e.g., an oil palm plantation) or rejuvenated through a slash-and-burn phase. This situation is to some extent representative of other cyclical agroforest types, such as benzoin agroforests, where there is a strong positive correlation between plant diversity and plot age and a clear trade-off between agroforest productivity which is tightly correlated to benzoin tree density and plant diversity.

These discoveries have sparked interest in the possibility of extending the productive life of rubber agroforests by ensuring a sufficient number of productive rubber trees per hectare. Although this would extend the rubber trees' dominance of the systems, their conservation potential would improve since only mature agroforests have the breadth of niches that allow for major colonization by late-successional plant species. Furthermore, when disturbance frequency reduces, a greater proportion of the landscape will be preserved under ancient agroforest cover, increasing landscape connectivity for forest dependent species. The damar and durian agroforests of Sumatra, which are smaller in size than the rubber agroforests, also have conservation potential. Thiollay discovered that damar agroforests were structurally the most similar to primary forest in Sumatra, with an often continuous canopy of 35-45 m height composed of at least 39 tree species larger than 20 cm dbh. 56-80 percent of the 245-500 trees per hectare were damars, which were largely connected with fruit trees. Rubber agroforests have a lower canopy (20-30 m) and a thicker understory than damar agroforests. Rubber trees made about 65 percent of the 750 trees per hectare.

At 30-45 m in height, durian agroforests had a more open canopy comprised of durian and other fruit and timber trees (350 trees per hectare) and a lower layer of smaller trees such as clove (Syzygiumaromaticum), cinnamon, nutmeg (Myristica fragrans), and coffee. The findings reported in Table 10.1 reveal that, whereas damar agroforests are architecturally comparable to primary forests, their tree species richness is substantially lower. Despite the larger basal area and older age of the damar forests, their species richness seems to be much lower than that of rubber agroforests. This is due to the fact that damar agroforests are more actively maintained than rubber agroforests, and other species, particularly fruit trees, are systematically interplanted with damar trees. The most coveted and often planted tree species are langsat (Lansiumdomesticum, in the midcanopy), durian, and petai (Parkia speciosa, in the high canopy).

Selection among spontaneously renewing plants, as well as removal of undesirable species, is more systematic in damar than in rubber agroforests. This more intense management of damar agroforests is most likely due to more restricted access to land along the coastal strip in southern Sumatra, where these agroforests are abundant, compared to central Sumatra and Kalimantan, where rubber agroforestry is practiced. Another aspect might be the perceived permanent character of damar agroforests (as opposed to the cycle nature of rubber agroforests), which drives attempts to preserve late-arriving or -producing economically valuable species at the price of spontaneous growth. Rubber groves in the center Amazon's Tapajós area are often char acterized by reducing maintenance (particularly weeding) intensity [9].

Height profiles of mean leaf cover in Sumatran main forest and agroforests based on rubber, damar, and durian. Agroforests are adequately defined as those occurring at larger distances from homesteads, and particularly those happening at greater distances from settlements. In contrast, groves near settlements are frequently more carefully maintained due to fear of snakes and fire, as well as a general desire for well-kept groves. Rubber tree density (more than 10 cm dbh) ranged from 100 to 700 trees per hectare in an inventory of eight agroforests ranging in age from 23 to more than 50 years and that of other trees ranged from 225 to 875 stems per hectare (more than 5 cm dbh; 0-575 stems per hectare for dbh more than 10 cm). The other five plots were near (past) homesteads and had some planted fruit trees in the midstory. Despite a downward tendency in rubber tree densities with age, groves 50 years or older showed a high density of rubber trees (100-425 per hectare), many of which were huge and in excellent condition.

The two groves with the highest tree species richness (23 and 27 species, respectively) appeared to have been abandoned for some time at an early age, resulting in high mortality of the rubber trees, allowing other species to develop, and the other directly neighbored primary forest as a seed source. Canopy Tree-Based Agroforest Faunal Communities Much less information is known on the faunal communities of canopy tree-based agroforests than on their floral composition and structure. Salafsky discovered that the primates most commonly encountered in agro forests were species adapted to disturbed forest, such as leaf monkeys (Presbytis rubicunda) and gibbons (Hylobates agilis), rather than taxa that prefer primary forest, such as orangutans (Pongo pygmaeus), or open agricultural areas, such as macaques (Macaca spp.). The presence of extremely endangered animals like as rhinoceros (Dicerorhinussumatrensis) and tigers (Panthera tigris) in damar agroforests is mentioned by the same authors, indicating that these systems may act as corridors and temporary habitat for these species. Thiollay discovered lower bird species richness and variety in agroforests than in primary forest, as well as low coefficients of similarity between agroforest and forest ecosystems in Sumatra. However, the species richness of agroforests was substantially greater than that of monoculture plantations of tree crops such as rubber, oil palm, and coconut palm in the same locations. In reality, early surveys revealed so few species in the monocultures that no thorough data were acquired.

Of the 216 bird species detected, 102 (47%) were present in the forest but absent or much less numerous in the agroforests, whereas 43 (20%) were found solely in the agroforests or significantly more common in the agroforests than in the forest. Seventy-one species exhibited no discernible pattern between environments. Small frugivores, foliage insectivores, and nectarivores, which are commonly linked with gaps, were more prevalent in agroforests than in forest. The bird communities of the rubber agroforests were the most comparable to those of the main forest, while those of the durian gardens were the most distinct and had the fewest forest specialists. Bird species linked with open woods and cultivated regions rose in relative abundance from forest to damar and durian agroforests, with rubber agroforests serving as an intermediary [10].

Reduced tree height, structural complexity, and diversity of food supplies, as well as hunting, human disturbance, and competition from dominant bird and animal species, explained the reduced species richness in agroforests. Although there is no quantitative data on the faunal communities of Amazonian rubber agroforests, it is extremely probable that they are also significantly impacted by hunting. 50 percent of 51 rubber agroforest owners questioned in the Tapajós National Forest buffer zone hunted in their agroforests, and another 6 percent did not hunt but knew that others did. Frequently reported game animals included armadillo (Dasypus sp.), paca (Agouti paca), brocket deer (Mazama sp.), agouti (Dasyprocta agouti), and collared peccaries (Tayassu tajacu), which are season arily drawn by falling fruits and rubber seeds. Macaws (Ara chloroptera) enter agroforests at the start of the dry season to eat on immature rubber seeds and are sought for food with slingshots while perched in tree canopies.

Although hunting in agroforests reduces their value as faunal habitat, it may also discourage farmers from hunting in the forest itself, and the net cost or benefit of rubber agroforestry along forest boundaries for forest fauna warrants further investigation. In conclusion, these studies reveal that the forest-like character and high tree variety of agroforests based on canopy tree crops offer important habitat and resources for animals, although less so than the original forest. The majority of these agroforests have a closed canopy, which may be highly dominated by a single species, as well as a dense understory and mid-story of canopy tree regeneration and other spontaneous regrowth. When growing smaller fruit trees in the understory, the canopy may need to be maintained more open to allow enough light entrance into the lower layers. Although the canopies of the majority of the agroforests described previously were dominated by a single tree crop species, they also contained a significant number of spontaneous primary and secondary forest trees that had developed from seeds or rootstocks of the previous forest vegetation and had been tolerated or, in the case of useful species, even favored during weeding. The presence of numerous primary forest species shows that the microclimate in the agroforest understory is conducive to their recovery and that abandoned agroforests may eventually revert to primary forest vegetation groups.

Although these agroforests provide habitat for a variety of fauna species, it is clear that the faunal communities of even the most extensive Indonesian agroforests differ significantly from those of undisturbed forest and may often be more similar to those of disturbed forests with a high density of gap-associated species. There are no statistics on Amazonian rubber agroforests, however their faunal communities are 10. The tiny size of many agroforests, which are often immersed in a mosaic of slash-and-burn plots and fallows, their proximity to main forest, and heavy hunting pressure are all likely to have an impact. Structure and Floral Composition of Agroforests Based on Understory Tree Crops Agroforests based on understory crops differ from canopy trees in that they have a more open canopy that is managed to allow adequate light transmission, as well as an understory and midstory dominated by planted tree crops rather than spontaneous regeneration. The cabruca chocolate fields in Bahia, Brazil, are an example of such agroforests. According to Johns (1999), the conventional method of constructing cabruca plantations was to remove around one-third of the native forest canopy trees, frequently the biggest, and replace them with cocoa plants. Most farmers believe a shade canopy of 50-60% to be required for maintaining a humid microclimate, keeping soil fertility, limiting weed development and insect assault, and protecting pollinator species.

In contrast, Alves reported cabruca farmers removing 90 percent of the trees (with densities of 65 trees per hectare in cabruca, compared to 742 trees per hectare in forest), the entire mid layer (replacing it with cocoa trees), and 83 percent of the for est herb layer. Furthermore, the majority of vines were removed from cabruca systems, and spontaneous renewal of canopy trees was often replaced with planted legume or other beneficial plants. Nonetheless, a 1964 study of 61 cabruca farms in southern Bahia found a density of 76 shade trees per hectare, representing 171 species in total. Many cabruca agroforests in Bahia may therefore serve as major genetic reservoirs, including valuable hardwood species that would otherwise be heavily logged from natural forests in the area. This potential is jeopardized, however, by the suppression of shade tree regrowth during routine system management, which includes periodic slashing of the undergrowth or even chemical weeding. In portions of the West African rainforest zone, under planting of deliberately opened forest is also a traditional method of cocoa and coffee planting. However, the extent of forest clearance varies greatly among locations and ethnic groups, having considerable implications for the structure and, undoubtedly, variety of the emerging agroforest communities.

De Rouw examined the techniques of native Oubi and immigrant Baoulé farmers from the savanna zone in constructing coffee and cocoa plantations in southern Côte d'Ivoire. Because of its sturdy wood or huge buttresses, the native Oubi leave two or three great forest trees per hectare while clearing a forest area, as well as a varied number of smaller. Agroforestry System Biodiversity refers to trees that are not damaging to agriculture, are difficult to down, generate beneficial seeds, or serve religious purposes. This results in stands of up to 19 forest trees with a height of more than 15 m per hectare. After clearing the undergrowth, they sow rice and eventually plant coffee and cocoa seedlings as the food crop matures. The shade canopy of a typical cabruca plot in Bahia, Brazil (top) and lateral view (bottom).

Although no forest trees are accepted, some individuals live due to thick or wet bark or a shortage of fuel. The Baoulé plant yam (Dioscorea sp.) and tree crop seedlings after burning and thorough soil preparation to make mounts. Whereas the original Oubi choose suitable species from spontaneous regrowth to shade the young tree crops, the Baoulé mostly employ planted food crops (taro, bananas), as well as some fruit trees. As a result of these disparities, Oubi plantations have more forest trees of intermediate height than Baoulé plantations, as well as some extremely big trees (greater than 40 m) that are missing from plantations developed by immigrants.

Different plantation establishment strategies and more intensive plantation management result in earlier and higher per-hectare cocoa yields for immigrant farmers, but lower native tree densities and diversity when compared to forest people, who typically have more forest area at their disposal and prefer larger, less intensively managed, and thus more diverse plantations (see Chapter 6, this volume, for a discussion of the historical and s The selection and active planting of suitable shade tree species may result in significant increases in the density of particular species in cocoa farms when compared to the rest of the landscape. In southern Cameroon, the density of African plum trees (Dacryodes edulis) was ten times greater in cocoa farms than elsewhere in the landscape, while that of the wood species limba (Terminalia superba) and iroko (Miliciaexcelsa) was three times higher.

In a study of 300 farmers from 21 communities in the same area, 93 percent planted fruit trees and 81 percent planted wood species in their plantations. The most commonly used fruit tree species was African plum, which was planted by 83 percent of all cocoa farmers and occurred in cocoa plantations at a density of 17 trees per hectare, and the most commonly used timber species were limba, obeche (Triplochiton scleroxylon), iroko, fuma (Ceiba pentandra), and Ficus mucuso (Sonwa et al. 2000a). Agroforest Faunal Communities Based on Understory Tree Crops Little is known about the faunal communities in shaded cocoa habitats. Alves discovered that faunal groups that rely on the understory, such as specialized understory bird species, big frugivores, and large terrestrial mammals, were underrepresented or absent from cocoa ecosystems in a comparison of cabruca and forest plots in Bahia, Brazil. Bird family richness in cabruca cocoa and forest was positively correlated with vegetation variables describing the height, density, and cover of the herb layer, midstory density, canopy cover, and structural complexity of the vegetation, i.e. variables that are significantly altered by cocoa plantation establishment and management.

Reitsma et al. discovered a 17 percent higher abundance and species richness in cocoa than in forest in a study of bird communities in abandoned and managed cocoa agroforests and natural forest in Talamanca, Costa Rica (130, 131, and 144 species in forest, abandoned cocoa, and managed cocoa, respectively). Despite the fact that cocoa plantations clearly provided habitat for a substantial number of forest-dependent species, cocoa plantations had fewer forest specialist species and more agricultural generalist species than forest. Specialist species detected in forest but not cocoa plots were largely understory insectivores, which are not suited to an understory dominated by cocoa trees, as in Alves' Brazilian research. The number of forest specialist bird species per observation site rose with the density and variety of canopy tree species, indicating that adequate shade management might boost the conservation value of cacao ecosystems even more. Distance to forest, on the other hand, was not substantially associated to the number of forest specialists detected, which the authors ascribed to the region's diverse mosaic of habitat types. Mammal populations in cocoa agroforests may be extremely varied as well.

DISCUSSION

A research conducted in Talamanca, Costa Rica, discovered that the species richness and relative abundance of ten species. 249 big animals (as recorded by mammal tracks) were found in cocoa agroforests and neighboring primary forest. A total of 10 mammal species were detected in each habitat in a study of five plots of agroforests and forest, and overall mammal abundances were comparable for all species with the exception of agoutis (Dasyprocta punctata), which was more numerous in forest. Locals reported 22 animal species typically spotted in cocoa agroforests, compared to 27 species in forest. The presence of two endangered cat species in the cocoa agroforests, the jaguarundi (Felis yagouaroundi) and the puma (Felis concolor), attests to their potential conservation importance. The high densities and diversity of mammals in these agroforests are likely due to their forest-like structure, as well as the abundance of forest cover in the areas surrounding these small agroforest patches, as well as the ability of many mammal species to move through different habitat types within a landscape.

More research is required to discover how dependent these animals are on the existence of natural forest, that is, if they can live and breed in settings with agroforests but few or no forest remains. According to preliminary Talamanca data, cocoa agroforests in an agricultural context have a far lower fauna in terms of both quality and quantity than agroforests immersed in a wooded landscape. Furthermore, the Talamancan cocoa agro forests' potential to maintain animal populations is strongly dependent on hunting rules and local people's conservation views.

Currently, practically all big animal and bird species that frequent these agroforests are hunted, reducing their conservation potential. The understory of cocoa groves, as it relates to age, stand structure, and management, has a significant impact on small mammal groups.

Barnett et al. discovered that biomass and diversity of small mammals were positively correlated with the density of the understory vegetation in a study of cocoa groves shaded primarily by the native oil palm in Sierra Leone, which was highest in either very young groves or old, degrading cocoa groves and lowest in a plot where the ground vegetation had recently been slashed. In a 10-year-old grove with poor ground cover, 50% of the rodents were trapped on 4% of the area with thick ground cover, suggesting that regions removed from management within agricultural systems may benefit particular species. The fauna of the cocoa groves included both savanna species, which were also found in agricultural field rodent fauna, and forest species, but the latter were edge and gap specialists rather than forest interior species. These findings supported previous research by Jeffrey on the impact of forest conversion into cocoa plantations on rodent groups in Ghana.

When she compared primary forest to new (1-2 years cleared and planted with food crops), immature (6-8 years cleared and planted with cocoa trees), and mature (about 20 years under cocoa) cocoa farms, she discovered that trap success (a proxy for small mammal density) increased initially when forest was cleared for planting establishment but then decreased in mature cocoa, which typically has little live ground cover. Rodent species richness rose from 6 species in the forest to 8 and 10 species in fresh clearings and immature cocoa, respectively, before falling back to 6 species in mature cocoa. Despite the general rise in species, two (Hybomystrivirgatus and Malacomysedwardsi) essentially vanished after clearing, and one (Hylomyscus stella) was less numerous. All three species were discovered on land that had been left fallow for 2-8 years, highlighting the critical function that areas set aside for substantial (or no) management within agricultural landscapes may play for species that are not suited to controlled ecosystems. According to these studies, the conversion of native forest into shaded cocoa plantations involves a significant modification of the original ecosystem, particularly the opening of the canopy, the replacement of most of the mid story by tree crops, the enrichment of the upper and mid canopy with a selection of fruit and timber tree species, and the suppression of ground vegetation by litter and shade of the tree crops, as well as mechanical or, in some cases, chemical weeding (Rice and Green).

These changes in the forest ecosystem must have an impact on faunal populations, which are affected by the severity of management, the availability of neighboring intact forest as a population source, and hunting pressure, among other variables. Although no direct comparisons seem to be available, one would anticipate wildlife to meet circumstances more akin to those seen in natural forest in a complex agroforest based on canopy tree crops such as rubber or damar than in a shaded cocoa or coffee plantation. However, the extent to which these structural and compositional changes influence distinct species of fauna requires more investigation. Complex Agroforests' Potential Role in Landscape Conservation Strategies In addition to providing habitat for a large number of plant and animal species, including many forest-dependent species, complex agroforests can make an important contribution to regional biodiversity conservation

Increasing landscape connectedness, decreasing edge impacts, and improving local microclimates. Whereas the preceding part focused on the biodiversity of agroforests, this section explores the capacity of complex agroforests to enhance biodiversity conservation in natural forests. These services, by definition, become inefficient when a forest disappears from a landscape, while agroforests may continue to play a significant role. Cabruca cocoa, forest, and other land uses are distributed across southern Bahia, Brazil. The inset map depicts the previous expanse of the Atlantic rainforest for the survival of species that are not entirely reliant on natural forests, and may become the final refuge for forest-dependent species. As previously shown, historical land use patterns in various tropical areas have resulted in landscapes with complex agroforests bridging agricultural or grazing land and natural forest. In some areas, remaining woods have been reduced to tiny patches inside an agricultural matrix, where agroforests are mixed with pasture and annual and perennial crops. In Bahia, Brazil, for example, the few remnant sections of Atlantic rainforest are interspersed with extensive regions occupied by grassland or cabruca cocoa.

Cabruca cocoa has lately gained popularity because to its capacity to house endangered species such as the golden-headed lion tamarin (Leontopithecuschrysomelis) and the newly discovered pink-legged graveteiro. There is evidence that these rare species rely on forest patches and only use cocoa systems as secondary habitat, implying that one important role of these agroforests within a land use mosaic may be to increase available area for forest fauna and to provide wildlife corridors between forest fragments that would otherwise be separated by pastures or other open agricultural areas. Observations of large endangered mammal species such as rhinoceros, tiger, and siamang in Sumatran damar gardens and tracks of endangered cat species on cocoa farms in Tala manca demonstrate the value of these agroforests as secondary habitat for forest fauna and their potential for use as buffer zones and landscape corridors. The agroforests' constant tree cover is anticipated to assist such animal migrations between forest and agroforest environments. As a result, cocoa agroforests in Talamanca, which is part of the Mesoamerican Biological Corridor, are being promoted as buffer zones and forest corridors.

Agroforests may also reduce edge effects that occur when forest borders on open agricultural fields or pasture, decreasing mortality of forest trees that are not adapted to the drier microclimate and gusty winds to which they are exposed near open forest edges. High tree mortality along edges, exacerbated by vine incursions and fire, may result in the diminishing and eventual collapse of isolated forest remnants and reserves in agricultural landscapes. Edge-related tree mortality was lower where forest margins bordered on tall secondary regrowth than where they bordered on open cow pasture in long-term observations on forest fragment dynamics in the middle Amazo. Because complex agroforests, particularly those based on canopy tree crops, are structurally comparable to secondary forests, the same protective benefits may be predicted if forest borders are buffered by a factor of ten. Instead of being exposed to open pastures or agricultural fields, Complex Agroforests 253 agroforests.

As a result, properly located agroforests may aid in the preservation of forest boundaries and residual forest patches in landscapes that include agricultural and forest environments. In certain tropical environments, as previously shown, traditional agroforests divide for est from more intensively exploited agriculture land. Fires, which may be started in agricultural and grazing regions for land clearance or other management goals but may encroach on wooded areas, are one of the most serious hazards to tropical forests surrounding populated areas. Most rain forest trees are very vulnerable to low-intensity fire, and increased leaf fall and tree death after a fire likely to enhance the chance of future fires in a positive feedback loop. Such hazards are mitigated when agroforests form the forest's boundaries because farmers take care to keep fires under control in order to prevent losing important tree crops. This may be particularly true if agroforests based on fire-sensitive tree crops like rubber and slash-and-burn plots create a small-scale mosaic, as in areas of the Amazon's Tapajós region. Farmers in this fire-prone area should build narrow firebreaks by clearing trash from the soil to prevent low-intensity surface fires from entering their agroforests.

Farmers in northern Thailand, according to Preechapanya, avoid forest fires and seldom conduct shifting cultivation in water sheds used for cultivating jungle tea. They speculate that jungle tea may have served as a buffer zone, preventing shifting cultivation from spreading into the forest. Without jungle tea, the forest is often destroyed due to shifting agriculture and fire. However, recent decreases in management intensity due to out-migration of young males, as well as reductions in usage of cattle grazing systems, seem to have resulted in more frequent fires, and the buffer role may be gradually lost. Griffith observed that when wildfires raged through Guatemala's Petén region in 1998, affecting the Maya Biosphere Reserve, some agroforest farms in the park's buffer zone may have served as critical refuges for forest fauna because their owners actively protected them from fire and retained some of the area's only intact vegetation. Agroforests in buffer zones of legally protected forests may also serve to lessen numerous demands on forest resources from the neighboring population.

In the region bordering the Kerinci-Seblat National Park in western villager's gradually clear community forest and, to a lesser extent, Park Forest to establish agro forests with a variety of fruit and other useful trees on the transition between village and park land. Villagers may own rice fields, mixed gardens, or both, and they may harvest a variety of Park Forest goods including as lumber, fuelwood, rattan, incense, palm fiber, game, and fish. Murniati et al. discovered that farmers who owned just rice fields had the greatest reliance on forest resources, whereas those who held had a far reduced reliance. The Biodiversity of Agroforestry Systems included rice fields and agroforests, with the former providing food and the latter providing income, lumber, and fuelwood. These families also had the most evenly distributed work throughout the year and minimal free time for gathering forest goods.

Poor farmers were the most reliant on forest resources in general, implying that diversifying agricultural methods coupled with revenue creation via expanded use of agroforests will lessen reliance on the national park. Gathering wood and other forest products in agroforests rather than faraway woods may also significantly save transportation time and effort, particularly for women, which may then be allocated to other household activities. Conclusions Complex agroforests are the most forest-like of all agroforestry systems and have the most promise for helping to conserve biodiversity in tropical forest environments. Thiol Lang concluded from his research on Sumatran agroforests that "traditional agroforests are one of the best possible compromises between biodiversity conservation and the economic and sustainable use of natural resources". Similarly, traditional agroforests may be found across the tropics. Although there are no direct comparisons of the species richness of agroforests based on canopy or understory tree crops, we believe that the former may have a greater potential to host forest-dependent understory species than the latter due to their closed canopy and greater tolerance of spontaneous regeneration in the understory and mid story.

Agroforests based on understory tree crops, on the other hand, may offer a better potential for the conservation of canopy trees and creatures that rely on various forest canopies. Because both strata are extensively controlled, the conservation value of multi strata systems comprising of both canopy and understory tree crops, such as cocoa covered by rubber or coconut trees, is unquestionably considerably lower. The presence of many forest-dependent species in complex agroforests, as well as the species richness of flora and fauna, clearly justify efforts to conserve and promote these traditional agroecosystems, both in buffer zones of protected areas and in largely deforested regions, where complex agroforests may offer some of the last habitats for forest-dependent flora and fauna and greatly enhance landscape connectivity. However, the data presented show that, despite their exceptional biodiversity for agricultural systems and the presence of threatened fauna species on occasion, complex agroforests are poor substitutes for natural forests because many forest-dependent species are absent or underrepresented.

The availability of intact forest clearly influences the degree to which complex agroforests are required as partial replacements for natural forest in landscape conservation schemes. For instance, in portions of Sumatra's lowlands. There is relatively little remaining primary forest, and secondary forests older than around 20 years are predominantly jungle rubber. The habitat quality of these agroforests for native fauna and plants is thus crucial at this location for landscape-scale biodiversity conservation. The scenario may be considerably different in a big forest reserve's buffer zone, such as the Amazon, which still has enormous tracts of primary forest. In this case, the importance of an agroforest as a refuge for wild species may be much less significant for regional biodiversity conservation than its role in protecting forest borders from fire and connecting forest remnants in increasingly fragmented environments.

Many situations are intermediate, such as small-scale mosaics of forest patches and agricultural areas interspersed with complex agroforests in Central America and Bahia, Brazil, where complex agroforests may play an important role as habitats in their own right as well as in the protection and linkage of remnant forests. In conclusion, when there is still a lot of forest remaining, agroforests may play the most significant role in protecting the forest, which in turn conserves biodiversity; where intact forest is uncommon, complex agroforests are frequently the final accessible habitats for forest-dependent species and flora. The presence of many primary forest species in complex agroforests suggests that they are a good starting point for forest regeneration if they have been abandoned due to factors such as low productivity or consistently low commodity prices—unless, of course, they are converted to another, less diverse land use.

Many indigenous agroforests in the tropics are under danger from rising demands to intensify or modernize land use, such as the Sumatran lowlands' jungle rubber systems, which are gradually being lost to expanding oil palm and monoculture rubber plantations. Others, like the Amazonian rubber agroforests, which were abandoned and some converted into slash-and-burn fields or pastures 10-20 years ago but now enjoy increased product prices and government support, and cocoa ecosystems, which also experienced price slumps in the late 1980s and early 1990s but now enjoy higher commodity prices. It is worth noting that complex agroforests have often persisted only because farmers have resisted government attempts to upgrade (and simplify) their traditional systems. Brazilian cabruca farmers, for example, declined to lower the shade canopies of their cocoa plantations, which would have enhanced cocoa yields but increased their reliance on agrochemical inputs.

Similarly, jungle tea farmers in northern Thailand believed that natural vegetation cover was more effective than terraces at controlling erosion and runoff, and they resisted extension efforts to convert their traditional, diverse agroforests into terraced tea monocultures. Complex agroforests, on the other hand, must be lucrative and contribute to biodiversity conservation if they are to play a role in future tropical landscapes and contribute to biodiversity conservation. Agroforestry System Biodiversity makes substantial benefits to the livelihoods of their owners. It is not feasible to examine all of the agronomic challenges associated with the intensification of low-productivity agroforests in this chapter, but a few significant research and development techniques should be included. Increased agroforest product diversification through the association of more valuable fruit and timber tree species with the main tree crops protects smallholder farmers from fluctuating commodity prices and ecological risks, such as diseases that threaten cocoa agroforests in several tropical regions. When applied to agroforests with a high proportion of spontaneous vegetation, this technique results in enhanced domestication of the system by replacing unplanned with planned variety, on a path that may eventually lead to home garden-like systems. The extent to which this form of domestication affects faunal diversity requires additional investigation. Increased management of agroforestry for timber production is another important option, particularly in regions such as Indonesia, Central America, and parts of West Africa where natural forests are becoming scarce, but also in the Amazon, where natural forest exploitation and marketing are increasingly subject to environmental regulation. Most crucially, further efforts are required to boost the profitability of complex agroforest's economic backbone species. This may include the selection of disease-resistant cocoa varieties, as well as more intensive disease management, the incorporation of more productive planting material into rubber agroforests, and management practices that improve the health and longevity of tree crops such as rubber without compromising, or even increasing, yields. Developing intensification approaches for tropical agroforests that boost profitability while preserving biodiversity is a key scientific problem.

CONCLUSION

Traditional knowledge and methods that have been handed down through generations are often used in complex agroforestry systems. Landscape conservation projects benefit local communities' cultural heritage by encouraging the adoption and maintenance of these systems. Sharing knowledge among farmers, academics, and conservation groups may lead to the creation of novel and context-specific agroforestry systems that benefit both biodiversity conservation and cultural values. Complex agroforests contribute significantly to landscape conservation by fostering biodiversity, habitat connectivity, soil and water conservation, carbon sequestration, livelihood diversification, and cultural preservation. Incorporating these systems into agricultural landscapes may help to promote sustainable land use practices that benefit both people and the environment.

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CHAPTER 18

BIODIVERSITY CONSERVATION TOOLS IN FRAGMENTED TROPICAL LANDSCAPES

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ABSTRACT:

Biodiversity conservation in fragmented tropical settings may be difficult owing to habitat loss and fragmentation. Several technologies and initiatives, on the other hand, may assist reduce the negative effects of fragmentation and promote biodiversity conservation. Creating and properly administering protected areas is a critical tool for biodiversity conservation. Protected areas may include a variety of ecosystems and offer shelter for a variety of animals. They are important conservation areas because they help to keep animal populations alive and vital ecosystems intact. Protected areas should be created to provide representative sampling of the landscape's many ecosystems and habitats.

KEYWORDS:

Agroforestry Elements, Bird Species, Ione Trees, Isolated Trees, Solitary Trees, Tree Species.

INTRODUCTION

Many deforested tropical landscapes seem to be simple mosaics of forest patches intermingled with pastures and agricultural fields at first look. Closer inspection indicates that many agricultural regions still have substantial and visible tree cover, whether as solitary isolated trees, live fences, windbreaks, or clusters of trees. Some of these trees are remnants of the old forest that were left standing when the land was cleared, while others have grown naturally or have been planted by farmers. Often, individual trees, live fences, and windbreaks are part of agroforestry systems through which farmers gain a diverse range of commodities and services. Despite the fact that this on-farm tree cover is frequently overlooked or ignored in land use surveys, analyses of forest fragmentation patterns, and conservation efforts, it may be critical to maintaining biodiversity in the fragmented landscapes that characterize many tropical regions [1].

The presence of live fences, isolated trees, windbreaks, and other agroforestry elements in deforested areas could aid in biodiversity conservation by acting as habitats, corridors, or stepping stones for plant and animal species, while also adding structural and floristic complexity to the agricultural landscape and improving landscape connectivity. While the importance of these agroforestry elements in temperate regions has been extensively studied, little attention has been paid to their ability to help conserve species in deforested tropics. Until recently, the extensive research on the impacts of forest fragmentation on the survival of plant and animal populations 261 in the tropics generally neglected the underlying agricultural matrix's potential to maintain species variety and improve species persistence.

In this chapter, we investigate the possible significance of three popular agroforestry elements live fences, windbreaks, and solitary trees in assisting in the retention of plant and animal species as well as the continuity of species populations and ecological processes in fragmented tropical environments. We concentrate on these features because they are seen in many tropical locations, are readily implemented into agriculture methods, and seem to have conservation potential. We begin by describing the profusion of live fences, lone trees, and windbreaks in tropical areas, as well as how farmers maintain them. Following that, we present information on the floristic and structural diversity that they represent, as well as the fauna associated with them, with a focus on the potential role of agroforestry elements as habitats, food resources, stepping stones, and corridors. Finally, we highlight critical gaps in our understanding of their involvement in conservation efforts. Our emphasis on Central American examples reflects the increased availability of information in this area; nonetheless, we add examples from other tropical regions when possible. Throughout this chapter, live fences are defined as small lines of trees or shrub species placed on farm borders or between pastures, fields, or animal enclosures with the primary objective of controlling animal or human movement.

Live fences are often made out of a single row of trees or shrubs planted at equal spacing and may support barbed wire, however they can also grow naturally under fence lines. Wind breaks are linear plantings of trees and shrubs typically several rows wide and linear strips of residual vegetation with the main purpose of protecting crops, animals, and residences from wind damage. Although we concentrate on windbreaks, many of the generalizations regarding the relationships between windbreak construction, species composition, and biodiversity protection apply to hedges as well. Isolated trees are trees that are distributed across pastures, fields, or near dwellings, exist in varied densities and spatial configurations, and have diverse origins. With the exception of commercial crops grown in large expanses (e.g., sugar cane, pineapple, and banana), most tropical agricultural landscapes contain at least some trees, though the density, diversity, and spatial arrangement vary greatly between sites. The use of live fences to delineate crop fields, pastures, and farm boundaries is widespread in Central America, Mexico, South America, Africa (Westley 1990), and several Caribbean countries [2].

Although a single tree, live fence, or windbreak is unlikely to have a significant impact on landscape structure or conservation efforts, the presence of several agroforestry elements in the agricultural landscape may greatly enhance tree cover and structural heterogeneity and provide complementary habitats and resources to the remaining forest remnants, thereby contributing to biodiversity maintenance. Assessments of the prevalence of lone trees, live fences, and windbreaks in tropical environments on a large scale. In Central and South American landscapes, for example, 60-95 percent of cow ranches have live fences, whereas 25-93 percent of farms have dispersed, isolated trees in pastures. In a research conducted in Veracruz, Mexico, solitary trees represented around 3.3 percent of the total area in a 5,509-ha environment, resulting in a fragmented, discontinuous canopy that promoted biotic connection.

The abundance and distribution of live fences, windbreaks, and isolated trees in a specific region reflect the history of deforestation and land use, as well as farm tree resource management. Farmers often retain some forest patches, strips of trees along rivers or streams, and remnant forest trees when clearing forests to create agricultural lands as sources of future products and services, though in some tropical regions, such as Brazil's Mata Atlantica and parts of northeastern Australia's Wet Tropics, farmers have extensively cleared the land and left little tree cover. Isolated trees are typically retained in pastures and agricultural areas due to their value as sources of timber, fence posts, firewood, and fruits, as shade and forage for cattle, and as sources of organic matter for improving soil fertility, or because cutting them is illegal. They may also be kept or planted to improve the aesthetics and economic value of the agricultural landscape. Windbreaks are maintained or planted mainly to offer wind protection and soil erosion prevention, while they may also provide other functions and benefits.

Live fences, on the other hand, are often used to demarcate boundaries with neighboring properties, split pastures into smaller areas for cattle rotation, and keep animals and people from straying. Farmers often chose healthy trees that have useful timber or firewood, produce fruits for people, or serve as cattle pasture when deciding which trees to keep on their farms. Producers may also carefully plan the location of trees on their farm, as in Honduras, where maize producers confine trees to field boundaries to minimize shade of allied crops. This is in contrast to Tree distributions in pastures, where trees are frequently widely dispersed throughout the whole pasture to provide shade and supplemental food to cattle as they graze. Individual trees may be protected by farmers by clearing around the stem while they are saplings when weeding fields and pastures. Farmers not only maintain tree densities and configurations to avoid competition between trees and agricultural crops or pastures, but they also cut lower branches of trees to decrease shadow, taking care not to impact tree growth. Thus, farmers' tree management is likely to impact the land's ability to maintain biodiversity [3].

Floristic and Structural Diversity of Live Fences, Isolated Trees, and Windbreaks The conservation value of individual agroforestry components is heavily influenced by their floristic composition and structural diversity. In general, the larger the floristic and structural variety of the agroforestry element, the greater it’s capacity to offer habitat and supplies for animals. We will look at the floristic and structural variety seen in live fences, lone trees, and windbreaks. Live Fence Floristic and Structural Diversity When planted by farmers, live fences are typically simple linear plantings of trees (generally of a single species) that are regularly spaced and pollarded and pruned on a regular basis. Although several tree species may be employed, most live fences are made up of a handful. In Costa Rica, for example, whereas more than 100 species are utilized in live fences, just eight species account for 95 percent of the posts.

However, only a few plant species grow due to the narrow space below the live fences, the open, exposed environment, and the frequent disturbance by cattle and people. Unlike planted fences, those that grow naturally under existing fences (from seeds distributed by animals or wind) or are relics of the original vegetation support a larger range of living forms and plant species. A total of 247 plant species were identified in a study of the flora in the understory of 19 spontaneously regenerated live fences in Piedemonte Llanero, Colombia. There were 265 live fences, isolated trees, and windbreaks discovered, the majority of which were bird-dispersed species. Birds, monkeys, and other frugivores are drawn to naturally regenerate live fences due to the availability of fruiting plants. The density and species richness of plants in the understory may change as live fences age and become more structurally complex, reflecting a combination of ecological factors (seed input, seed banks, and regeneration dynamics), biophysical conditions, and management (e.g., pollarding and herbiciding), but forest plants rarely establish in these exposed areas. Whether the live fences are species sparse or floristically diverse, their presence enriches the landscape's structural variety, breaking up the monotony of pastures and agricultural fields and providing vertical and hortizontal complexity. Live fences with a range of plant species with varied canopy physiognomies and some fully grown trees obviously provide more structural diversity than uniform rows of a single tree species or those that are frequently pruned to huge, leafless stumps. Live fences often create intricate rectilinear networks that follow field borders and topographic characteristics, allowing for some degree of biotic connectivity.

A study of cattle farms in La Fortuna, Costa Rica, for example, discovered an average of 0.16-0.19 km of live fence per hectare of pasture, with individual farms containing up to 52 km of live, clearly influencing tree cover and connectivity within the farm. Isolated trees may have more floral and structural diversity than planted live fences, depending on the tree origin (relict, regenerated, or planted), density, location within the landscape, and farmer management. Although the floristic diversity represented by solitary trees varies greatly, these trees may represent a considerable fraction of the original tree species present in the forest in certain areas. For example, isolated trees in Monteverde, Costa Rica, accounted for 60% of the species present in the study area, whereas isolated trees in Veracruz, Mexico, accounted for 33% of the total rain forest tree flora, albeit at much lower densities. Tree diversity can be quite high in traditional agricultural systems where farmers pollard or cut trees to provide mulch for crop production. Because many trees survive despite being pollarded and report in subsequent years [4].

In other areas where deforestation has been more extensive and there are fewer isolated trees, floristic diversity may be minimal: for example, in the Brazilian Amazon, 10-year-old pastures retained only 20 of the 326 plant species present in the original forest and only 6 of the 196 tree species present in the current forest. Isolated trees from a single species or group of species may dominate the landscape in certain locations. For example, Acacia penatulata dominates pastures in Moropotente, Nicaragua, with mean densities of 240 trees per hectare. Guevara et al, on the other hand, observe that the species com location of lone trees vary greatly among pastures in Veracruz, Mexico, with no particular species or group of species dominating. Isolated trees may contribute to the floristic variety kept in the environment by supporting varied epiphyte groups, especially if they are relics of the original forest. In Veracruz, Mexico, for example, a research discovered 35 orchid species on lone pasture trees, compared to 51 orchid species in forest remnants and 25 on shade trees in coffee plantations. Another research in the same location discovered that despite the differences in microclimates between pastures and forests, solitary trees kept 37 percent (58 species) of the vascular epiphytic and hemi-epiphytic forest flora.

Although epiphyte abundance was lower on isolated trees than on counterpart trees in adjacent forests, epiphytic species richness per tree was similar in both habitats, implying that isolated relict trees may be suitable habitats for epiphytes, at least in the short term after deforestation; however, it is unknown whether these trees will maintain epiphytes in the long term. In contrast to remnant trees, trees planted in pastures tend to lack epiphytes or have poorly formed communities, most likely due to restricted colonization in pasture habitats, which is exacerbated by the pasture microclimate's unsuitability. Another method solitary trees might boost floristic variety is by acting as forest regeneration nuclei. Many birds that visit isolated trees regurgitate or defecate seeds while perched, dispersing seeds from forest patches into agricultural areas and increasing both the abundance and species richness of seed input. For example, in the, seeds from 25 different tree and shrub species were gathered beneath solitary trees in meadows.

DISCUSSION

The Biodiversity of Agroforestry Systems in Costa Rica's Caribbean Lowlands. Similarly, seeds from 107 plant species were found beneath lone trees in Veracruz, Mexico, with 56 of them being distributed by vertebrate frugivores. In general, seed rain that falls on solitary trees consists mostly of small-seeded pioneer species disseminated by frugivorous birds and bats. The volume and kind of seeds that arrive in pastures beneath solitary trees seem to be influenced by the type of fruit produced (fleshy or dry), tree height, distance to neighboring forest, and maybe tree canopy architecture. Large, fruiting trees may attract more birds because they offer both eating areas and suitable perches for predator spotting. The modified microclimatic conditions (reduced solar irradiation and reduced temperature and humidity fluctuations) below tree crowns may be more favorable, and the soils may have better physical structure and water infiltration than open pastures, resulting in higher seed germination and plant establishment. The mean species richness of regenerating plants per quadrant was significantly higher under isolated tree canopies than at the canopy perimeter and in open pastures in a study of vegetation under isolated trees in neo tropical pastures in Veracruz, Mexico; a total of 193 species (109 woody and 84 herbaceous) were present under 50 isolated trees. Similarly, 48 canopy tree species were discovered regenerating under the crowns of large remnant trees in a subtropical rain forest location in southern Queensland, Australia, with the number of species rising with tree height and crown area [5].

The presence of isolated trees in pastures creates a positive feedback loop by increasing seed input and providing safe sites for tree establishment, resulting in the growth of more trees and the creation of more perch and feeding sites for seed-dispersing animals. The long-term advantage of improved forest regeneration, however, will be realized only if the region is subsequently abandoned and allowed to recover. Windbreak Floristic and Structural Diversity Planted windbreaks are typically composed of a small number of species carefully chosen for their quick development, capacity to offer enough wind protection, and compatibility for a certain climatic zone. Windbreaks are also prevalent in African nations, with the Eucalyptus, Senna, Leucaena, Prosopis, Casuarina, Azadirachta, and Acacia species being employed in arid locations. Windbreaks in tropical Australia are often made up of Eucalyptus spp., hoop pine (Araucaria cunninghamiana), and the exotic conifer Caribbean pine. Unfortunately, many of these typical windbreak species provide little in terms of animal resources. Despite the fact that the floristic diversity of planted windbreaks is typically quite limited, they have the potential to facilitate natural regeneration in their understories by serving as perching and seed deposition sites for birds and other animals, as well as providing a modified microclimate that promotes the establishment of some forest trees.

Windbreaks (Montanoaguatemalensis, Cupressus lusitanica, Casuarina equisetifolia, and Croton niveus) received 40 times as many tree seeds and more than twice as many species of seeds as adjacent pastures due to increased bird visitation, indicating the potential for windbreaks as foci for regeneration. Surveys of windbreak understory showed 91 tree species (including major and secondary forest species) as seedlings just 5-6 years after the windbreaks were installed. Windbreaks linked to woods exhibited considerably more tree species and greater densities of tree seedlings than those separated from forests by 20-50 m. This trend is most likely due to increased frugivorous bird activity in linked windbreaks. In León, Nicaragua, planted windbreaks of Eucalyptus camaldulensis, Tecoma stans, and Leucaena leucocephala appeared to serve as habitats for plant regeneration, despite the fact that the density and species richness of trees (33 species) in windbreak understories were low, owing to the frequent use of fire in adjacent agricultural lands. Although it is unknown how many of the regenerating seedlings will survive and develop into adult trees, there is a good possibility that the windbreaks will be colonized by native species. The destiny of the seedlings is heavily influenced by windbreak management strategies, particularly the exclusion of cattle. Animals Associated with Live Fences, Isolated Trees, and Windbreaks A wide range of animal species may use agroforestry features in fragmented landscapes as habitats, feeding locations, corridors, or stepping stones to traverse open regions.

The Biodiversity of Agroforestry Systems on Fauna employing live fences, solitary trees, and windbreaks, and identifying criteria that impact the utility of these agroforestry features for fauna conservation. Live fences offer perching, shelter, and feeding locations for various creatures in tropical settings, including birds, bats, beetles, and nonflying mammals. In Veracruz, Mexico, for example, a total of 98 bird species (representing 54% of the bird species detected in adjacent forest fragments) were detected in a 6-kilometer-long live fence made up of Bursera simaruba and Gliricidiasepium (with a few naturally regenerated species). Similarly, 105 bird species from 45 families were observed in naturally regenerated live fences in Colombia, with older, more structurally complicated live fences having more bird species and more bird's characteristic of forest margins and secondary growth. Although live fences are frequently dominated by bird species common to edge or open habitats, a few forest interior resident species, including those that seldom leave the forest, visit them as well. In some cases, isolated trees may help maintain some animal populations in fragmented landscapes by serving as stepping stones for both local and regional movement and as stopover points for shelter and resting during landscape-scale movements [6].

A study of birds visiting isolated fig trees in Veracruz, Mexico, for example, discovered that the frequency of flight direction of birds arriving at the fig trees was highly correlated with the presence of live fences, other isolated trees, or other remnant vegetation, implying that bird movement patterns closely follow arboreal elements in the landscape. Trees in Australian pastures seem to act similarly as stepping stones for a range of species, including Major Mitchell's cockatoos, foliage-foraging birds, and several granivores and nectarivores. Birds that undertake landscape-scale movements or migrations may use isolated trees for shelter and resting, as appears to be the case in Monteverde, Costa Rica, where the threatened three-wattled bellbird (Procniastricarunculata) and the resplendent quetzal (Pharomachrusmoccino) migrate altitudinally from high, forested areas to lower, fragmented habitate. Some frugivorous birds fly around the landscape, taking use of riparian corridors and solitary trees for safety and food supplies. However, the matrix tolerance of each bird species limits their ability to utilize agricultural environment. Windbreak Fauna Numerous detailed studies from temperate regions have shown that windbreaks may help conserve a large number of plant and animal species, including a limited number of forest-dependent species, by providing food, cover from predators, refuge, and travel lanes. Windbreaks have the highest conservation value when they contain a diverse range of native plant species and life forms, are connected to intact forest or other natural vegetation, are wide (allowing for some interior habitat), and are protected from grazing cattle.

In general, the more structural and floristic variety there is, the more ecological niches there are for different plants and animals. Windbreaks that link forest fragments or other remaining vegetation may also act as wildlife corridors Microclimatic conditions in windbreaks may be more favorable than those in open pastures or fields and provide protection from weather extremes; however, these microclimatic conditions are likely to be spatially and temporally variable along the length of the windbreak. The majority of the species that benefit from windbreaks are edge species that can use significantly modified habitats; few forest interior species seem to gain from windbreak environment. In contrast to the many extensive studies of the fauna linked with windbreaks in temperate environments, little is known about the usefulness of windbreaks for tropical biodiversity protection. This is due, in part, to windbreaks' shorter history and the relatively recent destruction and conversion of wooded regions to agricultural use. However, new evidence suggests that tropical windbreaks may provide many of the same functions as their temperate counterparts. Windbreaks may provide crucial habitat for certain tropical bird species, according to some data.

A three-year study of birds in Monteverde, Costa Rica, discovered 64 bird species in windbreaks planted with three exotic species (Casuarina equisetifolia, Cupressus lusitanica, and Croton niveus) and one native species (Montanoaguatemalensis), compared to 74 bird species in natural windbreaks that were remnants of the original forest (Nielson and De Rosier 2000). Interestingly, natural windbreaks appeared to serve as habitats and nesting sites for birds, whereas planted windbreaks appeared to be only transient foraging sites and travel paths, implying that natural windbreaks are better habitats for birds than planted windbreaks. In a comparable research with planted windbreaks (Eucalyptus camaldulensis, Leucaena leucocephala, and Tecoma stans) in León, Nicaragua, 35 bird species were seen utilizing the windbreaks. The most common species were widespread and open habitat species, but the windbreaks also housed four vulnerable species

Although windbreaks may aid in the conservation of certain taxa, other species may not benefit or may be severely impacted by their existence. A study of fauna in planted windbreaks (one or two lines of Eucalyptus trees grazed by cattle) and riparian areas in Queensland, Australia, found that while the windbreaks were useful for some bird species (except for rainforest species), they were insignificant habitat for mammals and had a much lower value as wildlife habitat than the riparian vegetation. The windbreaks were home to 37 different bird species, compared to 62 in the riparian regeneration vegetation. In the windbreaks, only a few rainforest specialized bird species and no small mammals or arboreal animals were collected, perhaps due to their reduced structural complexity and monospecific character [7].

Windbreaks could serve as corridors or travel lanes for some animal species, especially if they are structurally and floristically similar to forest habitats and connected to patches of suitable habitat, but whether animals use windbreaks as linkages depends on their ability to disperse through the matrix. Windbreaks, living fences, and other linking networks have been shown to channel a restricted number of plant and animal species in temperate zones. A few recent studies in the tropics give tentative evidence that bird species may utilize windbreaks as corridors. In tropical Australia, the construction of a 1.5 km by 100 m corridor connecting two forest patches has resulted in fast colonization and migration of a variety of creatures. Over the course of three years, the corridor was colonized by 119 new plant species, 40% of which were not found in the surrounding agricultural matrix. The bulk of new species were brought to the location by birds, although spectacled flying foxes (Pteropusconspicillatus) and other animals were also involved. Within three years, avian populations in the restoration were almost comparable to intact forests, and a small mammal community comprised mostly of forest species was also present.

Furthermore, 18 morphospecies of wood-boring beetle (Coleoptera) colonized dead wood placed in the corridor prior to plant establishment, indicating that invertebrate colonization can be quite rapid, although seasonal fluctuations in species diversity are most likely due to edge-related effects during the dry season. Despite the clear potential of agroforestry elements to maintain biodiversity in agricultural landscapes, there is concern that the diversity and density of trees in agricultural landscapes are slowly eroding due to a combination of tree harvesting and natural death. Many of the relict primary forest tree species in pastures do not recover in open environments under present management techniques and will not be replaced if they die or are removed. Because many tree species in pastures have low densities, the removal or natural death of even a few trees may result in the local extinction of that species from the landscape. This lack of regeneration is typically reflected in the size distribution of main forest trees in pastures and agriculture areas. In Monteverde and Caas, Costa 11, there are few persons in the small size groups. Live fences, isolated trees, and windbreaks are examples of windbreaks in Costa Rica [8].

The similar trend toward reduced tree densities and species richness that seems to be happening on farms appears to be occurring in West African parklands. Ficus trees are also disappearing from pastures in northeastern Queensland, Australia, and the absence of active replacement may have an impact on both cattle productivity and conservation. These trends toward lower tree densities on farms may be reversed if new management strategies that promote tree establishment were applied, such as lowering grazing, avoiding fires, and fencing off areas to encourage regeneration. The variety of tree species employed as live fences has also decreased in several tropical locations in recent years.

In Costa Rica, for example, while more than 100 species have been reported in live fences, just a few species currently dominate the environment. Natural regenerating living fences have been destroyed in certain regions to make space for the building of new roads, the extension of agricultural land, or farm automation, diminishing wildlife habitat available. What We Don't Know Despite the fact that a significant subset of the original flora and fauna may use live fences, isolated trees, and windbreaks as resources, habitats, corridors, or stepping stones, our understanding of the conservation value of these agroforestry elements is still in its infanc.

We discuss some of the important concerns that must be addressed immediately if the conservation potential of these agroforestry aspects is to be fully appreciated and used. For starters, additional information on the richness, density, variety, and spatial arrangements of windbreaks, living fences, and lone trees, as well as the logical sequences of these various configurations, is required for biodiversity conservation. In addition to documenting the distribution of agroforestry elements in the landscape, it is critical to understand how these agroforestry elements complement remnant vegetation in the landscape and the extent to which animals or plants that use them rely on or use alternative habitats (particularly remnant vegetation). Because almost all of the studies reported in this chapter (and in the literature) were conducted in landscapes with some remnant vegetation, it is unclear whether the biodiversity recorded in agroforestry elements reflects the habitat value of the agroforestry elements themselves or is a function of the surrounding landscape's remaining remnant vegetation. More research is required to better understand how agroforestry components complement residual vegetation and how biodiversity in agroforestry elements evolves as the remaining forest cover rises or diminishes in the area. It will also be necessary to investigate the scale on which live fences, wind. Individual populations of plants and animals depend on whether isolated trees contribute to both local and regional biodiversity or only to local biodiversity, as Dunn discovered for isolated trees in pastures and ant communities.

There is also a scarcity of information on how windbreaks, isolated trees, and live fences affect ecological processes such as animal dispersal, migration, seed dispersal, and pollen flow in fragmented landscapes. In-depth research is also required to establish how plants and animals utilize agroforestry components and to what extent they rely on them for food, shelter, or reproduction (in comparison to other habitats in the landscape). The sheer existence of animal or plant populations in live fences, windbreaks, and lone trees does not imply that these habitats are conducive for their survival until it is shown that they reproduce and survive in them. Even when animals or plants reproduce in live fences, windbreaks, and solitary trees, it is unknown if survival rates are comparable to those seen in the original forest, or whether individuals face increased predation or competition [9].

More knowledge on the population biology of plant and animal species that use or exist in live fences, windbreaks, and solitary trees would help us determine if these habitats are population drains or sources, as well as whether populations are long-term sustainable. A few studies have suggested the potential importance of isolated trees, windbreaks, and live fences as animal movement conduits, but more detailed studies of animal movement patterns and the factors that influence the use of agroforestry elements as corridors and stepping stones are still needed. It will be critical to ascertain if the inclusion of agroforestry components enhances gene flow in the fragmented landscape, colonization rates of unoccupied patches, and adaptive genetic variance for population fitness. If these systems do serve as corridors, it is critical to ensure that they do not facilitate the spread of alien or generalist species at the cost of forest interior species.

To present, available data demonstrates a substantial bias toward birds, bats, and other mammals, with few research focusing on insects and belowground creatures. However, because individual species and taxonomic groups respond differently to fragmented landscapes and agroforestry elements (depending on their behavior, dispersal capabilities, habitat needs, and ability to adapt to modified landscapes), it is critical to study and compare a diverse range of organisms to determine which species or guilds will be able to benefit from live fences, isolated trees, or windbreaks. Another gap in our knowledge is how farmers create and manages living fences, windbreaks, and lone trees, as well as how farmer actions effect their conservation value.

Because live fences, windbreaks, and isolated trees are human-created and maintained features of agricultural lands, any efforts to integrate these arboreal elements into conservation efforts must carefully understand their role in the farming system and the rural society that maintains them. It will be critical to understand how farmers select whether to keep, plant, or remove agroforestry components, in what densities and patterns they place them, which species they plant or keep, and how they maintain them. Another critical need is to identify the advantages and disadvantages of various agroforestry systems for farm productivity, including potential changes in farm productivity and pest dynamics, as well as potential trade-offs or synergies between retaining agroforestry elements in the landscape for conservation or agricultural purposes. Finally, since tropical landscapes are dynamic entities impacted by both socioeconomic and biological processes, it is critical to understand how changes in agroforestry element abundance, distribution, and variety affect plant and animal populations. The long-term repercussions of the slow loss of relict solitary trees in pastures and agriculture fields due to natural death and harvesting are of special concern.

Emerging studies imply that live fences, windbreaks, and solitary trees may help to biodiversity conservation, and that keeping or establishing trees on agricultural fields may be an important component of conservation efforts in fragmented landscapes. Although the value of each agroforestry element depends on its structure, composition, management, and position in the landscape, the floristic diversity conserved in these agroforestry systems can be high, and a significant number of animal species may exploit these habitats for feeding, movement, and, in some cases, reproduction. Many of the species that benefit from agroforestry systems are generalists, although certain forest specialists are frequently present as well. Live fences, windbreaks, and lone trees may also improve landscape connectivity and help to biodiversity conservation at various scales by building networks of natural habitats [2].

However, it should be noted that, although these agroforestry elements are helpful additions or complements to natural habitat protection, they are not replacements for the original vegetation. Live fences, windbreaks, and lone trees are not complete biological units and cannot supply the entire range of habitats or services of the original environment; as a result, the species in them are likely to rely on surrounding residual habitats to some extent.

Conservation efforts in fragmented environments should thus aim on building landscape-scale solutions that combine. The retention and establishment of windbreaks, live fences, isolated trees, and other agroforestry elements with the conservation of forest fragments, the retention of riparian vegetation, the maintenance of connectivity in the agricultural landscape, and other conservation strategies.

CONCLUSION

Effective biodiversity protection strategies and governance systems are required in fragmented environments. Governments may enact laws and regulations to support habitat preservation, sustainable land use practices, and the incorporation of biodiversity concerns into development plans. Conservation groups and stakeholders may campaign for and secure the adoption of supporting policies. Combining these methods and tactics may help alleviate the negative effects of fragmentation and enhance biodiversity conservation in tropical environments that are fragmented. To address the complex issues associated with habitat fragmentation, a coordinated and multidisciplinary strategy including governments, conservation groups, local people, researchers, and other stakeholders is required.

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CHAPTER 19

TRADE-OFFS RELATED TO COLONIZATION IN TROPICAL FORESTS AND THEIR IMPACT ON PLANT SPECIES DIVERSITY

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ABSTRACT:

In tropical forests, colonization entails the introduction of human settlements and the conversion of natural ecosystems into agricultural or urban areas. While colonization may provide socioeconomic advantages and satisfy the requirements of expanding populations, it also comes with trade-offs and has a substantial influence on plant species diversity. The conversion of natural forest habitats to agricultural fields or urban areas results in a direct loss of plant species diversity. Clearing land for towns and agriculture destroys forest ecosystems, displacing native plant species, and lowering biodiversity overall.

KEYWORDS:

Competition Colonization Trade Off, Regeneration Sites, Seed Size, Seed Mass, Tropical Forest.

INTRODUCTION

Interspecific trade-offs involving colonization capacity may significantly contribute to the preservation of plant species variety and are often suggested as a possible mechanism behind high tropical forest diversity. The well-known competition-colonization trade-off, which exists between the ability to win a regeneration site after arrival and the ability to arrive, can theoretically maintain very high species diversity, but only if there is strong competitive asymmetry among species, with the best competitor present being highly disproportionately likely to win. Other, less-studied trade-offs involving colonization capacity might help to diversity preservation when habitat heterogeneity is acceptable, by allowing habitat niche partitioning [1].

A trade-off between fecundity and stress tolerance, combined with corresponding variation in stress among regeneration sites, can result in coexistence of more tolerant species capable of winning high stress sites and more fecund species numerically more likely to win low stress sites. Given regional heterogeneity in the density of potential regeneration sites, a trade-off between fecundity and dispersion may also contribute to coexistence. Empirical studies of species trait relationships, current understanding of the asymmetry of competitive interactions among seedlings, and the results of a seed addition experiment all indicate that the classic competition-colonization trade-off does not exist among tropical trees and thus does not contribute to their coexistence. Trait connections, on the other hand, show that a tolerance-fecundity trade-off is present, mediated by seed size, with small-seeded species having greater fecundity and poorer stress tolerance than large-seeded species.

The evidence for a dispersal-fecundity trade-off is conflicting and inconclusive. To better understand the roles of these colonization-related trade-offs, and specifically to assess their contributions, if any, to species coexistence in tropical forests, more research is needed in natural systems, field experiments, and/or models of how spatiotemporal variation in environmental conditions and seed arrival affects regeneration success. Interspecific trade-offs involving species' abilities to reach or "colonize" regeneration sites can play multiple roles in niche partitioning and diversity maintenance among tropical forest tree species and other communities. The best-known examples are competition-colonization trade-offs between a species' ability to reach sites with its recruits and the ability of each recruit to win sites where recruits arrive. The conditions for competition-colonization trade-offs to maintain diversity, on the other hand, are stringent and likely to be uncommon in nature, and in the absence of these conditions, these trade-offs need not be a powerful or even significant force enhancing coexistence. Other colonization-related trade-offs might contribute to species habitat partitioning and hence coexistence in varied environments. When there is geographical diversity in resource availability or the severity of circumstances across local regeneration sites, a trade-off between fecundity and the capacity to withstand low resource conditions or harsh environments might mediate coexistence.

In the presence of regional heterogeneity in the number of sites favorable for regeneration, a trade-off between fecundity and dispersion distance may mediate coexistence. While competition-colonization trade-offs have received substantial theoretical and empirical investigation in a variety of plant communities, other colonization-related trade-offs have received less attention. Even on competition-colonization trade-offs in tropical forests, little study has been conducted. In tropical forests, the limited analysis of such trade-offs has been focused on whether they may contribute to the coexistence of shade-tolerant and gap-dependent species [2].

Nonetheless, a number of pertinent empirical investigations in tropical forests have shed light on the possibility for colonization-related trade-offs to contribute to the preservation of species richness in these varied plant communities. In this chapter, I examine the theory and data on the role of colonization-related trade-offs in tropical forest diversity maintenance. Because of its dominant position in the literature on colonization-related trade-offs, and therefore the number of relevant theoretical and empirical investigations, I give the greatest attention to the competition-colonization trade-off throughout. I begin by summarizing the relevant theory quickly, outlining the major assumptions and predictions of models in which these trade-offs contribute to variety preservation. I next address the methodologies for documenting these trade-offs and their functions in actual societies, as well as the relevant empirical data from tropical forests in particular. I finish with suggestions for future study and a recap of what we have learned so far.

DISCUSSION

According to Chess on, colonization-related trade-offs have the potential to have equalizing and/or stabilizing effects on diversity maintenance. Equalizing impacts reduce fitness disparities across species, which would otherwise lead to competitive exclusive, resulting in less exclusionary and more neutral dynamics. If only partial equalization occurs, such that species remain less than fully equal, dynamics are near-neutral, and weaker species are deterministically eliminated, although at a slower pace than they would be without the trade-off. If there is perfect or total equalization, species' competitive abilities become equal, and they are therefore prone to neutral drift. Stabilizing impacts, on the other hand, actively contribute to variety preservation by enhancing negative intraspecific interactions compared to negative interspecific interactions. This guarantees that each species is proportionally advantaged when uncommon and disadvantageous when common, preventing extinction or monodominance. Stabilizing impacts alter dynamics in a manner that preserves variety rather than leads to competitive exclusion. The most well-known theoretical model of the competition-colonization trade-off is self-stabilizing and so has enormous diversity-maintenance potential. Many recorded competition-colonization trade-offs, on the other hand, consist of characteristic connections that are simply equalizing in nature. A trade-off between seed production and seed survival, for example, may only totally equalize species' competitive skills by guaranteeing that all species have the same number of seedlings per adult. Similarly, while habitat partitioning mechanisms are invariably stabilizing when the theoretical conditions under which they are defined are met, they are only perfectly equalizing at the exact boundary of those conditions, and they operate as partially equalizing on the other side of the conditions. Thus, before we can assess the importance of colonization-related trade-offs in actual communities, we must first determine which model assumptions are crucial to predicting the presence and size of stabilizing impacts on diversity. Competition-colonization trade-offs in homogeneous settings Skellam’s basic competition-colonization trade-off model encapsulates the inherent ability of such trade-offs to contribute to diversity maintenance in homogenous environments in a stabilizing way.

Many later articles, most notably Hastings and Tilman, have investigated its dynamics in depth. Space is split into separate sites in this concept, each inhabited by a single adult. Adults generate seeds that are randomly dispersed throughout all locations and die at a constant rate. Species have stringent competitive rankings that are the exact opposite of their seed production rankings. When a seed arrives to a site inhabited by an adult of a lesser rival, it immediately displaces the tenant and becomes the site's new adult. Under these circumstances, an endless number of species with varying competition and colonization skills may live indefinitely. While this model illustrates the potential strength of the trade-off, its assumptions of perfectly asymmetric competition (the better competitor always wins, even if only slightly better) and immediate displacement are highly unrealistic for plant communities, and its behavior is a poor match to real community dynamics [3].

For example, species with stronger competitive capacities are more numerous while also being more sensitive to habitat destruction, contradicting extensive evidence that rare species are the most endangered. Furthermore, if species features are allowed to develop, each species advances to greater and higher competitive ability and decreased fertility, eventually leading to extinction. Alternative models of competition-colonization trade-offs encapsulating a variety of more realistic assumptions show that strong competitive asymmetry is a critical requirement for stable coexistence under this mechanism. The above-mentioned traditional model incorporates complete competitive asymmetry: the superior competitor always gets the site. In contrast, if competition is purely symmetric, such that competitive differences are merely density independent (e.g., if there is interspecific variation in density-independent seed survival and all surviving propagules are equally likely to win a site), stable coexistence is impossible. Geritz et al. establish the quantitative impact of asymmetry in their model of annual plants, in which seed size mediates a trade-off between seed output and competitive capacity.

Competitive ability is defined by both a density-independent survival term an equalizing force and the likelihood of prevailing in the face of competition a stabilizing impact. The per capita likelihood of winning is defined as an exponential function of seed mass, which contains a parameter for the degree of competitive asymmetry: as this asymmetry parameter grows, the species with the greatest seed mass becomes more likely to win the site. Geritz et al. investigate the evolutionary and ecological dynamics of this model, demonstrating that as the degree of competitive asymmetry grows, so does the number of types (species) that develop and persist stably. Adler and Mosquera use the competition-colonization trade-off to analyze the circumstances under which one, two, and infinite numbers of species may live, demonstrating that infinite coexistence is only conceivable with perfect asymmetry. Kisdi and Geritz show comparable effects of altering asymmetry in perennial plant models. The importance of asymmetry in these models is consistent with the findings of Tilman and Kisdi and Geritz, who find infinite coexistence in models with totally asymmetric competition, and with the findings of Levine and Rees, who find restricted coexistence in models with low asymmetry. Thus, the conventional competition-colonization trade-off may be a major stabilizing factor for diversity preservation, but only if competitive asymmetry is sufficient. Perfect asymmetry, which is unachievable in actual societies, is essential for the theoretical models' effectively limitless cohabitation. In contrast, if competition is entirely symmetric, this trade-off's contribution to diversity preservation can only be equalizing. Even modest differences that make the tradeoff partly rather than totally equalizing are sufficient to make certain species better competitors and shorten coexistence [4].

Finally, if competition is somewhat asymmetric, as is most typical in natural communities, the trade-off may be able to contribute to the stable coexistence of a few species, or it may simply be a partially equalizing factor. While only certain competition-colonization trade-offs can have a stabilizing influence on diversity maintenance in homogeneous environments, a broader range of colonization-related trade-offs can have a stabilizing influence given appropriate spatial or temporal environmental heterogeneity. These trade-offs can specifically contribute to diversity maintenance if the combination of each species' colonization and competitive abilities on the different habitats results in each species having the highest population growth rate at some time or place. Because both habitat heterogeneity and variation in species performance on various habitats are common in natural ecosystems, these trade-offs have the potential to play key roles in maintaining variety.

In this section, I will look at two particular examples: tolerance-fecundity trade-offs and dispersal-fecundity trade-offs. When there is regional diversity in resource availability and hence in the degree of recruit provisioning required to tolerate local circumstances and have a chance of winning the regeneration site, a tolerance-fecundity trade-off might mediate coexistence. In this case, a trade-off between recruit provisioning (e.g., seed mass) and fecundity (e.g., seed production) can mediate coexistence by allowing the more fecund species to succeed disproportionately often in sites where little provisioning is required, thus compensating for the consistent success of the better-provisioned species on sites with low resource availability. Many species may coexist in theory if there is enough variety in habitat quality between locations and acceptable constancy in the trade-off between habitat tolerance and fecundity. Such a trade-off will be stabilizing if the fecundity of each less tolerant species surpasses that of the following more tolerant species by a certain multiple, with the multiple dependent on their respective habitat tolerances and seed survival, if applicable.

If the less tolerant species' fecundity is less than (or equal to) this multiple of the more tolerant species' fecundity, the trade-off will be partly (or completely) equalizing. Given regional heterogeneity in the number of viable regeneration sites, a dispersal-fecundity trade-off may enable two rivals to coexist. The more fecund species is more successful in high density regions, while the better disperser is more successful in low population areas, allowing coexistence. In theory, several species might coexist if there was enough geographical variety in the density of regeneration sites. Again, there is a certain quantitative threshold for the correlations between species' fecundities and dispersion capacities beyond which the trade-off is stabilizing, perfectly equalizing, and partly equalizing. Tolerance-fecundity trade-offs and dispersal-fecundity trade-offs are only two examples of colonization-related trade-offs that might help maintain variety in the face of habitat heterogeneity. These two strategies divide geographical heterogeneity. Trade-offs involving dormancy or dispersion in time in general may help to partition temporal heterogeneity and hence stabilize coexistence in temporally changing settings.

There is a substantial literature on species coexistence via habitat partitioning; however, the emphasis has mostly been on species variations in competitive ability in various environments. Similarly, the emphasis of research on colonization-related trade-offs has been on coexistence in homogenous environments owing to these trade-offs alone. More theoretical work is required to investigate how species colonization differences combine with habitat heterogeneity to contribute to species coexistence. In order to investigate colonization-related trade-offs in actual societies, a variety of methodologies are available [5].

The most typical method is to simply measure certain species attributes and analyze correlations between these qualities to test for the existence of a specific trade-off between species. This provides useful information on the presence of the trade-off but says little about its role in species coexistence; measurements of other key features of the community or individual interactions within it (such as competitive asymmetry in the case of the competition-colonization trade-off) are generally required to evaluate theoretical conditions for coexistence. An alternate technique investigates spatiotemporal variance in field recruiting success and assesses the extent to which it may be explained by model predictions. Community-level field experiments may also be used to analyze the role of trade-offs, which can test either general model predictions or specific predictions depending on additional information. In theory, any of the aforementioned efforts might be used to parametrize models of the postulated processes, allowing for additional theoretical assessments of whether requirements for stable coexistence are satisfied, either analytically or via simulations.

Clearly, a colonization-related trade-off can only influence community dynamics if it exists. As a result, the first inquiry is whether species features trade off as predicted. This question is often addressed by species trait correlation or regression analysis. Because most accessible data are acquired for other or at least wider goals, they often do not concern the most important trade-off measures, but rather another component contributing attribute. Furthermore, the most effective integrative attributes (for example, "colonization ability," "competitive ability") are sometimes difficult to quantify or characterize. As a result, the resultant correlation studies seldom yield conclusive answers on the existence of the overall trade-off. Studies linking spatiotemporal variation in environmental conditions, seed arrival, and successful recruitment have long been used to evaluate the relative importance of seed arrival and habitat suitability to population-level recruitment patterns.

Analyses of environmental spatial patterns and species distributions have also been utilized to investigate the significance of habitat partitioning at the community level. Similar methodologies might be used to assess the predictions of the competition-colonization, tolerance-fecundity, and dispersal-fecundity trade-off models for patterns of recruitment success given seed arrival and environmental circumstances. Such studies may simply test for the broad patterns predicted under various theories; for example, in the competition-colonization trade-off, the assumption would be that certain species win whenever they come, and others only when the dominating rivals fail to arrive.

Alternatively, independent data on species features (e.g., competitive rankings) might be utilized to forecast precise patterns of which species would win where. Community-level seed addition studies are the most powerful technique to explore the competition-colonization trade-off, allowing us to determine if the trade-off is stabilizing or equalizing, and to what extent - even when species competitive rankings are unknown. If the trade-off is stabilizing, then species with worse colonists and better competitors should gradually exclude those with better colonists and poorer competitors as more seeds are introduced, with bigger compositional changes suggesting a more robust stabilizing impact. If, on the other hand, the trade-off is simply equalizing, or if habitat-mediated tolerance-fecundity trade-offs alone are stabilizing, increasing seed rain of all species by the same multiplicative factor should have no effect on species composition [6].

Combining seed addition experiments with early successional removal experiments can provide additional insight into the relative importance of a competition-colonization trade off in the coexistence of early successional pioneers and late successional shade tolerant. The latter, as described by Pacala and Rees, entails removing early successional seedlings from places where late successional seedlings have already arrived. The combination of this experiment and a community-level seed addition experiment allows us to quantify to what extent successional diversity is maintained by a successful niche that is, some species competing better in early successional (high light) sites and others competing better in late successional (low light) sites - and to what extent it is maintained by a competition-colonization trade-off.

Measurements of species attributes, field investigations of causes of spatiotemporal variation in recruitment success, and/or field experiments might possibly be utilized to parametrize models that allow for further research of the roles of colonization-related trade-offs. Analytical criteria for steady coexistence of certain species may be quantitatively evaluated by explicitly considering model requirements and estimating critical features. Furthermore, the parametrization and application of individual-based community models allows for the conduct of virtual experiments that would be impossible to do in the actual world. All of the experiments outlined above may be included in such simulation trials, which could be conducted in models for considerably longer time periods and at far greater geographical scales than they could be carried out in the field. While there are several techniques to explore colonization-related trade-offs in tropical forests, current data is mostly restricted to trait connections. Research on colonization-related trade-offs has focused on the possibility for seed-size mediated trade-offs, particularly in temperate systems.

The notion is that species may be excellent colonists, generating many little seeds with poor competitive ability and/or stress tolerance, or they may be good competitors and/or stress tolerators, producing few big seeds with great competitive ability and/or stress tolerance. In extra-tropical environments, there is considerable empirical evidence for these connections, and it has been anticipated that the benefits of big seeds are even greater in tropical forests. In this section, I first address the seed mass-fecundity relationship, which underpins all three trade-offs reviewed in this chapter, and then assess the various sorts of evidence supporting each trade-off in turn. Although data are limited, seed mass and fertility seem to be negatively associated in tropical forests, as they are in other plant groups. Moles et al. Had reproductive data for just five tropical forest species in their worldwide meta-analysis of seed size and seed output, with no significant relationship. Dalling and Hubbell show a negative correlation between seed mass and seed density in a Panamanian wet tropical forest soil seed bank for 15 pioneer species; this is consistent with a negative relationship between seed mass and seed production, though seed density also includes the effects of adult abundance [7].

Muller-Landau et al. discover a substantial negative association between seed mass and per basal area seed production across 40 tree species with diverse life history strategies in the same forest, a relationship well-fit by a power function. No tropical research have directly evaluated the extent to which seed mass predicts overall competitive ability - the result of competition among seedlings. Some features thought to offer a competitive advantage seem to be positively connected to seed mass, but not all. Seed mass is related to seedling size at germination and for the first two years, but because small seeded species have faster relative growth rates, this advantage fades as seedlings age. Seed mass is also connected to the likelihood of a seed becoming an established seedling a transition probability that includes seed survival, germination probability, and early seedling survival. While interspecific trait relationships appear to show some evidence consistent with a competition-colonization trade-off when habitat independent competitive traits are measured, habitat-specific analyses suggest that the trade-off is not of the type encapsulated in the classical model of the competition-colonization trade-off. In all settings, seed mass is adversely associated to fecundity the traditional measure of colonization capacity, but it is not uniformly positively connected to competitive qualities.

Larger-seeded species should continuously outcompete small-seeded species in all habitats, regardless of habitat circumstances, if they are to be better competitors as envisioned by the usual competition-colonization trade-off. Reduced-seeded species, on the other hand, are as excellent as or better at securing high light locations, with no seedling survival disadvantage and faster growth rates that quickly compensate for their reduced starting size. This suggests that smaller-seeded species can win in high light environments even when larger-seeded and presumably more competitive species are present, whether due to numerical dominance fecundity-tolerance trade off or specific adaptations for these.

This plainly defies the expectations of the perfect asymmetry competition-colonization trade-off model. Furthermore, evidence showing large-seeded species do not have a permanent per capita advantage in seedling survival and growth in high light settings contradicts even partial asymmetry. As Leigh et al. suggest, we may exclude the competition-colonization model as a plausible explanation for the coexistence of pioneer and shade-tolerant organisms for the time being. However, it may be argued that competition-colonization trade-offs could still play a role in species coexistence inside understory areas, where bigger seeds seem to benefit consistently. Svenning and Wright show that even in the shaded forest understory, any seed-size mediated competition-colonization trade-off may be neither stabilizing nor fully equalizing in a series of population level seed addition experiments. Evening and Wright supplemented understory locations with seeds from 32 shade-tolerant species with seed masses spanning three orders of magnitude. If the trade-off is simply equalizing and dependent on seed mass, increasing seed rain of all species by the same absolute total mass of seed supplied should result in the same absolute rise in seedling abundance. If the trade-off is stability, the same increase in seed mass arriving should result in bigger increases in seedling abundance in species that are excellent competitors but poor colonists than in species that are bad competitors but good colonists [8].

Svenning and Wright discovered that the likelihood of an additional seed germinating, establishing, and surviving for 1 or 2 years did not change substantially with seed size. This shows that adding equivalent biomass of seeds from all species would result in a disproportionate rise in seedling numbers of small-seeded species, contrary to the competition-colonization theory, which predicts that large-seeded species would benefit the most. However, the advantage of small seeded species decreased from year 1 to year 2, so a long enough seed addition experiment could eventually find an equal or greater effect of seed addition in large-seeded species, consistent with a perfectly equalizing or stabilizing effect of a competition-colonization trade-off. However, at this stage, the results from the first two years of the trial can only be interpreted as indicating a very weakly equalizing impact.

Overall, the findings rule out the likelihood that a classic competition-colonization trade-off contributes to tropical forest diversity preservation. Empirical research have explored the association of seed mass to tolerance across tropical tree species. The findings reveal that large-seeded species have greater survival rates in the face of specific risks and in low light settings. Higher seeded species have higher reserves in store cotyledons and are therefore more likely to resprouts after severe seedling herbivory or injury. In a meta-analysis of data for tropical species, however, high seed mass does not seem to be related with better survival of either pre-dispersal seed predation or post-dispersal seed removal.

Seed mass is associated with seedling survival in the shade but not with seedling survival in high light. Because light is a critical limiting resource in tropical forests, particularly for seedlings, greater seed mass may provide an advantage in enduring low resource circumstances. The growing evidence of a negative association between seed size and fecundity and a positive link between seed mass and tolerance to low light, herbivory, and damage in tropical forests supports the possibility of a seed-size mediated fecundity-tolerance trade-off. Such a trade-off might contribute to the partitioning of regeneration sites across species depending on resource and stress levels of the sites, as well as the species' stress tolerance. The data, in particular, support the idea that large-seeded species win sites that are too low in resources or too high in stress for small-seeded species to tolerate, while small-seeded species win disproportionately in high resource, low stress sites where their numerical dominance in seed arrival becomes a dominance in seedling recruits.

Numerous studies on geographic variation in understory light levels and the stochasticity of physical damage give further evidence for the partitioning of abundant relevant heterogeneity. It is important to note, however, that the numerical success of small-seeded species in high resource sites is likely due in part to their specific adaptations for these environments, and thus at least in part to the successional niche mechanism, rather than a fecundity-tolerance trade-off. More study is required to determine the relative relevance of these two pathways.

Trade-offs between dispersal and fecundity If seed mass and fecundity are strongly inversely linked across species, then dispersion and fecundity may be substantially inversely related (i.e., trade off) only if seed mass and dispersal are also positively associated. Such a link has been postulated for animal-dispersed species, whereas the reverse relationship is expected for wind-dispersed species, which account for 70-100% of plants in wet tropical forests. It is hypothesized that larger-seeded fruits are eaten by larger-bodied animal species, and that these animal species have slower gut passage time and larger home ranges, which should result in longer dispersal distances. Furthermore, dispersal distances are projected to grow with seed size in scatter-hoarding rats because bigger seeds provide greater reward for the effort of caching [9].

Larger-seeded species, on the other hand, are projected to have greater terminal velocities and hence shorter dispersion lengths among wind-dispersed species, a prediction verified by empirical investigations. It is crucial to note that, like any coexistence mechanism, a dispersal-fecundity trade-off might play a role in the coexistence of one set of species (e.g., those distributed by a certain kind of animal) even if it is not present in others. There are currently limited data on the link between seed mass and seed distribution among animal distributed tropical species. Holbrook and Smith discovered that among nine taxa distributed by hornbills, stomach passage durations and hence estimated dispersion lengths were greater in bigger-seeded taxa, while Levey discovered that gut passage times were lower for larger seeds across nine bird species. Westcott and Graham show a positive, almost linear relationship between disperser body mass and median dispersal distance in eight tropical bird species, which would imply a positive relationship between seed size and dispersal distance if disperser body size is positively related to seed size - but there is little evidence to support this hypothesis. Furthermore, since seeds of any particular tropical plant species are often dispersed by a variety of animal species, total dispersion by all agents must be investigated in order to assess the complete pattern of seed dispersal.

Muller-Landau et al. discovered that seed mass was negatively related to estimate mean dispersal distances (by all animal species combined) among 31 animal-dispersed species in Panama using inverse modeling; however, the data and methods used are insufficient to quantify long-distance dispersal. At the moment, the scant information implies that dispersal-fecundity trade-offs do not exist in all tropical species, however they may exist within select groups. There is evidence for their occurrence among bird-dispersed species, but evidence for the reverse trend a positive dispersal-fecundity association among wind-dispersed species and animal-dispersed species in general. It is unknown if there is enough regional variation in the density of potential regeneration sites to allow coexistence through a dispersal-fecundity trade-off, assuming one exists. Thus, further study is needed to determine the significance, if any, of dispersal-fecundity trade-offs in tropical trees.

Theoretical and empirical attention has long focused on the competition-colonization trade off, which was early demonstrated to have the potential to contribute strongly to the diversity maintenance of many species. However, the criteria for these contributions are strict, and current research shows that this trade-off does not exist in tropical forests in their traditional form, and so does not contribute to the preservation of variety in this environment. Recent research has revealed two further colonization-related trade-offs as potentially essential diversity-maintaining mechanisms: fecundity vs tolerance of low resources or severe stress, and fecundity versus dispersion. Furthermore, tolerance-fecundity trade-offs seem to exist in tropical forests, with small-seeded species having greater fecundity but a lesser capacity to survive low resource or high stress settings than large-seeded species. Theoretical and empirical evidence are inadequate to assess the ability of the tolerance-fecundity trade-off to exert stabilizing or equalizing influences in tropical forests. The sparse data on dispersal-fecundity trade-offs show that they are not common, but cannot rule out the potential that they play a role in certain communities. To examine the potential and actual relevance of tolerance-fecundity and dispersal-fecundity trade-offs in tropical forests, further theoretical and empirical research, as well as unique integration of the two, is required.

To define the circumstances under which this process is stabilizing for different scenarios of community dynamics - particularly, how must the fecundity and tolerance of two species be connected in order for them to live stably - theoretical work on the tolerance-fecundity trade-off is required. In this context, a particularly important issue is the relative role of fecundity-tolerance trade-offs versus species trade-offs in habitat performance in contributing to habitat niche partitioning. Further measurements of habitat tolerances, fecundities, and dispersal abilities of species would allow us to better characterize the trade-offs, determine which environmental axes are involved in the tolerance mechanism, and determine whether or not the fecundity-dispersal trade-off exists. Empirical assessments of dispersal should consider not only dispersal distance but also differential dispersal to specific habitats (including directed dispersal), clumping, and other more complex phenomena influencing arrival rates, as well as correlations with seed size and other possible trade-offs. The distribution of the relevant habitat categories being partitioned, as well as environmental variables and optimal site densities, must be assessed.

This, in conjunction with information on species features and theory, should allow for some assessments of the importance of colonization-related trade-offs. Finally, research on these trade-offs should go beyond simple trait measures and theory to include additional, more robust examinations of the trade-offs' functions in actual societies. To assess the extent to which diverse processes might explain recruitment patterns, community-level field investigations of spatiotemporal variation in environmental mental circumstances, seed arrival, and successful recruitment should be done. Field studies that manipulate seed arrival, seedling recruitment, and climatic factors might give even more robust assessments of the systems. Models parametrized from field data might be a valuable tool for exploring long-term, large-scale dynamical consequences of recorded phenomena at temporal and geographical scales where such field research and experiments are infeasible. We should be able to get a much better knowledge of colonization-related trade-offs in tropical forests in the future using this combination of technologies.

CONCLUSION

Indigenous groups' traditional ecological knowledge may be lost as a consequence of colonization. Indigenous people often have a thorough awareness of local plant species, their applications, and their ecological responsibilities. Their knowledge and activities help to keep biodiversity alive. Displacement of indigenous groups and disturbance of traditional land management methods may result in a loss of this vital knowledge and the conservation practices that go with it. Addressing the trade-offs associated with colonization and reducing the negative consequences on plant species variety necessitates the implementation of sustainable land use practices, the promotion of conservation methods, and the involvement of local populations. This involves integrating indigenous knowledge and practices into conservation efforts, as well as establishing land-use planning that emphasizes the protection of surviving forest areas, promoting sustainable agricultural methods that reduce habitat loss and degradation, and incorporating indigenous knowledge and practices into conservation efforts. To preserve the long-term viability of both, it is critical to find a balance between serving human needs and protecting the unique biodiversity of tropical forests.

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CHAPTER 20

A BRIEF OVERVIEW OF THE LANDSCAPE CONSERVATION COOPERATIVES AND LANDSCAPE GENETICS

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ABSTRACT:

Landscape Conservation Cooperatives (LCCs) are collaborative partnerships formed in the United States to solve conservation concerns at the landscape scale. LCCs bring together a diverse range of stakeholders, including federal and state agencies, tribes, non-profit groups, academic institutions, and other interested parties, to collaborate on conservation problems that cross political lines. LCCs' major purpose is to incorporate science-based information and tools into decision-making for landscape-level conservation and natural resource management. They advocate for a collaborative approach to addressing ecological, social, and economic issues over vast geographic areas, such as ecoregions or watersheds. LCCs want to create more effective and efficient conservation results by combining efforts and pooling resources.

KEYWORDS:

Genetic Data, Landscape Genetics, Landscape Ecological, Landscape Characteristics, Population Genetics.

INTRODUCTION

The Landscape Conservation Cooperatives (LCC) are a 2009 network of 22 regional conservation organizations that encompass the whole United States and nearby territories. They are self-governing cooperatives funded by the US Department of the Interior with the goal of developing coordinated conservation techniques applicable to wide regions of terrain. Conservation groups, both government and non-government, create alliances. Similar programs have begun or are being promoted in various regions of the globe. Conservation organizations must overcome barriers to cooperation, build governance structures, combine ecological, biological, and physical sciences with social science insights, and improve with new information in response to rapid changes in large landscapes and marine landscapes, as well as uncertain environmental and social changes. The Adaptive Common Governance Framework is a social network backed by many stakeholders that provides adaptive knowledge via dynamic learning. Deep-rooted organizational culture, competing tasks/jurisdiction, and competing stakeholder interests are all barriers to adaptive co-governance. Bridging entities may encourage adaptive co-governance by providing communication, a platform for relationship development, and stakeholder involvement. This research emphasizes the need of institutionalizing social ecosystem adaptive adaption and proposes that landscape conservation cooperatives (LCCs) develop cross-border entities within a larger framework of common governance. Rural credit cooperatives are a network of government and non-government organizations that seek to maintain rapidly changing social ecosystems by providing a framework and incentives for cooperation and shared learning [1].

Modern landscape planning and design is a body of work that organizes man's interaction with environment in the course of human growth, societal advancement, and natural evolution. Land development, land use, and environmental quality are some of the issues covered in landscape planning study. Troll coined the term "landscape ecology." The landscape was defined as "the whole of space and everything that the vision touches in the human living environment." Buchwald considers the so-called landscape to be a full aspect of a certain place on the surface. The notion of the complete human ecology was introduced by Egler. Dansereau believes that "human ecology" should be used to analyze the influence of people on the landscape. Mc Harg advocated that landscape ecology and landscape ecological planning be applied to the whole human environment. Landscape planning is the practice of assisting individuals living in natural systems or utilizing the resources in the system to find the most suitable path. It is an ecological theory and knowledge-based strategy.

Landscape ecology investigates the structural and functional interactions between the many landscape features relatively homogenous ecosystems in the human living environment as an important aspect of the broader human ecosystem. Landscape ecology is the overarching philosophy that guides landscape ecological design. The process of humans actively arranging and coordinating the aspects of the whole landscape including natural and cultural features with the information society as the backdrop is landscape ecological design. All landscape features, as a design variable and aim, eventually maximize the structure and function of the landscape system. Landscape planning, in close coordination with spatial planning, offers a full solution. River basin planning, regional planning, land planning, and ecological remediation and restoration are all examples of landscape planning. The items immediately confronting landscape planning have been expanded to include the land complex [2].

Landscape planning is a material spatial plan with the overarching purpose of establishing sustainable landscapes or ecosystems via protection and utilization of land and natural resources. The essential concepts of landscape ecological planning are as follows: natural priority principle, overall design principle, design flexibility principle, and interdisciplinary comprehensive principle. According to Beta Langfi, "it is not only to study parts and processes in isolation, but also the interaction of various parts." The organism as a whole or system should be evaluated. Environmental preservation requires methodical thought. Overall planning necessitates landscape planning.

Maintaining biodiversity in a controlled environment by conserving a representative and well-connected habitat network necessitates protecting, managing, and restoring habitats at many scales. Scholars believe that combining scientific and social sciences in the form of "two-dimensional gap analysis" is a useful instrument for implementing biodiversity policy. The tool connects physiologically relevant "horizontal" ecological challenges with "vertical" institutional and other social issues. It demonstrates how to link the biological and institutional components of biodiversity protection to achieve ecologically sustainable regional development using forest biodiversity as an example. Regional gap analysis, in particular, is used to identify local forest types and define habitat modeling for "green infrastructure" functional connectivity as a technique for horizontal gap analysis. It is recommended for the vertical dimension how to measure the performance of social sciences in implementing biodiversity policies in actual landscapes by identifying institutional constraints to policy implementation. This multidisciplinary approach is thought to be applicable to a variety of different habitats, such as other terrestrial biota and aquatic ecosystems, where functional habitat connectivity, non-linear response to habitat loss, and numerous economic and social advantages coexist. In the same setting.

There is a significant need for policies and practices that incorporate biodiversity concerns into sectors outside of the protected area, particularly given the considerable decentralization of land use choices by local governments. As a result, individuals must create systematic (targeted) protection planning goods that are both user-friendly and valuable to consumers, as well as products that are appropriate to local government officials, consultants, and elected decision makers. Through the systematic conservation planning evaluation of South African subtropical jungle biomes, implementation possibilities and limitations are evaluated from the start in order to collaborate with stakeholders to generate products (maps and guides) that can be utilized for local government land use planning.

Arctic LLC contributed roughly $2 million in financing for climate-related research and data integration in 2010, as well as the same amount of assistance via in-kind personnel contributions and money from other agencies and NGOs. One outcome of this first cycle is the report "Integrating the Alaska Landscape into the Future." The study use a climatic envelope model technique to evaluate how future climate scenarios correspond to average temperature and precipitation levels from 2000 to 2009. According to the findings, nearly 60% of Alaska may be changed into a new climatic biome by the twenty-first century [3]. In 2011, the Arctic LCC will provide $1.3 million in financing and leverage $1 million to more than 20 distinct research and data integration initiatives. The ALCC Steering Committee makes a temporary selection of ideas based on responsiveness, feasibility, degree of collaboration, reaction to management difficulties, and many other criteria for ALCC goals as part of the construction of a long-term scientific strategy. Currently, six technical working groups permafrost, coastal processes, climate modeling, hydrology, Arctic biology, and geospatial data contribute input to the Arctic LCC Science Program, which will guide future project finance options. The proposed plan will be made public before the end of 2011.

The conservation of tropical biodiversity in agricultural landscapes is becoming more crucial as the area covered by natural ecosystems shrinks. The Shadow Coffee Cooperative in El Salvador investigated the influence of local livelihoods, methods of cooperation, and selected biophysical factors on tree biodiversity (height, slope, percent shadow, forest distance, coffee density, and coffee age). The coffee cooperative's tree stock of 51 samples includes 2,743 individuals from 46 families and 123 recognized tree species. Some cooperatives vary in terms of species richness and diameter, and the larger the abundance, the greater the stem density; other biophysical characteristics have minimal influence on variety. The quantity of shade in coffee plants varies amongst cooperatives, particularly during the rainy season. 16% of the species found in two places were found in a survey of surrounding woods and cooperatives (N = 227 species). Three coffee farms account for 35% of all species reported by cooperatives.

According to research, the number of tree species found in coffee plantations rises with the density of shade trees in the system. In turn, the composition of the shady canopy is directly affected by agro-ecological management, which is determined by farmers' livelihood choices and kinds of collaboration. Important considerations include the kind of farmer organization, the expense of preserving protected species, and the possible advantages of safeguarding a farmer's livelihood plan. The area of system protection planning has advanced to the point that it can be used successfully on the mainland. It employs a quantitative geospatial method to spatially prioritize conservation choices, influenced by anything from computer science to conservation biology (Ball et al. 2009). The primary aspect is to conserve ecosystems, species, and processes in the network that are linked to environmental change and can adapt to it. The LCC system spans a large geographic area and is well suited to applied science to achieve the following goals: (a) the layout of core protected areas, (b) network connectivity to address climate change, and (c) assessing land-use vulnerability changes, (d) combining social constraints with biodiversity and ecosystem services goals, and (e) comparing options.

While system protection plans need a big data set on protection objectives, the LCC structure aids in data collecting, resulting in cost savings when partners exchange data and knowledge. Conservation scientists from academic institutions, corporate corporations, and non-governmental organizations work on LCC Science. As stakeholder participation enhances the science of systems protection planning, this collaborative "bottom-up" approach offers modelers with a crucial source of knowledge for creating conservation objectives, setting targets, and analyzing outcomes... Finally, since the collaborators establish a route back to their institutions, organizations, institutions, and the public, the LCC structure is precisely the same as the distribution outcomes. A total of twenty-two low-cost lines are linked to the National Network Coordinator and the Small Employee Network. LCC has already launched wildlife conservation programs involving many states and non-governmental organizations. These are difficult to sustain, however, since there are no nationally administered cooperatives to finance and arrange the essential spatially precise data to assist prioritize regional protection expenditures. When rural information centers concentrate on the whole landscape, species and ecosystems, ecological processes, human effects and interests, and priorities for time and space activities, they often plan (and often carry out) efforts to safeguard the country's biodiversity [4].

DISCUSSION

Landscape genetics is a branch of biology that integrates population genetics with landscape ecology. It basically refers to any research that examines plant or animal population genetic data in combination with data on landscape characteristics and matrix quality in the area where the sampled population dwells. This provides for a more realistic perspective of how populations interact with their surroundings by analyzing micro-evolutionary processes influencing the species in light of landscape spatial patterns. Landscape genetics studies which landscape characteristics impede dispersion and gene flow, how human-induced landscape changes impact population evolution, the source-sink dynamics of a specific population, and how diseases or invasive species move across landscapes.

Landscape genetics varies from biogeography and phylo geography in that it provides information at smaller temporal and geographical dimensions (i.e., individual genetic variation within a population). Landscape genetics has the benefit of not requiring the subjective definition of distinct populations prior to analysis since it concentrates on sampling people. To find abrupt genetic changes between individuals within a population, genetic methods are utilized, and statistical tools are used to link these genetic discontinuities with landscape and environmental variables. Landscape genetics research might have significant implications for conservation biology and land management techniques.

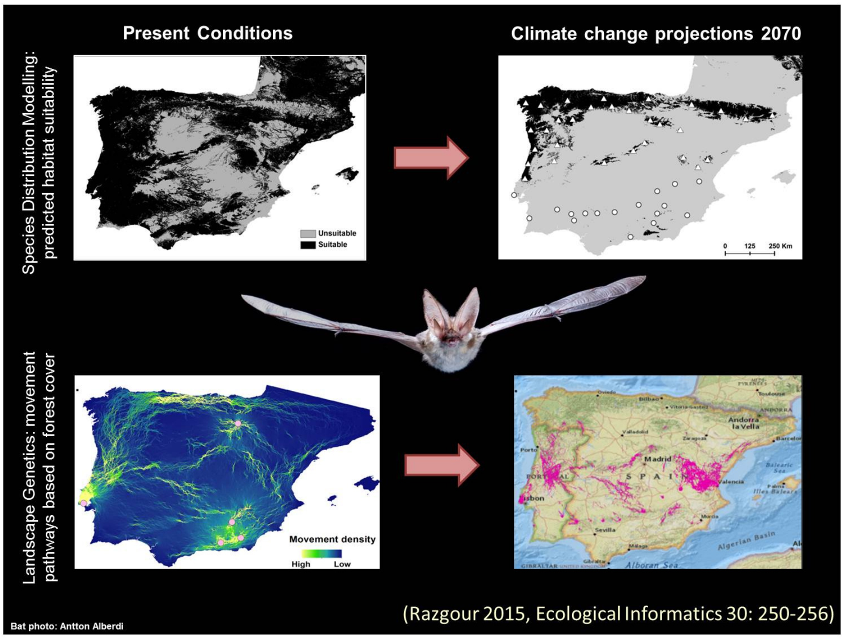
Landscape genetics developed as its own subject in 2003, with the publication of the foundational paper "Landscape genetics: combining landscape ecology and population genetics" by Manel et al. in the journal Trends in Ecology and Evolution. According to the article, the idea that landscape patterns influence how organisms are dispersed goes back to the 18th and 19th centuries, when Augustin Pyramus de Candolle and Alfred Russel Wallace published their works. The present discipline is multidisciplinary, including not just population genetics and landscape ecology, but also spatial statistics. As of 2008, approximately 655 publications in genetics and ecology journals have been published in the topic [5].

Landscape genetics has revolutionized ecological and evolutionary theory by allowing researchers to better grasp how gene flow and adaption occur in natural diverse environments. It has also made it possible to estimate functional connectedness across landscapes. Elucidating landscape characteristics that operate as dispersion barriers or facilitators may help guide the design or maintenance of wildlife corridors that link fragmented areas. Landscape genetics may also aid in predicting how diseases move over a landscape or how planned management activities will influence populations. Finally, landscape genetics may assist in predicting how effectively populations will adapt to ongoing world change.

DNA microsatellites, mitochondrial DNA, amplified fragment length polymorphisms, and allenzymes are examined in random individuals of a certain species over a landscape. These indicators are used to identify an individual's genotype (genetic make-up). Landscape characteristics include landscape composition (the number and diversity of patch types), landscape configuration (how these patches are distributed in space), and matrix quality (the distance in a landscape between patches of habitat for a certain species. Landscape characteristics include topography, height, habitat kinds, and possible obstacles such as rivers or roads [6].

To find genetic patterns from the genetic markers obtained, several statistical methods are used. Fixation index (FST) and Bayesian assignment techniques are often used to divide people into subpopulations based on genetic differentiation or distance. However, these approaches are restricted since persons are sometimes equally dispersed rather than geographically grouped throughout a landscape, and new ways are being developed. To associate genetic patterns with landscape characteristics, statistical procedures such as the Mantel test or partial Mantel test are widely utilized. Linear regression models and ordination methods are also often used. By putting genetic data on a map of the terrain, geographic information systems (GIS) may be utilized to visualize genetic trends across space.

A 2012 research examined the landscape genetics of white tail deer in Wisconsin and Illinois. They retrieved DNA from the lymph nodes of 2,069 harvested deer from 64 townships around the country. For genotyping, fifteen microsatellite markers were employed. Based on the genomic data, a Bayesian population assignment test discovered no different subpopulations. Correlo grams were utilized to illustrate fine-scale social structure, and it was shown that townships that were more densely wooded and dispersed had higher genetic relatedness between individual deer. Broad-scale population connection was shown using spatial principal component analysis. Partial Mantel testing discovered a link between genetic distance and geographical obstacles, namely highways and rivers (Figure.1). These, however, were not absolute barriers that separated the deer into discrete subpopulations.



(Razgour 2015, Ecological Informatics 30: 250-256)

Figure 1: Landscape genetics: Diagram showing the overview of the landscape genetics (Global change genetics).

The discovery of strong genetic linkage among the deer studied has management implications for establishing harvest and population targets. The discovery of strong genetic linkage among deer has implications for the spread of chronic wasting illness. Seascape genetics is a subfield of landscape genomics that scientists began using in 2006. Landscape genetics, breakthroughs in genetic laboratory equipment, and greater resolution marine environmental data all contributed to the creation of this area. Seascape genetics, like landscape genetics, is an interdisciplinary field. Oceanography, ecology, and population genetics are all areas of knowledge employed in seascape genetics. Because of differences in connection in the aquatic environment, seascapes vary from landscapes. Currents allow for improved connection in certain areas while restricting connectivity in others. Many creatures that dwell in the water depend on currents to transport their gametes and larvae, a process known as dispersion. Variable dispersal availability results in subpopulations with varied structures; as a result, subpopulations are subject to diverse selection pressures, suffer distinct rates of drift, and have distinct genetic diversity [7].

To further understand dispersion, seascape genomics uses genetic markers in conjunction with current trends. Another significant distinction when investigating marine systems is that many creatures have extraordinarily huge populations. Significant population numbers in the maritime context allow for increased adaptation potential with bigger effective population sizes, implying that the proportion of the population reproducing and passing on genes rises. Selection has a bigger impact on a large population than drift, hence marine creatures are more likely to have higher degrees of local adaptation. When the whole life cycle is unknown or cannot be examined using ecology, genetic data provides for improved species knowledge and tracking in seascape assessments. Population genetics encompasses a wide range of ideas and approaches, all of which must be considered while conducting seascape and landscape analysis. There are numerous methods for gathering genomic data. Single nucleotide polymorphisms (SNPs), mitochondrial DNA, random amplified polymorphic DNAs, microsatellites, all zymes, and whole genomes have all been popular tools in seascape genetics. In the past, gathering and processing adequate samples was a time-consuming operation. Because it enables for the quick sequencing of extraordinarily large genomes, next generation sequencing has helped to extend the study of landscape genomics [8].

Seascape genomics may be used to solve concerns concerning genetic impacts on population dynamics in marine organisms with varied life histories. Analyses on sessile creatures, animals that live in the same location their whole lives, such as clams, may be readily investigated to better understand environmental evolutionary forces. Salmoni et al. for example, utilized environmental data and genetic research to uncover a heat resistant gene in corals. Many more research on creatures such as oysters, seagrass, and mussels have been conducted. Seascape genomics has also been used to study motile creatures, or animals that can move about. DiBattista and his colleagues investigated how hydrodynamics impacts snapper larval dispersal and were able to assess population connectedness. Seascape genomics research may be utilized in conservation and restoration initiatives. This sort of research may assist in defining resilient people or classifying regions that would be ideal for marine protected areas owing to their ecological function.

Landscape genomics, like population genomics, connects genetic data with landscape data, but the genetic data originates from many loci (locations on a chromosome) throughout the organism's genome. Landscape genomics often examines single nucleotide polymorphisms at hundreds of loci, while landscape genetics generally measures fewer than a dozen distinct microsatellites in an organism. This enables the detection of outlier loci that may be selected. Correlation with landscape data enables the discovery of landscape elements that influence genetic adaptability. Because of advancements in next-generation sequencing methods, this sector is expanding [9].

As a young and rapidly expanding multidisciplinary discipline with no clearly established best practices, it has been plagued by faults in both research design and interpretation. A 2016 paper listed four typical difficulties in landscape genetics research that should be addressed. These include thinking that gene flow is always beneficial, overgeneralizing findings, forgetting to examine other processes that influence population genetic structure, and mistaking quantitative approaches for rigorous research design. Authors have been specifically urged to report on their sample strategy, repeatability of molecular data, and information on the geographical data collection and spatial analysis used. Because the effects of landscape on gene flow are not universal, broad generalizations are not possible, and species-specific research are required Many of these stumbling blocks stem from the multidisciplinary character of landscape genetics and might be avoided with stronger cooperation among experts in population genetics, landscape ecology, spatial statistics, and geography [10].

CONCLUSION

Landscape genetics uses genetic data, spatial analytic tools, and ecological information to answer concerns about the effects of landscape changes on genetic processes and biodiversity conservation. It sheds light on the consequences of habitat fragmentation, landscape connectedness, and gene flow obstacles on population survival, adaptability, and evolution. Landscape genetics may inform conservation and management efforts by integrating genetic and landscape data. It aids in the identification of regions with significant genetic diversity and connection, which are critical for sustaining genetic resilience and adaptive capacity. Landscape genetics may also be used to influence the design of protected areas, restoration initiatives, and landscape planning in order to enhance genetic diversity and sustain population connectedness.

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CHAPTER 21

GAPS IN TROPICAL FORESTS AND THE MAINTENANCE OF PLANT SPECIES DIVERSITY

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ABSTRACT:

Gaps, also known as canopy openings or treefall gaps, are essential biological characteristics of tropical forests that help to sustain plant species variety. When a mature tree falls or dies, it leaves holes in the forest canopy. These gaps vary in size, shape, and length, and they produce distinct microenvironments that impact the composition and dynamics of plant species. The following are some essential aspects concerning the significance of gaps in preserving plant species diversity in tropical forests: Gaps allow for the development and growth of new plants. Gaps enable more sunshine to reach the forest floor, promoting seed germination and seedling development. Shade-intolerant plant species that need a lot of light to develop flourish in these canopy openings. Gaps provide ideal circumstances for the recruitment of tree species that would otherwise be unable to establish themselves beneath a dense forest canopy.

KEYWORDS:

Gap-Phase Regeneration, Treefall Gaps, Tree Species, Species Diversity, Shad-Tolerant Species, Resource Partitioning.

INTRODUCTION

Treefall gaps, one of the most important types of disturbance in tropical forests, are thought to preserve species variety in three distinct and non-exclusive ways. First, they generate high light environments, allowing early successional shade-intolerant and intermediate-tolerant species to achieve reproductive age and hence avoid competitive elimination by more shade-tolerant species. Second, species may specialize on and divide resources along resource gradients that differ significantly from the gap center to the forest interior, allowing for species coexistence. Third, species might specialize along a gap size gradient, with certain species regenerating in tiny gaps and others in big gaps, allowing for stable species coexistence. The gap theory has mixed support, however data shows that certain plant groups may benefit more than others from gaps. For effective regeneration or reproductive maturity, pioneer tree species and at least some liana species seem to need or rely on gaps [1].

This may also be true for shrubs and herbaceous plants, however these growth types are seldom taken into account in gap dynamics research. Gaps not only offer a critical regeneration habitat for particular growth forms, but they may also supply the resources required for reproduction; this latter element of gap dynamics has received less attention. In contrast, gaps do not seem to preserve shade-tolerant tree variety, which might be owing to a combination of seed, dispersion, and recruitment limitations, the latter likely due to competition with other plants, notably lianas. Nonetheless, treefall gaps preserve the variety of certain plant groupings, which may constitute a considerable fraction of the vascular plant population in many tropical forests. There is a long history in ecology of the establishment of treefall gaps and their impact on forest regeneration and dynamics.

Whitmore proposed that "gaps, openings in the forest canopy, drive the forest cycle," and that "the gap phase is thus the most important part of the growth cycle for the determination of floristic composition." Watt, Autryville, and Jones described the patchy nature of mature forest communities. Watt expanded on these concepts by defining "the gap phase" as a general phenomenon in which succession occurs within tiny areas of relatively stable plant communities independent of habitat. Following the development of non-equilibrium explanations for diversity maintenance a number of authors expanded the concept of gap-phase regeneration into an important theory to explain the maintenance of species diversity in tropical forests. The variety of ideas on the role of gaps in the maintenance of diversity can be synthesized into a single "gap hypothesis." The formation of canopy gaps by the death of one to a few canopy trees creates sufficient resource heterogeneity to allow for resource partitioning and niche differentiation, or releases sufficient resources (e.g., light and nutrients) to allow the establishment or reproduction of plant species that would otherwise be excluded. While most of today's gap theory was developed in the late 1970s and early 1980s, community-level empirical testing of this hypothesis were rare until the late 1990s. Given the gap hypothesis's historical significance, it is surprising that few research directly investigated it in tropical forests. Previous experiments focused on plants' ability to split resources or react quickly to increased resource availability. Collectively, these experiments revealed that gaps preserved the variety of certain plant development types whereas gaps did not preserve the diversity of others. As a result, evidence supporting the gap hypothesis as a universal mechanism for preserving plant species variety is likely to be dependent on the functional category or growth type under investigation [2].

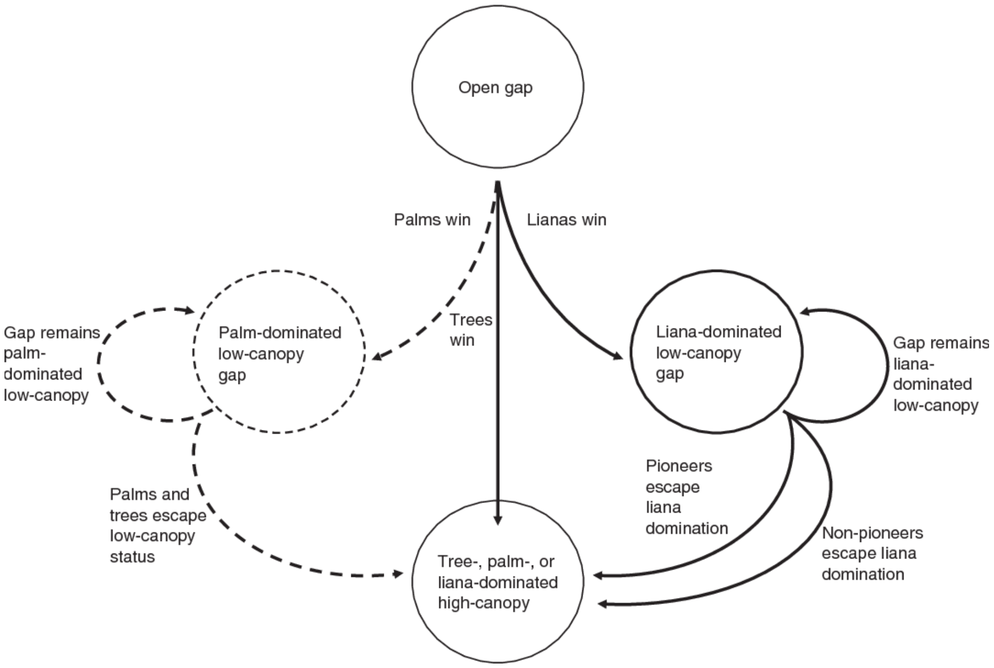

Figure 1: Model of potential gap-phase regeneration routes: Diagram showing the Model of potential gap-phase regeneration routes (Semantic scholar).

The purpose of this chapter is to consolidate new and previously published data in order to present a coherent picture of the function of treefall gaps in tropical forest regeneration and dynamics, as well as to establish the degree to which the gap hypothesis has empirical validity. We will specifically describe and investigate the following key topics the main processes and pathways of gap-phase regeneration the models and mechanisms proposed to maintain diversity through treefall gaps empirical evidence for the gap hypothesis as applied to major plant growth forms or functional groups variation in the impact of gaps across broad environmental gradients the relationship between the gap hypothesis and the intermedia hypothesis. We define the gap hypothesis as canopy gaps caused by the standing mortality or toppling of one to a few trees, or by a major limb-fall. Larger-scale stand replacement disturbances are not covered by the gap theory. We recognize that there is a continuum of disturbance events ranging from small gaps to large clearings however, single- to multiple-tree canopy gaps are the most common type of disturbance in many tropical forests.

Gap-phase regeneration processes and pathways

The process of gap colonization may be classified into four different types, only some of which are mutually incompatible. Plants recruit from seeds that were present in the soil seed bank before to gap development or are disseminated into the gap by wind or animals shortly thereafter (Figure.1). For germination, seeds of shade-intolerant pioneer species often need the high light and temperature conditions of gaps. Once established, these forerunners may fill voids in the market via exceptionally quick growth rates. Shade-tolerant species may also recruit from seed just after gap development. As a result of advanced regeneration. Shade-tolerant seedlings and saplings in the understory develop quickly to fill the gap. Resulting from vegetative reproduction. Trees or shrubs inside the gap or lianas pushed into the gap by fallen trees generate multiple clonal shoots. From the surrounding undamaged woodland growing laterally into the gap. Some growth forms, primarily lianas and herbaceous vines, may recruit into and fill treefall gaps by growing laterally from neighboring intact forest. Trees use the first two regeneration pathways and occasionally the third, whereas lianas use all four due to their ability to disperse seeds throughout the forest, persist in the shaded understory, rapidly produce clonal shoots from fallen stems, and maintain positive growth rates in the understory [3].

While crown growth is not a true recruitment pathway in the sense of those mentioned above, it is likely responsible for the partial or complete closure of small gaps originating from the death of a single small tree or a large limb. Plant recruitment and growth are especially strong after gap creation over the first several years.

Most lianas survive the first treefall, after which they proliferate copiously, generating a thick tangle of vegetation in the high resource environment. Lianas that colonize the gap from seed or advance regeneration, or that grow into gaps from the intact forest, all contribute to these liana tangles, which can continue to grow in size and density if lianas do not find trellises. Once established, liana tangles obstruct and delay gap-phase regeneration of trees by a combination of below-ground competition, light pre-emption, and mechanical interference. Lianas may stymie gap-phase regrowth at low canopy heights for at least 13 years, and possibly considerably longer. Some trees) may eventually escape vertically through the liana tangle and close the canopy. The legacy of these previously halted gaps is often an impenetrable tangle of liana stems that persist in the understory

When palms are plentiful in a recently created gap, they might produce an entirely distinct successional trajectory of gap-phase regeneration. Understory palms limit seedling regrowth by providing heavy shadow and dropping enormous fronds that decay slowly and suffocate seedlings. As a result, prior to gap formation, there is often a depauperate seedling layer underneath palms in intact forests. Palms may also operate as a regeneration filter, allowing only particularly shade-tolerant species that are also resistant to mechanical injury to fill the newly formed gap. Thus, the suite of species found in palm-dominated gaps may vary significantly from that found in liana-dominated or tree-dominated gaps, and the route of gap-phase regeneration in a particular forest would most likely rely on the relative abundance of the various growth types.

Hypotheses and Mechanisms for Maintaining Diversity

Theories that invoke disturbance as a mechanism for maintaining diversity frequently assume that communities never reach an equilibrium state because disturbance prevents competitively dominant species from excluding competitively inferior, early successional species. Because the death of a canopy tree and the subsequent formation of a treefall gap initiate a successional sequence that begins with pioneer species and eventually transitions to dominance by shade-tolerant species, the gap hypothesis may be considered a non-equilibrium mechanism for the maintenance of diversity. Thus, treefall gaps provide a regeneration niche for shade-intolerant pioneer species or intermediate shade-tolerant species to establish and regenerate, preventing competitive exclusion from the community [4].

This is the most basic form of the gap hypothesis, which allows the coexistence of both early successional species occupying gaps and late successional species occupying gaps at the landscape scale. The gap hypothesis also offers an equilibrium and stabilizing niche-based explanation for diversity preservation. Light, soil moisture, and soil nutrients, for example, may be partitioned by species with differing regeneration needs. If each species competes optimally for a specific combination of resources, then within-gap resource gradients may allow species to coexist in equilibrium across the landscape, provided that the species is not seed limited and can disperse its seeds to newly formed gaps. Species may also specialize along a gap size gradient, with some specializing in tiny gaps and others specializing in big gaps. Gaps encourage species cohabitation by creating a varied environment at the landscape scale, with gaps of varying widths offering varying quantities of resources on which various species specialize. The resource niche perspective implies that gaps provide sufficiently substantial resource gradients, either inside the gap or between gaps, for species to live stably at equilibrium.

These three proposed mechanisms for maintaining diversity through canopy gaps provide the following testable prediction resources will be measurably more heterogeneous within gaps (or among gaps of different sizes and characteristics) than in a comparable area within the intact forest; some species will require the increase in resource quantity or heterogeneity from canopy gaps to establish and survive some species will require the increase in resource quantity or heterogeneity from canopy gaps to establish and survive Even though thinning diminishes diversity as gaps narrow, gaps may retain diversity if they are high fecundity places for numerous species. The gap hypothesis's second and third predictions have received little attention.

There is evidence that gaps preserve a high amount of tropical plant species diversity, especially for certain plant groupings. Pioneer tree species, for example, need gaps for colonization and regeneration, which are nearly always lacking in the entire shaded understory. Thus, for pioneer trees to survive in the community, cyclical and predictable disruption from treefall gaps is required. Pioneer trees recruit into gaps immediately after gap development and are eventually replaced by shade-tolerant species in the idealized success sional route in tropical forests. If species are individually adapted to resources in various zones within a single gap or among gaps of varying sizes, resource partitioning may be used to preserve tree variety. Popma et al. found that numerous pioneer species exhibited strong preferences for regeneration in either the gap center or the margin of a rainforest in Los Tuxtlas, Mexico.

Brokaw found that Trema micrantha, Miconia argentea, and Cecropia insignis all specialized in varying widths of gaps in a Panamanian damp forest. While gap-size partitioning may occur when gaps differ greatly in size (and thus microclimate), Brown argued that the relationship between gap size and microclimate is unpredictable due to large spatial and temporal variation in microclimate. Brown and Whitmore and Whitmore and Brown, for example, found no evidence to support the hypothesis that pioneer tree species specialized on gaps of varying widths in a Malaysian tropical forest. Nonetheless, there is little disagreement on the overall requirement of gaps in tropical forests for the survival of light-demanding pioneer plants. Is shade-tolerant tree diversity maintained by treefall gaps via resource partitioning inside or between gaps? Many tree species vary in their growth rate or have a trade-off between growth and survival that is dependent on their light compensation point. While the light compensation requirements of pioneer and shade-tolerant species differ significantly, lesser differences among shade-tolerant species may also be sufficient to allow their coexistence along light gradients, which are known to exist within and between gaps, as well as in the intact forest [5].

Thus, resource partitioning may be able to preserve the variety of shade-tolerant species; however, in situ evidence of niche partitioning leading to species cohabitation are required to confirm this assertion. There is currently only a limited amount of evidence that shade-tolerant tree species divide resources inside or across gaps, for example, showed that some shade-tolerant tree species were non-randomly connected with various locations inside gaps. However, there is no solid evidence that gaps sustain more than a handful of the hundreds of shade-tolerant tree species in tropical forests by resource partitioning within or across gaps. As a result, the gap hypothesis has received considerable criticism as a mechanism for maintaining tree species diversity because it appears to fail to explain the maintenance of diversity for a dominant group of species: shade-tolerant tree species for example, performed a sapling census of over 1200 canopy gap and non-gap sites in a permanent 50 ha old growth forest plot on Barro Colorado Island (BCI) in central Panama. After accounting for density differences between gap and non-gap sites, they concluded that gaps played a "relatively neutral role in maintaining [tree] species richness." Similarly, Brown and Jennings questioned whether a gradient in light availability was a viable axis for niche differentiation in the majority of tropical trees. Furthermore, these authors contended that the "excessive emphasis" on treefall gaps has diverted attention away from other essential processes that more likely impact community composition. As a result, there are still radically opposing opinions on the gap hypothesis's feasibility as an explanation for the persistence of species variety in tropical forests.

Most gap studies have overlooked important plant groups other than trees, as well as the influence of gaps on plant reproduction. Although lianas are infrequently studied in gap research, they are an essential component of many tropical forests due to their high stem density and leaf area, are much diversified, and have a direct and distinctive influence on gap-phase regeneration.

In many tropical forests, lianas account for around 25% of woody stems and almost 30% of woody species. Schnitzer and Carson found that liana and pioneer tree abundance (density) and richness were significantly higher in both 5- and 10-year-old gaps than in non-gap sites on both a per area and per stem basis in a test of the gap hypothesis in the same 50 ha area of for est on BCI where Hubbell et al. (1999) found no difference in tree diversity between gap and non-gap sites.

Lianas and pioneer trees may account for more than 40% of woody species variety in many tropical forests, suggesting that gaps are critical for preserving woody species diversity even if they do not preserve shade-tolerant tree diversity. Lianas may be very plentiful and varied in gaps because they may colonize gaps in four different ways, while trees usually only employ two. Lianas, like trees, invade gaps both from seed and by advance regeneration. In addition, most studies have failed to consider the per capita impact of gaps on size- or age-specific rates of reproduction of species. For example, if gaps increase light and allow shade-tolerant trees to become reproductive or produce more seeds while still in the understory, then they may promote diversity by increasing fecundity. This aspect of the gap hypothesis has received little attention, but it may be especially important for herbs, herbaceous vines, shrubs, and mid-sized trees, which do not typically reach the canopy but may rely on treefall gaps to initiate reproduction [6].

The fertility of forest herbs and shrubs, for example, may be much greater in gaps than in neighboring complete forest. These groupings of understory plants account for almost one-third of the vascular plant flora on BCI; when coupled with lianas and pioneer tree species, they account for 65% of all plant species on BCI and the bulk of tropical forest flora globally. When both reproduction and diversity are considered, gaps may retain the bulk of the flora in many tropical forests. To fully understand the impact of treefall gaps in sustaining species variety, both species growth and survival, as well as reproductive output, must be examined. Shade-tolerant trees, lianas, and treefall gaps Despite the fact that just a few studies have been conducted, gaps do not seem to have a significant impact on the area or per capita variety of shade-tolerant tree species. Shade tolerant trees typically establish prior to gap formation and are present as advance regeneration; thus, processes that occur prior to gap formation may influence the composition and abundance of species that are available to exploit a newly formed gap. Furthermore, many shade-tolerant tree species are constrained by low seed production or poor dispersal, and thus cannot distribute enough propagules into newly formed treefall gaps to exploit these ephemeral, high-resource environments. Finally, lianas and palms may co-opt gap phase regeneration in treefall gaps, reducing shade-tolerant tree abundance and diversity.

Shade-tolerant trees may have structural traits that make them more vulnerable to liana competition. Shade-tolerant tree species develop slowly and are evolved to optimize light interception by forming a dense canopy of branches that may serve as trellises for lianas, enabling them to ascend and occasionally cover shade-tolerant trees beneath a layer of foliage. Pioneer trees and palms, on the other hand, have characteristics that may assist them to shed or avoid lianas, such as quick growth, smooth or peeling bark, and a monopodial, unbranched trunk. While the severity of liana competition varies according to tree species identity, with lianas affecting some tree species or guilds more than others, lianas may create conditions in gaps that are harmful to shade-tolerant species.

Lianas also lowered the relative growth rates of shade-tolerant trees significantly. However, lianas had little effect on shade-tolerant tree death, suggesting that lianas diminish shade-tolerant tree density via restricting recruitment and growth rather than raising mortality. Nonetheless, shade-tolerant tree mortality was somewhat greater in areas where lianas were present, and the overall accumulation of shade-tolerant trees (recruitment minus mortality) after 8 years was 70% higher in gaps where lianas were removed. As a result, gaps may fail to preserve shade-tolerant tree variety because lianas significantly limit shade-tolerant tree recruitment into gaps. Previously, the absence of shade-tolerant tree recruitment in gaps was taken as evidence of seed or dispersion constraint. However, our findings show that lianas also have a role in reducing shade-tolerant tree recruitment in gaps. Further study is needed to identify the relative relevance of plant competition against seed and dispersion restriction in explaining why gaps fail to maintain shade-tolerant tree variety [7].

DISCUSSION

The effect of gaps on species diversity and forest regeneration is anticipated to vary across large-scale environmental gradients. In theory, the impact of gaps should be greatest in forests where treefalls generate steep resource gradients from the gap-center to the undamaged understory since these steep gradients give the greatest possibility for resource partitioning. Gaps should be especially critical in a seasonal tropical wet forests, which have dark understories and rather poor soils. The combination of high year-round cloud cover, few deciduous trees, and many understory strata that effectively intercept light before it reaches the forest floor causes these gloomy understories. Light level gradients from a gap center to the intact forest, on the other hand, are likely to be much lower in seasonally moist and dry forests, which tend to have lower cloud cover and a much higher proportion of deciduous trees, allowing far lighter to penetrate the intact canopy into the understory, especially during the dry season. Dry woods, in example, have shorter stature, less complicated structure, and smaller leaf area, allowing more light to penetrate all year. The steepness of nutrient gradients in treefall gaps often mirrors that of light gradients: it rises with increasing rainfall.

The nutrients in the photomasks go into the soil when a tree dies, where they are swiftly digested by resident flora or leached from the soil. The availability of nutrients in a treefall gap may offer a high, if transitory, gradient, particularly under the fallen crown, when leaves release a pulse of nutrients into the soil. Although there are exceptions to this general trend, nutrient gradients should be steepest in a seasonal wet forests, which may have lower nutrient levels because high year-round precipitation leaches nutrients out of the soil. Treefall gaps may also be more prevalent in a seasonal forests than in seasonally dry forests, due to the year-round occurrence of unstable, waterlogged soils, which increases treefall rates.

If this is true, the increased frequency of gaps may help to alleviate dispersion constraint in wet forests by shortening the distance between gaps and propagule sources, allowing for better resource partitioning over the landscape. Furthermore, since liana abundance is lower in a seasonal wet forests, the detrimental effect of lianas on tree recruitment and development of shade-tolerant trees may be significantly smaller. Overall, we estimate that gaps will have the greatest influence on the preservation of variety and forest regeneration in a seasonal wet forests because light is most limited in the understory, nutrient gradients are more extreme, and gaps are more likely to occur. To investigate this notion more completely, comparative investigations of gaps along precipitation gradients are necessary. The intermediate disturbance hypothesis (IDH) says that diversity will be strongest at intermediate levels of disturbance magnitude and frequency, as well as time since the previous disturbance [8].

Large and frequent disruptions, according to the IDH, limit diversity by physically removing individuals and thereby extirpating species. When disturbances occur infrequently, competitive exclusion occurs, resulting in lesser species diversity. Diversity will peak only at some intermediate threshold of disturbance. If treefall gaps reflect an intermediate degree of disturbance in tropical forests, the gap hypothesis might be explored within the context of the IDH. The underlying problem with this strategy is that treefall gaps are unlikely to be wide enough or varied enough in size to properly test the IDH. Even if the gaps covered a wide enough range of disturbances that diversity changed with gap size, testing the IDH with treefall gaps is problematic since the lack of a unimodal response does not rule out the IDH. A linear rise in variety with gap size, for example, may imply that the gap disturbance is on the low disturbance side of the unimodal IDH curve.

A positive association between gap size and diversity, on the other hand, does not indicate whether the real curve would ultimately become unimodal with diminishing disturbance. Hubbell, for example, used species-individual curves from BCI to contradict the IDH, demonstrating that species accumulation (diversity) rose as gap size decreased, with the non-gap forest having the maximum diversity accumulation. The IDH may still be valid if diversity drops when disturbance levels fall below the baseline (non-gap) disturbance regime on BCI. Even the old growth forest on BCI has a history of disturbance, which might indicate that it is still experiencing succession, and so diversity in the non-gap forest could potentially diminish over time, which would be consistent with the IDH. Furthermore, Hubbell et al. ignored growth types most likely to be disturbance sensitive in light-limited forests. A robust examination of the IDH necessitates taking into account key important development forms throughout a disturbance gradient spanning from minor to catastrophic. These constraints make rigorous IDH testing exceedingly difficult. Treefall gaps provide both equilibrium and non-equilibrium reasons for the preservation of species diversity in tropical forests. Although the gap hypothesis is one of the principal theories presented to explain the persistence of species variety in tropical forests, more work has to be done to evaluate the entire range of predictions derived from this theory. Currently, the degree to which gaps preserve variety is believed to be determined by the growth form and life-history features of the species under consideration. The variety of liana and pioneer trees, as well as shrubs and herbaceous plants, seems to be preserved to a significant extent through treefall gaps. Little evidence shows that gaps preserve shade-tolerant tree variety, owing to dispersion and recruitment constraints, which may be worsened by liana competition. A thorough examination of the impact of gaps on the diversity of all dominant plant functional groups (e.g., trees, lianas, shrubs, and herbs), as well as an examination of whether gaps allow some species to remain in the community by increasing size-, age-, or growth-form-specific rates of reproduction [9], [10].

CONCLUSION

It is vital to remember that the magnitude and length of gaps might have an impact on plant species diversity. Greater gaps support a greater variety of light-demanding species, while smaller gaps may benefit shade-tolerant species. Furthermore, the time it takes for gaps to close and return to a closed canopy state may have an impact on the persistence of gap-associated species. Understanding the dynamics of gaps and their ecological importance is critical for tropical forest conservation and management. Conserving and fostering gap dynamics within tropical forests may help preserve plant species variety, assist forest regeneration processes, and improve forest ecosystem resilience in the face of disturbances and environmental changes.

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CHAPTER 22

JANZEN-CONNELL HYPOTHESIS TESTING AND FALSIFICATION CHALLENGES

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ABSTRACT:

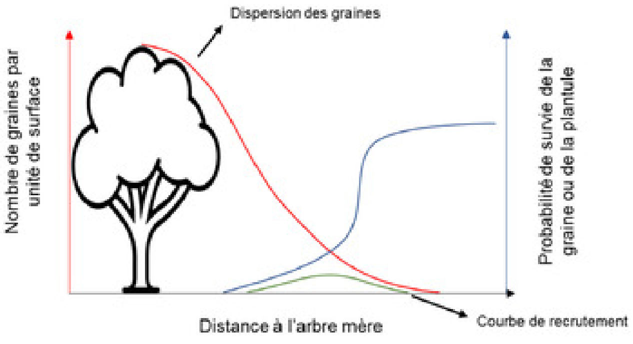
The Janzen-Connell hypothesis is an ecological theory developed in the 1970s by Daniel H. Janzen and Joseph Connell. According to the concept, plant species diversity in tropical forests is maintained by a mix of specialized herbivory and disease interactions. It is proposed that host-specific herbivores and infections have a higher influence on common plant species' survival and development, while less common species endure less herbivory and pathogen pressure, enabling them to survive and cohabit.

KEYWORDS:

Janzen-Connell Theory, Janzen-Connell Effects, Pest Pressure, Tropical Forests, Woody Species.

INTRODUCTION

The Janzen-Connell theory posits that natural enemies govern plant populations based on density and distance, hence increasing alpha-diversity and perhaps contributing to the latitudinal gradient in species richness. Over 50 research have been conducted to test the predictions of this concept, and our assessment reveals that numerous tree species display patterns compatible with Janzen-Connell effects. In this section, we discuss research aiming to test the Janzen-Connell hypothesis and highlight a number of general difficulties and obstacles associated with evaluating it. First, the Janzen-Connell hypothesis is primarily a community-level theory that predicts that enemies create increased alpha-diversity; however, this important prediction has yet to be validated at the right size. Second, in its broadest sense, the Janzen-Connell theory is a kind of keystone predation in which expert foes hold superior rivals in check (Figure.1). It is uncertain if the elimination of enemies for any woody species would result in a decrease in alpha-diversity [1].



Modèle de l'effet Janzen-Connell, adapté de Janzen (1970)

Figure 1: Janzen-Connell theory: Diagram showing the overview of the Janzen-Connell theory (wikiwand).

Overall, the Janzen-Connell theory is difficult to refute since it may increase variety if enemies serve as keystone species by retaining only a small proportion of better rivals in low abundance. Rare species with shade-tolerant juveniles and big seeds may be the most likely to exhibit Janzen-Connell effects but are less likely to be included in research owing to low adult population numbers. Third, Janzen-Connell effects are characterized by complicated trade-offs, specifically a trade-off between competitive or establishment competence and susceptibility to foes. Many Janzen-Connell hypotheses tests implicitly imply that features conferring high survivability in the shade are linked with qualities that promote survivability under sustained pest pressure in the understory. This association does not true for all shade-tolerant tree species, and the strength of this relationship must be investigated directly. As a result, an often ignored but significant trade-off for plant species coexistence may be the allocation of physiological and morphological qualities conferring survival in low light vs those conferring survival under varied degrees of pest pressure. Fourth, occasional outbreaks of specialised pests, which may impair adult survivability, growth, and fecundity when adults are highly aggregated, may help to preserve variety [2].

Although the influence of enemies on adults was first stressed by Janzen, it has gotten significantly less attention than the effect of enemies on juveniles, despite the fact that it is widely recognized to be relevant outside of the tropics. Despite the challenges, Janzen-Connell effects are ubiquitous in tropical environments and are therefore a probable fundamental mechanism for sustaining high plant variety. The Janzen-Connell hypothesis states that specialist pests and pathogens keep key plant species rare enough or reduce their competitive ability enough to allow space for many other species. In ecology, this concept has a long history. "Where too many plants of one species are grown together, they are very apt to be attacked by some pest, insect, or fungus," Ridley observed almost 80 years ago. It is partly owing to this, in Nature, because one plant associations are avoided and neutralized by improved seed distribution." Later, Gillett offered a non-equilibrium version of this idea. Finally, Janzen and Connell established this concept as a staple of tropical biology. They both showed evidence that tree seedlings and saplings display repelled recruitment patterns near adults, possibly opening up room for a variety of plant species. This broad premise was acknowledged as valid by MacArthur. Nonetheless, a meta-analysis conducted by Hyattet al. (found little support for the hypothesis's distance-dependent prediction and concluded that "further testing to explore this hypothesis as a diversity-maintaining mechanism is unnecessary." In the end, they were unable to prove the hypothesis's validity beyond a reasonable doubt. Below, we evaluate research that investigated various components of the Janzen-Connell hypothesis and discuss a variety of concerns and challenges related with it.

We omitted a limited number of studies (less than five) that solely examined static distribution patterns of one life-history stage as a function of distance from the closest adult conspecific or conspecific juvenile density. These studies, we felt, were less informative than those that sampled focal plants over time to examine how distance- and density-dependent effects influence performance (survivorship and growth rate), or compared two or more life-history stages to assess changes in distribution patterns due to density- or distance-dependent factors. The bulk of research (58%) concentrated on a single species, 21% on two to nine species, and 21% on ten or more species. The majority of research (51%) were solely observational, 34% were purely experimental, and 15% employed mixed experimental and observational methods. Around 75%

of the research focused on seeds and seedlings, whereas 17% focused on saplings. Only one research focused on adults, and only two looked at all life phases.

Almost half of the papers (47%) omitted to indicate the seed size of the species under research, which Janzen and Connell both considered was relevant. Fifty of the 53 investigations discovered evidence compatible with either density or distance dependence, however half of these studies found no evidence for the mechanism behind the pattern. There was a nearly equal split between vertebrates (eight studies), invertebrates (10 studies), and pathogens (seven research) where a plausible mechanism was tentatively found. Several studies hypothesized that Janzen-Connell patterns were caused by intraspecific competition. Host specificity, another attribute considered crucial by both Janzen and Connell, was recorded in just one-third of the investigations, most likely due to its uncertain status. Five of the nine studies that looked at it found great host specificity, three found poor specificity, and one found both specialists and generalists. The average research period was 3.5 years (4 SD), ranging from 18 years to 0 years.

Which analyzed the dispersion of seeds that exhibited indications of vertebrate and invertebrate predation). Most studies did not sample individuals frequently during time, but merely at the beginning and finish. Ninety-two percent of the research were done at a single location, with 40% of the experiments taking place on or around Barro Colorado Island (BCI). The majority of studies (58%) either explicitly or implicitly considered a number of factors contributing to plant performance in addition to density or distance (e.g., light level, drought, hetero-specific abundance) in lowland and moist tropical forests (72%), with only 13% occurring in other tropical forests (e.g., floodplain, dry, etc.) and 15% in temperate regions. Only seven research looked at the impacts of Janzen-Connell on species diversity [3].

Three of these studies utilized solely BCI data, whereas the other two used both BCI and Pasoh data. As a result, the majority of our generalizations about the Janzen-Connell hypothesis are based on a single forest plot (BCI). The other four investigations did not mention their focus species. Three of these experiments took place on BCI or at Pasoh, and hence the species from these studies and those mentioned would have some overlap. Nonetheless, we recognize that under-represents the species for whom this theory has been investigated, particularly since Peters discovered that almost 80% of 732 species at BCI and Pasoh displayed patterns compatible with the Janzen-Connell hypothesis. The bulk of the species surveyed (81%) were canopy and understory trees, with just a few lianas, palms, and shrubs included. For 125 species, density dependency was assessed. In a species was deemed to have density dependency if density dependence occurred at any point in its life cycle.

40% of the species showed negative density dependency, 57% showed no density dependence or positive density dependence, and 3% had findings that differed among investigations. Distance dependency was assessed for 129 species, with 36% showing Janzen-Connell patterns. Sixty percent exhibited no density dependency or survival reduced with distance from adult conspecifics, whereas 4% had outcomes that differed across research. The majority of the species surveyed (79.8%) came from lowland tropical forests, some of which had long dry seasons. Only 7% of the species were found in dry tropical forests, while fewer than 2% were found in mature tropical floodplains or swampy tropical environments. Temperate forests accounted for 10% of the species investigated, whereas temperate desert forests and montane tropical forests received just one research each. 63% of the species analyzed were discovered on or around BCI. Only 18% of studies provided seed dry weights (X = 1.8 g 3.9 SD). For 27 species, adult abundance was not provided, thus the majority of species were simply classed as common (100 species), moderately abundant (one species), or rare (two species).

The species recorded had a mean abundance of 45 adults per hectare (70.6 SD). This short study evaluation leads us to the following findings. There have now been several investigations of the Janzen-Connell hypothesis's distance- and density-dependent predictions, and many species exhibit Janzen-Connell effects. However, few studies have been conducted outside of the lowland tropics, and Dirzo and Boege expect that pest pressure will be decreased where resource availability is seasonal and episodic (e.g., dry forest). Furthermore, there have been much too few investigations of life-forms other than trees, as well as far too few research of species in places other than on or around BCI. Much more emphasis should be placed on the sources of Janzen-Connell effects and the extent to which they occur in later life-history stages (post small-sapling phases) [4].

Janzen concluded, host-specific or facultative host-specific seed and seedling predators will decrease tree population density of a given tree species and/or increase distances between new adults. Either of these effects of predation will result in "more space in the habitat for other species of trees and thus a higher total number of tree species." As with Paine's original test of keystone predation, the most unequivocal tests of Janzen-Connell will come from studies that experimentally remove enemies or subsets of enemies over long periods of time and quantify the change in species diversity. This is not a simple process, to say the least. Nonetheless, other important hurdles in tropical forest research have been addressed (for example, constructing and sustaining 50 ha plots). Janzen offered five field experiments or observational investigations to evaluate his model's predictions. However, none of these experiments addressed the key prediction that the exclusion of host-specific predators would result in a decrease in diversity as tree species with greater establishment or competitive ability formed low-diversity seedling and sapling communities with dominance concentrated in a few species. Connell proposed such an experiment: "if all enemies of trees were removed from an entire forest, each species would almost certainly develop little groves, and the faster growing species would progressively expand throughout the ecosystem.

The end result would be lower pattern diversity and, as a result, fewer species in any local area of forest." We propose that new studies be designed to test the diversity prediction, building on species-specific studies that have shown patterns consistent with the Janzen-Connell model. In the tropics, there have been a few community-level analyses of Janzen-Connell effects However, these investigations did not explicitly test the diversity prediction, were not experimental, and did not evaluate the reasons of patterns reported to be compatible with Janzen-Connell effects (e.g., pest pressure vs intraspecific competition). According to Wright, "field measurements only show that niche differences, Janzen-Connell effects, and negative density dependence occur." The implications for species cohabitation and plant diversification are yet unknown." Is the Janzen-Connell theory a kind of keystone predation? We believe the Janzen-Connell hypothesis is a form of, or a subset of, keystone predation. Janzen accepted this to some extent in his original study.

Janzen was perplexed as to how so many species could coexist in a tropical environment. His response was that his study was an extension of Paine’s findings that "the number of predators in the system and their efficiency in preventing a single species from monopolizing" space or resources. As a result, we believe the Janzen-Connell theory may be regarded in this broad framework. Natural enemies, according to the keystone species idea, restrict the quantity of superior rivals that might otherwise displace subordinate species, hence increasing alpha-diversity. As a result, the suppression of stronger rivals has the ability to sustain variety. The abundance of potentially dominant prey species (woody species that are superior competitors) does not change the nature of keystone predation, though we acknowledge that traditional ideas about keystone predation did not focus on rare species advantage.

The Janzen-Connell hypothesis is based on complex trade-offs: to what extent are tolerance to pest pressure and tolerance to low light correlated? A trade-off between establishment or competitive aptitude and susceptibility to seed and seedling predation is implicit in the Janzen-Connell theory. Janzen described a trade-off in which large-seeded species are typically more vulnerable to seed predators or less likely to be produced in sufficient quantity to satiate predators but have a higher likelihood of establishing relative to small-seeded species, particularly in deeply shaded microsites. Connell proposed that the trade-off was between vulnerability to predation and rapid growth. Janzen concluded that "a tree may persist in the face of very heavy predation if the occasional surviving seedling is a very superior competitor, and a tree with very light predation may be a very poor competitor yet survive by repeated trials at establishment." Regardless, both stated that trade-offs are likely to play a central part in how Janzen-Connell effects work in tropical forests, a notion shared by others. There appears to be a species continuum in both temperate and tropical forests, ranging from pioneers with rapidly growing saplings in high light to mature forest species with saplings that persist for years in the shaded understory [5].

DISCUSSION

Shade-tolerant species typically have seedlings and saplings with a suite of correlated within shaded understories, dense wood, well-defended leaves, low photosynthetic capacity, slower growth, higher survivability, and low responsiveness to increased light) that confer an advantage both in the shade and under conditions of prolonged exposure to pathogens and herbivores in the understory. It is unknown to what extent features conferring high survivability under low light circumstances are positively associated with those conferring high survivability under extended pest pressure. Shade tolerance has come to be defined in the literature as the capacity to live in the understory for lengthy periods of time while remaining tiny in size.

This characteristic or technique might be the result of various combinations of the capacity to live in low light and the ability to withstand (tolerate, resist, or avoid) protracted periods of browsing or herbivore damage before to reaching a size refuge (e.g., from browsers) or reaching the canopy. In the extreme, a species may be able to live in the shaded understory only in years or locales when pest pressure is exceedingly minimal, resulting in youngsters being observed only seldom. This might lead to the incorrect conclusion that the species is shade sensitive. We provide two instances from North American temperate deciduous woods. Eastern hemlock (Tsuga canadensis) and American beech (Fagus grandifolia) can persist in intense shadow for lengthy periods of time. Beech is also quite browse resistant, although hemlock is not. As a result, when browsers are plentiful, hemlock may fail to regenerate and become limited to refugia, while beech becomes common.

We believe that the degree of shade tolerance for any species will vary and will likely reduce as herbivore damage increases. For example, we discovered that saplings of sugar maple (Acer saccharum), a putatively highly shade-tolerant species, had growth and mortality patterns similar to saplings of black cherry (Prunus serotina), a shade-intolerant species, in the presence of browsers in the understory of a temperate forest. Sugar maple exhibited growth and death patterns consistent with its categorization as very shade tolerant in the absence of browsers. These results highlight the need of rigorously evaluating the link between tolerance to low light and tolerance to herbivore damage, since these characteristics are not necessarily strongly connected across coexisting species. Thus, we hypothesize that there may be another crucial trade-off among certain coexisting species in forest understories, namely allocation to physiological and morphological qualities conferring survival in low light vs traits conferring survival under varied degrees of pest assault [6].

There are hundreds of shade-tolerant species in tropical forests, and their tolerance to herbivores varies - and as herbivore damage grows, the degree of shade tolerance relative to each other may shift significantly. To test the presence of this trade-off or thoroughly evaluate the relationship connection between low light survival and resistance to enemy harm, investigations of growth and survivorship along a continuum of light levels and concurrently a continuum of herbivore or pathogen damage will be required. If species' shadow tolerance hierarchies vary as pest damage rises, forest dynamics models would forecast varied future canopy compositions depending on pest load. The influence of enemies on aggregated adults and outbreaks has been overlooked. The major emphasis of Janzen-Connell model studies has been on how enemies form repelled patterns of juvenile recruitment near adults owing to density- and distance-dependent predation. Studies have devoted significantly less attention to the influence of natural enemies on adult plants; nonetheless, adults in dense aggregations may be exposed to greater per capita rates of pest attack and damage, in addition to their youngsters. Root formalized this concept in a classic paper and proposed the resource concentration hypothesis: "herbivores are more likely to find and remain on hosts that are growing in dense or nearly pure stands." Although much evidence supports this hypothesis for plant populations, its importance for the overall maintenance of diversity in plant communities is underappreciated. Insect herbivores and diseases may operate as keystone species by lowering the vigor, abundance, and fecundity of aggregated stands of adult conspecifics, enhancing the variety of coexisting species. These taxa are often among the most numerous woody species in the community.

As a result, conspecific aggregations are in double risk since both their adults and their juveniles are more exposed to foes and suffer higher per capita rates of assault or injury. In tropical woods, significantly less attention has been paid to how adult aggregations render them more susceptible to predators. Janzen recognized that pre-dispersal seed predation would have a significant influence on the "intensity and patterns of seed shadows cast by parent trees" and considered this a critical component of his hypothesis. Indeed, Janzen proposed a graphical model in which intensive pre-dispersal seed predation resulted in seedling abundance peaks that were smaller and closer to the parent tree than mild pre-dispersal seed predation. As a result, when adults congregate, enemies are more likely to have a stronger influence on both juveniles and adults of any particular plant species. Further, these aggregations may result in periods of abundant insects or episodic outbreaks of specialist enemies that function as keystone species, defoliating and sometimes killing adults over large areas, thereby increasing plant species diversity in the habitat.

When seen from a phytobenthic viewpoint, these outbreaks or times of high insect abundance may be common in the tropics. A specialized outbreak that happens just once every 50 years suggests that it happens several times in the life of a long-lived tree species. In tropical forests, outbreaks of specialists have defoliated common or abundant woody species found in Indonesian forests that outbreaks often occurred when tree species developed in aggregation and that low-diversity stands exacerbated such outbreaks. Because outbreaks are geographically and temporally patchy and occur high in the canopy, they are likely to be more prevalent than previously anticipated. Furthermore, if relatively occasional times of high herbivore abundance manage populations, then short-term studies of insect abundance and dam age, or the occurrence of specialist's vs generalists, will be unimportant for the Janzen-Connell hypothesis. Long-term research is required to determine how insect abundance and damage on adults vary with host abundance, and how this damage influences lifetime fecundity and juvenile mortality. Outside of the Tropics, the notion that insects and insect outbreaks have a substantial top-down influence on plant communities is widely documented. Despite popular belief, there is no reliable empirical data at the proper temporal and geographical dimensions to imply that outbreaks are either less prevalent or have a lower effect in tropical forests than in temperate forests. Janzen-Connell effects may be stronger in tropical than temperate forests due to higher abundances of natural enemies, a greater degree of specialization in a seasonal tropical habitats, and higher rates of damage even when leaves are better defended. Both Janzen and Connell hypothesized that these disparities in species richness may help explain the latitudinal gradient. Despite this, relatively little work has been put into comparing Janzen-Connell effects across latitude. We discovered that the vast majority of research investigating the Janzen-Connell hypothesis were conducted in tropical environments. However, evidence for density- and distance-dependent mortality in temperate forests has been observed in the few temperate studies that have been conducted. HilleRis Lambers et al., for example, concluded that density-dependent mortality occurs equally in temperate and tropical forests, albeit they noted that the severity of Janzen-Connell effects may be larger in the tropics. Furthermore, the logic that implicates the Janzen-Connell hypothesis in the latitudinal gradient in species richness should apply to habitats with substantively different levels of diversity within the same general latitude. Tropical forests with extended flooded or dry seasons generally have lower diversity than a seasonal tropical forests. This seasonality may also reduce the abandoning and impact of natural enemies, weakening the Janzen-Connell effects [7].

Despite this, relatively few research have looked into the Janzen-Connell hypothesis in abiotic ally harsh tropical habitats, and none have sought to compare data from abiotically stressful and abiotically more benign forests. Overall, research is needed to examine the incidence and severity of Janzen-Connell effects, as well as their repercussions, both within and across latitudes, or anywhere there are steep stress gradients and dramatically different patterns of species diversity (e.g., dry season duration). As Janzen pointed out, high predation may maintain certain species scarce and widely dispersed, and these species may also be the greatest competitors. If this is the case, the species most likely to form dense aggregations and limit variety in local stands may be the ones least likely to be examined by ecologists, either because they are so rare or because such rare species are thought to be unlikely to be governed by density dependence.

This suggests that even if just a portion of the woody species in a diversified tropical forest are held in check by their predators, the Janzen-Connell model still remains true if these species are better competitors in the community or can establish and develop fast across the environment, or both. As a result, the inability to identify Janzen-Connell effects for what may be hundreds of tree species does not rule out the theory (though it does diminish the hypothesis's importance in explaining the coexistence of all species in the community). Condit et al., for example, investigated patterns of recruitment near reproductive adults in 80 species. They discovered repelled recruitment syndromes in just 15 species and concluded that Janzen-Connell effects occurred across short distances and in a limited number of species. If, on the other hand, just a few of these tree species were great competitors and pests generated similar patterns, then these pests would be keystone species and Janzen-Connell would be at work. When Hyatt et al. came to the conclusion that there was "no widespread evidence for the distance dependent prediction of the hypothesis. However, Hyatt et al. discovered "individual cases of conformity to the hypothesis," which is all that is required for the hypothesis to work if the specific cases represent tree species that are excellent competitors, highly shade tolerant, or habitat generalists, or some combination of these traits [8].

Evaluating if rebuffed recruitment syndromes are strong for rare tree species, especially shade-tolerant species with big seeds that are ostensibly appealing to seed predators or foes, may provide insight into the challenge of evaluating the Janzen-Connell hypothesis. Exclusion trials (using enclosures or pesticides) nestled under these trees may also result in dense and depauperate stands of young conspecifics in less than a decade. As previously discussed, the Janzen-Connell model is a community-level model whose key prediction is that predation ultimately leads directly to the maintenance of high woody species diversity in tropical forests. To identify predation as the indirect cause of woody species diversity will require long-term experiments that rule out other explanations. Furthermore, Connell believed that predation was more important at the seedling and early sapling stages rather than the seed stage. Because there is little evidence for competition among tropical tree seedlings, even at high densities, experiments may need to be carried out for many years, up to and through the sapling stage, as large and dense understory layers begin to thin. Furthermore, recurrent outbreaks of specialized insects in the understory or over story may generate a Janzen-Connell effect.

If these outbreaks cause the Janzen-Connell effect, then studies will need to go through a normal outbreak cycle, which will very definitely be long for the great majority of species. There are other significant practical and conceptual obstacles to proving the Janzen-Connell hypothesis. These difficulties include identifying the key enemies to exclude in experimental tests the ability to remove or significantly reduce entire or even partial enemy trophic levels over long periods of time (pathogens are a particular challenge) directly linking distance and/or density effects to their putative causes (i.e., enemies) demonstrating the entire chain of events required, specifically that enemies respond in a distance- or density-dependent. Overall, it is quite difficult to dismiss the Janzen-Connell model. The essential tests testing the prediction of more variety must yet be carried out, which will need large-scale, logistically difficult, long-term investigations [9], [10].

A crucial but modest step for testing Janzen-Connell is to connect rejected recruitment symptoms to life-history tactics or features that contribute to good survivability in low light in the absence of attackers. Clearly, theoretical techniques that include field study data will have to play a significant role in assessing the relative relevance of different variety promoting processes, including the Janzen-Connell hypothesis. According to the Janzen-Connell hypothesis, if only a small number of tree species (5-20%) are kept in check by their enemies, this may explain why these tree species do not spread to exclude others, but it does not explain the coexistence of many additional species in these species-rich communities. As a result, the Janzen-Connell hypothesis is a required but inadequate explanation for tree variety. Nonetheless, Janzen-Connell may easily promote cohabitation when combined with other mechanisms required to explain hyper-diverse communities. We absolutely agree with Barot and Gignoux when they state that the essential challenge is to "evaluate the differential effect of each mechanism for various societies and identify the key factors shaping their biodiversity."

CONCLUSION

To address these issues, multidisciplinary research methodologies, long-term monitoring, and the integration of many lines of data, such as field experiments, observational studies, and molecular techniques, are required. Collaboration among ecologists, entomologists, pathologists, and other specialists is critical for collecting the data and knowledge needed to evaluate and refine the Janzen-Connell hypothesis. While some research supported the Janzen-Connell theory, others found mixed or inconclusive findings. The complexity of tropical forest ecosystems, as well as the difficulties in verifying and falsifying ecological theories, make it a continuous subject of study and discussion. The Janzen-Connell hypothesis requires more exploration and refinement to acquire a better understanding of its relevance, processes, and ecological consequences in preserving plant species variety in tropical forests.

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CHAPTER 23

COEXISTENCE OF PIONEER TREE SPECIES AND SEED LIMITATION

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ABSTRACT:

The phenomenon of coexistence of pioneer tree species and seed limitation refers to the finding that certain tree species that are typically considered pioneers, capable of rapid colonization of disturbed habitats, persist in low-density or limited numbers despite the availability of suitable habitat. This coexistence pattern begs the issue of what variables govern the population dynamics and seed availability of pioneer tree species. The paucity or restricted availability of seeds for germination and establishment of new individuals is referred to as seed restriction.

KEYWORDS:

Pioneer Species, Soil Seed, Seed Rain, Seep Dispersion, Seed Persistence.

INTRODUCTION

Seed restriction, defined as the inability of seeds to reach at recruitment locations, may be a major driver organizing plant communities. When there is a scarcity of seeds, interspecific rivalry is decreased, and competitive exclusion may be delayed to the point where variety may be preserved by speciation and migration. Seed restriction may be particularly relevant in controlling the recruitment patterns of pioneer tree species in mature tropical forests. For effective seedling establishment, these plants rely on dispersion to occasional and transitory treefall gaps. Despite this necessity, pioneers exhibit a broad range of life-history features that influence dispersion capacity. We demonstrate that seed restriction has a major influence on seedling recruitment patterns using seed trap data from a 50 ha forest dynamics project on Barro Colorado Island (BCI), Panama. We next examine whether the impacts of restricted spatial dispersion might be mitigated by longer temporal dispersal through the formation of a persistent soil seed bank. We demonstrate, using a simulation model, that variation in dispersion in space has a surprisingly little influence on total seedling recruitment rates. This is due to a trade-off between the number of gaps colonized and the density of recruits per gap. While long-term seed persistence improves the proportion of gaps colonized, it cannot completely compensate for restricted space dispersion and entails a significant fitness penalty due to longer generation time [1].

Most processes assumed to contribute to species diversity maintenance (e.g., niche differentiation, competition, and density dependency) are based on the recruitment of individuals into the community. The arrival of a viable seed to a suitable place for seedling establishment is the first stage in the recruitment process. The probability of successful arrival is fundamentally limited by the resources available for plant reproduction, and it is further influenced by a suite of adaptive compromises that determine the size and number of seeds produced, as well as the resources allocated to ensure seed dispersal. The result of these recruitment limits is "seed limitation," which has been described as the inability of seeds to reach at areas appropriate for recruitment due to either restricted seed production or limited dispersion of the seeds produced. At the population level, seed constraint may limit population spread rates and possibilities for colonization of new appropriate habitat patches, as well as alter population genetic structure. Theoretical work has demonstrated that substantial seed restriction may enhance species cohabitation at the community level by significantly reducing competitive exclusion. This is because, when plants are seed limited, recruitment sites are typically won not by the greatest competitor in the community, but by the best competitor within the limited set of species that arrives at that site. If selective exclusion can be delayed enough, diversity may be preserved if species loss is offset by speciation and migration within the local community. The majority of the evidence for seed restriction comes from studies of seed catches in temperate forests.

According to these findings, even in stands with high con specific adult densities, most of the soil surface does not acquire seeds from any one species. While reduced seed distribution was the primary cause of this constraint, variation in reproductive output of individual trees and temporal variation in seed production also contributed to the observed seed limitation. We give evidence for seed restriction in tropical pioneer species in this paper. Pioneers confront unique hurdles when it comes to sustaining populations in mature forests. The characteristics that enable these species to attain high juvenile development rates also limit their initial recruitment to light gaps. In most forests, these sites are generated primarily by treefalls and landslides, and their densities stay astonishingly high over considerably longer time periods, implying that only a tiny proportion of new gap sites get reached by seed rain [2].

Seed restriction may occur when an insufficient number of seeds are generated, referred to as "source limitation," or when seeds are not distributed randomly throughout the landscape, referred to as "dispersal limitation". When seed trap data is available, the extent to which a tree population is source constrained may be assessed by randomly "redistributing" the total seed count across all traps utilized in the research. The proportion of traps that are still projected to fail to catch a single seed is thus described as source limitation. Variations in adult population density, adult size during reproduction, and mean seed mass result in differences in source restriction across species. Once source limitation has been computed, dispersal limitation may be estimated as the measure of how the percentage of traps receiving seeds is lowered beyond the limitations imposed by source limitation.

For species with large seed production and short dispersion distances or with strongly clumped dispersal, dispersal restriction is likely to be severe. Among the BCI pioneers, three species (Alchornea, Alseis, and Luehea) successfully avoid source constraint in a given year, with enough seed production at the population level to reach 99% of locations. In contrast, none of the species avoid dispersion constraint and hence seed limitation, with seeds from even the best disseminated species, Luehea, reaching just 76% of traps. There are obvious differences between species with wind-vectored seed dispersion and those with animal-vectored seed dissemination. While seeds from the five wind-dispersed species reached between 10 and 76% of the traps, seeds from animal-dispersed species only reached between 4 and 8% of the traps. This distinction reflects the more aggregated pattern of animal seed distribution, in which seeds are often found clumped together at eating roosts, sleeping roosts, and toilet sites. Croton billbergianus, a subcanopy tree with ballistic dispersal, was the species with the most severe seed restriction. This is one of the most numerous pioneers on BCI, demonstrating how pioneers may presumably recruit effectively despite severe seed and source constraints.

Measures of seed limitation, based on single seed catches in traps, reflect the lowest dispersal rates from which recruitment might theoretically occur. Even when recruitment circumstances are favorable, the chances of seed survival to germination and seedling survival to emergence and establishment may be relatively low. Furthermore, seedling emergence and establishment are substantially seed-size dependent, and are influenced by leaf litter density and other microsite conditions inside gaps. A variety of animals can reduce initially high seed densities on the soil surface, and fungal pathogens can prevent seeds from accumulating in the soil. As a result, seedling recruitment may be essentially unrelated to seed quantity, or may represent an interplay between seed abundance and substrate favorability, as seen in a north temperate forest community compared expected seed rain densities to actual seedling recruitment patterns in natural tree fall gaps to establish the connection between seed abundance and seedling recruitment. Data on seed captures to traps were combined with information on the size and location of potential seed sources to parameterize a seed dispersal model.

We are confident in our seed rain forecasts for wind and ballistic ally dispersed species since the fits to actual seed counts in traps were excellent. Predictions for animal distributed species, on the other hand, may be inadequate since model fits for these species were low. The low predictive power of dispersal models for animal-dispersed species based on seed trap data is consistent with observations that large birds and mammals frequently carry seeds hundreds of meters and that seeds are frequently secondarily dispersed from initial aggregations [3]. The number of seedling recruits per species in a gap was supposed to be proportional to the area possibly colonizable by seedlings in the first (null) model. In this model, the predicted seedling number per gap was calculated by dividing the total seedling number per species across all gaps by the total area of all gaps. Following models fit seedling abundance as a linear or non-linear (i.e., density dependent) function of expected seed rain to the gap. The Akaike information criterion was used to compare models. The models were compared, and it was discovered that the amount of seed rain does alter the likelihood of seedling recruitment, at least for certain pioneers. Overall, models adding seed rain outperformed the null model in predicting seedling recruitment for eight of the fourteen pioneer species. The variation in how well recruitment models matched the seedling abundance data reflected, in part, the fit of dispersal functions, but also the presence of mature trees in the plot and the closeness of seed suppliers to gaps.

Large Jacaranda trees may be seen throughout the plot, and most gaps have at least a few seedlings of this species. The fit for a rarer species, Cordia, on the other hand, illustrates the presence of a single gap with high predicted seed rain. Despite a high confidence in the dispersion function, the recruitment model suited Croton, another frequent pioneer species, unexpectedly badly. Croton seeds are transported ballistically, land near to the plant, and may be disseminated a few meters farther by ants. Seedling recruit abundance was an order of magnitude more than predicted yearly seed rain in three gaps that lacked mature Croton trees within 30 m. We assume that seedling recruitment in this species reflects several years of accumulation of viable seeds in the seed bank.

Recruitment patterns may represent contributions from seeds that linger in the soil for several years, in addition to yearly seed rain. Although most pioneers have soil seed banks, nothing is known about the time scale of seed persistence for tropical pioneers, or the relative contributions of buried seeds vs seed rain to recruitment in gaps. Mesh bags were employed to bury seeds several centimeters below the soil surface in direct tests of seed persistence in the soil. The majority of pioneer species preserve some seed viability after 2 years, according to these research. In Costa Rican cloud forest, comparisons of yearly seed rain inputs with soil seed bank densities indicate that seed persistence of 5 years or more is frequent. Direct measurements of seed age using 14C dating of soil-sifted seeds on BCI have revealed that viable seeds of three larger-seeded pioneer species with thick seed coats buried at depths of less than 3 cm below the soil surface can be more than 30 years old. In situ studies of seed persistence in soil, on the other hand, may exaggerate the seed bank's contribution to seedling recruitment. This is due to the poor success rates of "entering" and "leaving" the seed bank.

Seeds dispersed on the soil surface are particularly vulnerable to seed predation. In lowland tropical woods, rates of seed removal by ants (and rodents for bigger seeds) are quite high, with most seeds likely to be devoured. The substantial disparity between predicted seed rain and soil seed bank densities may be explained by these high early predation rates. Only 2% and 23% of yearly seed rain were absorbed into the seed bank for two small-seeded pioneer species on BCI, Cecropia insignis and Miconia argentea, respectively. Clearly, a direct assessment of the contribution of persistent seeds to pioneer recruitment success would be challenging since long-term data on seed survival and destiny would be required. As a result, we developed a spatially explicit simulation model to investigate the possible implications of seed persistence for recruiting success, as well as the relationships between persistence and other life-history features. We can simulate late seed distribution, gap creation, and recruitment over a 1000 m 500 m region using the model [4].

We utilized the model to investigate the influence of species-specific parameters for fecundity, dispersion, seed persistence, and germination rates in gaps on recruitment success and population growth rate. Despite the fact that seed burial trials and 14C dating research have yielded estimates of seed lifetime, the precise survival curves for buried seeds remain unknown. In the simulations reported here, we constructed hypothetical seed survivorship curves based on a model used to characterize the loss of viability of seeds held in constant conditions. This model assumes that seed mortality is normally distributed over time and produces a type I survivorship curve with a decreasing survival rate with seed age. We utilize the model to investigate how dispersion and persistence variables combine to effect recruitment by comparing three hypothetical species with diverse dispersal characteristics and changing seed persistence from less than a year to about 20 years.

Adult densities, fecundities, adult mortality rates, chances of assimilation into seed banks, and rates of germination in gaps all have an impact on recruitment rates and were therefore maintained constant in these simulations. Croton billbergianus (Euphorbiaceae), with ballistically dispersed seeds and an aggregated dispersal kernel (median dispersal distance = 2.2 m), and Jacaranda copaia (Bignoniaceae), with wind-dispersed seeds and relatively widespread dispersal (median= 21.2 m), were chosen for their dispersal functions. To study gap colonization under these differing dispersion scenarios, we simulated gap formation and closure using empirical data from the BCI 50 ha plot, which included about 5% of the forest area at all periods. The size distribution of gaps declining as a power law of gap size with gaps ranging from 25 m2 to 625 m2.

We discovered that gap colonization rates were much lower under aggregated dispersion (as in Croton) than under extensive dispersal (as in Jacaranda). Increased seed persistence resulted in a quick rise in gap colonization under extensive dispersion, but it tended to approach an asymptote with prolonged seed persistence. The functional shape of the connection between seed persistence and gap colonization success was comparable to that of Jacaranda under highly aggregated dispersion, although the initial rise was shallower and did not saturate during the time scale of our simulation.

Gap colonization success, on the other hand, was much reduced with aggregated dispersion, and seed persistence alone could not compensate for restricted dispersal. Despite the fact that aggregated seed dispersal leads in reduced gap colonization rates, total seedling recruitment rates may nevertheless equal those of more widely dispersing species provided high-density clusters of seeds meet gaps at a sufficient rate. We investigated recruitment performance by calculating total lifetime reproduction of individuals in two dispersion scenarios with varying amounts of seed persistence. Because the two species' adult densities and fecundities were assumed to be similar, each species spread the same amount of seeds each year in our model, and the same per-seed recruitment probabilities were applied in gaps [5].

Our simulation results reveal that long-term mean recruitment rates rose with seed persistence but were statistically identical between the two dispersion scenarios at all seed persistence levels evaluated. Increasing seed permanence in the soil seed bank resulted in an increase in long-term mean recruitment rates that was independent of dispersion. However, recruitment rates were substantially more varied from year to year with aggregated dispersion than with extensive dispersal. This was attributable to changes in seed density spatial variation between the two dispersion scenarios. Although recruitment rates were often low with aggregated dispersal, pulses of high recruitment were observed when light gaps occurred in quadrats with high seed densities. Increased geographic heterogeneity in seed concentrations resulted in higher inter-annual oscillations in recruitment, but as our simulations indicate, long-term mean recruitment rates for the two dispersion scenarios were comparable.

This demonstrates one possible method for equalizing recruitment success for species with diverse life histories, but it also emphasizes the relevance of geographical and temporal dimensions in understanding coexistence among pioneer species. Species may sometimes escape seed restriction when individuals grow sufficiently plentiful to overwhelm recruitment locations, despite the fact that steady-state seed limitation might assist sustain variety. Escaping seed restriction is presumably unusual for pioneers, which normally exist at low adult population densities, unless maybe when windstorms or landslides open wide regions that encourage recruitment of one or a few species. Shade-tolerant trees with seedlings that survive in the forest understory for years may be able to overcome recruitment constraint more regularly. Wright discusses the instance of Trichiliatuberculata, a very large-seeded, shade-tolerant tree species that recruits seedlings into the majority of seedling plots studied. In both temperate and tropical forests, density-dependent mortality is crucial in controlling population increase. Adult dispersal patterns are unlikely to be determined only by initial gap colonization patterns. Variation in gap characteristics, along with limits on species' capacity to spread and establish at recruitment locations, gives opportunities for species to coexist via niche differentiation. Same restriction is reflected in the significant diversity in seed mass among pioneers. Larger-seeded pioneers may establish at more microsites than small-seeded species, whereas small-seeded species can reach more of the rare microsites they need due to their larger fecundity. Temperate grassland pioneer groups face a similar colonization-establishment trade-off. Once seedlings exhaust their seed supplies, a second axis of niche differentiation becomes important for pioneer species. Growth rates of seedlings that are a few months old are unrelated to seed mass but substantially connected to death rate. This correlation reflects two general trade-offs: first, between growth investment versus herbivore defense, and second, between growth and susceptibility to drought-related mortality during the dry season.

Fast-growing species are therefore less likely to survive in gaps, but they are more likely to reach reproductive size before the gap closes, possibly shading out slower-growing rivals. Fast-growing plants are also known to need wider gap sizes, which may represent higher potential for herbivory escape when growth rates are high. We recommended that seed restriction be more severe for pioneer species due to their low population densities and the rarity with which recruitment sites become accessible. Evidence from BCI seed trap data demonstrates that seed restriction is severe for most pioneers, with just a few wind-dispersed species producing enough seeds to reach more than 90% of seed traps across two consecutive years of seed production. Long-term preservation of viable seeds in the soil seed bank may assist compensate for severe seed restriction, but as our simulations indicate, gap colonization rates with aggregated dispersion remain low. Furthermore, theoretical studies seem to indicate that long-term seed persistence is unlikely to be chosen for in perennial species owing to the fitness cost of longer generation time [6].

Nonetheless, there is direct evidence that seeds of certain tropical pioneer species stay viable in the soil seed bank for decades. As a result, whether long-term seed persistence represents a major axis of niche differentiation among tropical pioneer species remains unknown. Species with severe seed limitations are nonetheless successful in the BCI forest. Croton billbergianus, the most seed-limited species, has among the highest population densities in this functional category despite its poor fertility and short-distance dispersion. The capacity of larger-seeded pioneers to establish populations in this forest suggests that post-dispersal activities must play a role in preventing mining recruitment patterns. We've demonstrated that seedling distribution patterns mirror seed dispersion patterns for certain species, but we haven't looked at the impact of dispersal on adult distribution patterns. The creation of a comprehensive pioneer recruitment model that incorporates seed distribution, seed persistence, and seedling growth and death through maturity is now on the agenda. This will now offer the platform for investigating how differences in seed production, dispersion, and persistence impact species coexistence.

DISCUSSION

Some lichens grow on rocks without soil, suggesting that they were among the earliest living forms, breaking down the rocks into soil for plants. Pioneer species are frequently hardy plants with adaptations such as strong roots, root nodes carrying nitrogen-fixing bacteria, and leaves that use transpiration since some deserted territory may have thin, low quality soils with insufficient nutrients. It is worth noting that they are often photosynthetic plants, since no alternative source of energy (such as other species) is frequently available in the early stages of succession, making it less probable for a pioneer species to be non-photosynthetic.

Plants that are frequently pioneer species are also wind-pollinated rather than insect-pollinated, as insects are unlikely to be present in the typically barren conditions in which pioneer species grow; however, pioneer species tend to reproduce asexually entirely, as the extreme or barren conditions present make it more favourable to reproduce asexually in order to increase reproductive success rather than invest energy in sexual reproduction. Pioneer species will ultimately die, producing plant litter and decomposing as "leaf mold" over time, creating new soil for secondary succession and releasing nutrients for tiny fish and aquatic plants in nearby bodies of water [7].

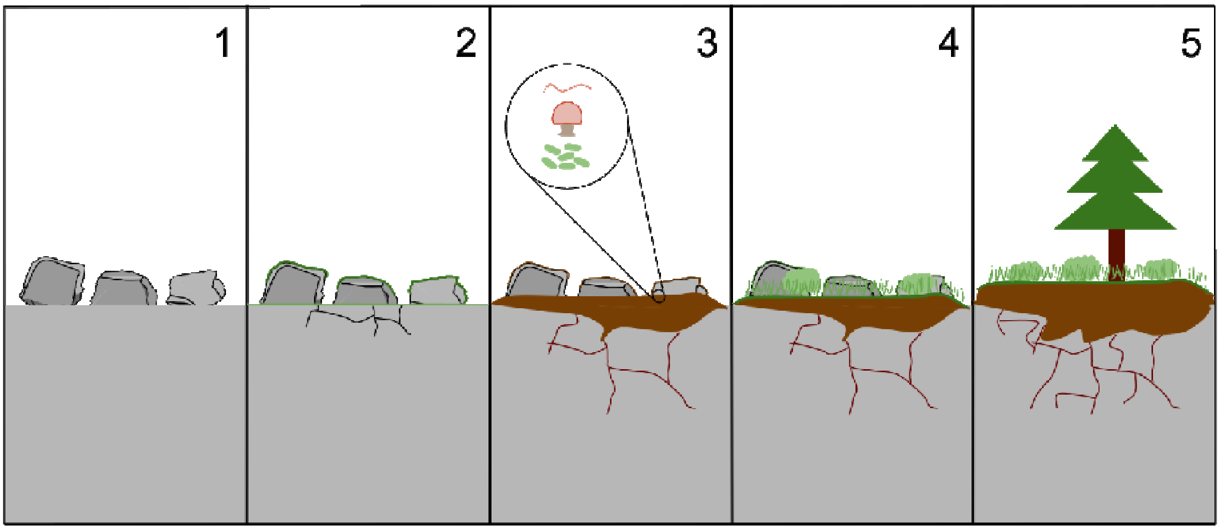

Figure 1: Pioneer species: Diagram showing the growth of the Pioneer species (Wikipedia).

Only when flora and fungi have colonized a region will pioneering animals invade it. Soil fauna, which includes tiny protists as well as bigger animals, play an important role in soil formation and nutrient cycling. Bacteria and fungus are the most significant organisms in the degradation of organic detritus left behind by primary producers such skeletal soil, moss, and algae (Figure.1). By breaking down debris, soil invertebrates promote fungal activity. Earthworms and ants modify soil qualities as it grows. Worm burrows aerate soil, and ant hills change sediment particle size distribution, drastically affecting soil character. There are certain exceptions to the rule that vertebrates are not pioneer species. Natter jack toads like open, thinly vegetated environments that may be in the early seral stage. Because they exploit a mosaic of habitats, wide-ranging generalists frequent early succession stage sites but are not obligatory species of those habitats.

Vertebrates may have an impact on early seral stages. Herbivores may influence plant development. Fossorial animals have the potential to influence soil and plant community formation. A seabird colony, for example, delivers significant nitrogen into barren soils, changing plant development. By generating new niches, a keystone species may aid in the introduction of pioneer species. Beavers, for example, may flood a region, enabling new species to move. The term pioneer species is often used to describe the first species, mainly plants that return to a disturbed region as part of the secondary succession process. Floods, tornadoes, forest fires, deforestation, and other forms of clearance are examples of disturbances. Pioneer species are often fast-growing, shade-intolerant, and generate a high number of offspring rapidly. Pioneer species seeds may occasionally survive in the soil seed bank for years or decades and are often prompted to sprout by disturbance. Mycorrhizal fungi have a significant impact on the development of pioneer species.

Seed dispersion in spermatophyte plants refers to the movement, dissemination, or transfer of seeds away from the parent plant. Plants have limited mobility and depend on a range of dispersion vectors, including both abiotic vectors like the wind and live (biotic) vectors like birds, to transfer their seeds. Seeds may be disseminated away from the parent plant either individually or collectively, and in both space and time. The dispersion mechanism determines seed dispersal patterns in major part, which has substantial consequences for the demographic and genetic structure of plant populations, as well as migratory patterns and species interactions. Gravity, wind, ballistic, water, and animal dissemination are the five basic means of seed distribution. Some plants are serotinous, meaning that they only distribute their seeds in reaction to an external stimulation. These modalities are usually inferred from adaptations like wings or luscious fruit. This simple picture, however, may overlook the intricacy of dissemination. Plants may propagate across modes without the usual accompanying adaptations, and plant features can be multipurpose [8].

Seed dispersion is expected to benefit a variety of plant species. Away from the parent plant, seed survival is frequently greater. This increased survival might be attributed to the activities of density-dependent seed and seedling predators and diseases, which often target large numbers of seeds underneath adults. When seeds are moved away from their parent, competition with mature plants may be reduced. Seed dispersion also enables plants to reach certain areas that are conducive to survival, a theory known as directed dispersal. Ocotea endresiana (Lauraceae), for example, is a tree species native to Latin America that is spread by various bird species, including the three-wattled bellbird. Male bellbirds sit on dead trees to attract mates, and they often defecate seeds underneath these perches, where the seeds have a better chance of survival due to high light conditions and escape from fungal infections. Endozoochory (seed dispersion in animal bellies) generally increases the number, speed, and asynchrony of germination in fleshy-fruited plants, which may have significant plant advantages [9], [10].

Ants distribute seeds (myrmecochory) by burying them underground as well as dispersing them across short distances. As a result, these seeds may escape negative environmental impacts like fire or drought, reach nutrient-rich microsites, and live longer than other seeds. These characteristics are unique to myrmecochory and may bring extra advantages not seen in other dispersion mechanisms. Plants may be able to colonize new habitats and even geographic areas as a result of seed dispersion. Dispersion lengths and deposition locations are determined by the disperser's movement range, and larger dispersion distances are occasionally achieved using diplochory, which is the sequential dissemination of two or more separate dispersal processes. According to new findings, the bulk of seed dispersion occurrences include more than one dispersal phase.

CONCLUSION

Understanding the coexistence of pioneer tree species and seed restriction necessitates taking into account the interactions of several ecological processes such as competition, seed production, dispersion, and establishment. A variety of variables impact these processes, including resource availability, ambient conditions, disturbance regimes, and interactions with other plant and animal species. Restoring or creating suitable habitats, enacting conservation measures to protect existing populations, and facilitating connectivity between patches of suitable habitat can also help alleviate seed limitation and promote the persistence and coexistence of pioneer tree species in dynamic forest ecosystems. It is crucial to highlight that the processes governing pioneer tree species cohabitation and seed restriction may differ among ecosystems and species assemblages. More study and empirical investigations are needed to better understand the unique elements and processes that influence the coexistence and population dynamics of pioneer tree species under seed constraint.

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CHAPTER 24

ENDOPHYTIC FUNGI: UNSEEN CONTRIBUTORS TO TROPICAL COMMUNITY ECOLOGY

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ABSTRACT:

Endophytic fungus create mutualistic connections with their hosts, giving a variety of advantages. They may improve plant growth and fitness by enhancing nutrient uptake, water absorption, and tolerance to environmental challenges including drought, diseases, and herbivory. Endophytic fungus may create growth hormones or aid in the uptake of nutrients from the soil, eventually adding to tropical plants' general health and performance. Endophytic fungi may operate as biocontrol agents, inhibiting plant pathogen development and activity. Secondary metabolites with antifungal or antibacterial activities are produced, protecting the host plant against illness. Endophytic fungus help to maintain plant variety and community structure in tropical settings by limiting the influence of diseases.

KEYWORDS:

Endophytes Communities, Fungal Endophytes, Fungal Propagules, Tropical Forest, Tropical Plants.

INTRODUCTION

While the ecological relevance of plant pathogenic fungi, decay fungi, and root symbionts is becoming well established in tropical biology, one significant category of ubiquitous symbionts - fungal endophytes of foliage - has yet to be investigated. Fungal endophytes are fungi that live inside plant tissues such as leaves without producing illness. They are extremely numerous and varied in tropical forests, where individual leaves may host dozens of species without any evident symptom of infection. Their ecological activities are still being clarified, but preliminary data shows that fungal endophytes play important, though often neglected, roles in tropical forest ecology. This chapter summarizes existing understanding on the natural history of foliar endophytes in tropical forests, reviews the various evidence for their ecological significance, and identifies a number of tractable topics for further study. The primary purpose of this chapter is to promote interdisciplinary study into the ecology of these little-known but ubiquitous tropical plant symbionts. Plant pathogenic and parasitic fungi are crucial in structuring tropical tree communities [1].

Similarly, nitrogen cycling by highly varied saprophytic fungus is essential to tropical ecological processes. Endosymbiotic fungus of living plants, which grow inside plant tissues without producing noticeable harm or symptoms, are less clear to ecologists. Mycorrhizal fungi are a subset of these fungi that reside in the rhizosphere and have a growing influence on tropical forest ecosystems. Tropical plants, on the other hand, have fungus in above-ground tissues such as leaves and stems. These are fungal endophytes, which are fungi that invade the inside of healthy plant tissues without causing disease. Endophytes have been found in the photosynthetic tissues of every tropical plant studied to date, and their diversity is astounding: individual leaves typically harbor more than a dozen species, and the number of taxa associated with individual trees is likely in the thousands. These little-known fungi provide a treasure mine of untapped biodiversity, as well as a commonly ignored component of tropical ecology.

Only a decade ago, Lodge et al. published the first research assessing the abundance and species composition of endophytes associated with a tropical dicotyledonous host. In the ensuing years, most investigations on tropical endophytes have been descriptive in nature, with some emphasis paid to the influence of tropical endophytes on estimates of world fungal. The majority of this research has been on endophytes of leaves (foliar endophytes), which are particularly varied and plentiful. Four recent studies have provided the first evidence for tropical foliar endophytes' ecologically relevant roles, such as increased host resistance to pathogens and physiological costs in terms of water relations and photosynthesis. These investigations are just the tip of the iceberg: although the mycotic of all ecosystems are understudied, the endophytic fungi of any tropical forest remain mostly unknown.

The study of tropical endophytes is now more accessible than ever before, because to increased interest from ecologists, bio prospectors, and mycologists, an expansion of research infrastructure in the tropics, and the development of novel methodologies. While basic taxonomic investigations are still required, the groundwork has been laid for experimental manipulations of endophyte abundance and diversity, as well as the investigation of ecological concerns. The goals of this chapter are threefold to synthesize current knowledge about the natural history of foliar endophytes in tropical forests to investigate current evidence about their ecological roles and to highlight a series of tractable questions for future research. This chapter's main purpose is to foster interdisciplinary study into the ecology of these little-known but widespread and possibly significant tropical plant symbionts [2].

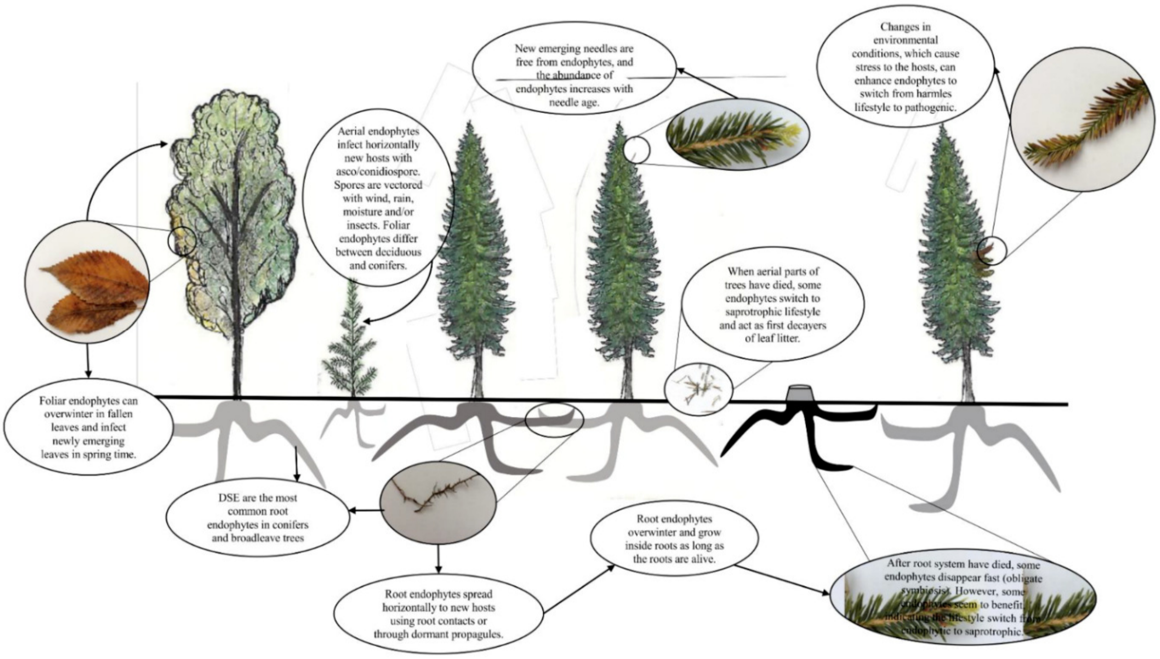

Figure 1: Forest tree microbes: Diagram showing the overview of the forest tree microbes (MDPI).

The great majority of fungal endophytes associated with leaves (hereinafter, endophytes) are Ascomycota, which includes all main lineages of non-lichenized, filamentous ascomycetes. Endophytes have been recovered from a variety of ecosystems, including hot deserts, tundra, and temperate croplands. The majority of endophyte research has been on a single family, some of whose members are found in the above-ground tissues of several temperate grasses. These vertically transmitted, systemic endophytes infect at least 300 grass species and are known for producing secondary compounds, including alkaloids that benefit hosts by deterring or sickening herbivores. Fungal endophytes of tropical plants, on the other hand, are transmitted predominantly by infectious spread (horizontal transmission) rather than through maternal inheritance. After leaf flush, these endophytes accumulate, developing intracellularly and subsisting on carbon in the applets (Figure.1).

Spores and hyphal fragments may be discharged passively or by physical disturbance such as wind, rain, or tree or limb fall. Insect herbivores may potentially spread fungal propagules. Many fungus, especially the endophyte-rich species Phyllosticta, generate slimy spores that depend on rain for dissemination at least in part. Although strong winds and rain are particularly effective in moving spores, even little precipitation may distribute conidia of Colletotrichum, a species of pathogenic and endophytic fungus. Light breeze and currents created by daily cycles of heating and cooling are also important for dispersion of xylariaceous species and certain Eurotiomycetidae. Although inoculum volume is critical in influencing the infection effectiveness of plant-associated fungus, the rate of fungal propagule deposition in tropical forests remained unknown until recently. Gilbert, Arnold, and Arnold and Herrey discovered that during the mid- and late wet seasons, typical leaves in the forest understory of Barro Colorado Island (BCI), Panama, acquire 10-15 viable fungal propagules per cm2 each hour. These statistics, when corrected for mean leaf area and extended to 24 hours, indicate that the typical leaf gets more than 15,000 viable fungal propagules every day (average based on mean leaf area for 28 tree species in the BCI understory) [3].

These figures are based on fungi that can grow on a single nutrient medium (malt extract agar) and are likely to underestimate total deposition. Fungi in the forest air column include pathogenic, saprophytic, and endophytic species, as well as a variety of species with unclear ecological significance. Although the fraction that may produce endophytic symbioses has not been determined, the amount of viable propagules in the air is positively related to the incidence of endophyte infections. Fungi propagules are abundant in the air column soon after significant rainfall events at BCI, and thereafter decline as a curvi linear function with increasing time since significant rainfall. UV exposure and desiccation both play important roles in the death of fungal propagules: Arnold and Herre discovered that the deposition and persistence of live propagules on leaves was higher under the forest canopy than in the experimental area at BCI. After one week, sterile plants in the lab clearing had much fewer endophyte infections than plants in the forest understory.

Endophyte colonization and abundance in tropical leaves

The high abundance of inoculum in the air column, combined with the seemingly universal receptivity of tropical plants to colonization by endophytic fungi, results in high infection rates in tropical tree mature foliage. Arnold recovered endophytic fungi from 100% of mature leaves collected at BCI from 28 species of woody plants representing 24 families and 14 orders of angiosperms (N = 9 leaves from three individuals per species in the late secondary forest understory). Similar findings have been reported in Puerto Rico and Guyana. Although most plant groups have not yet been studied, the percentage of endophyte infected leaves seems to rise from the arctic to the tropics.

Precipitation, humidity, elevation, irradiance, and air pollution all impact the frequency of endophyte infections in the temperate zone, but their functions in the tropics have not been well investigated. Tropical savannas and dry forests, as well as the forest canopy in moist or wet forests, have distinct climatic circumstances due to high irradiance, high temperature, and geographic proximity to endophyte-rich forests. Plants in these communities might harbor a plethora of unique endophyte species. At the time of emergence, neither seedlings nor leaves of tropical trees normally possess cultural endophytes, although colonization occurs quickly due to the presence of airborne inoculum and high relative humidity or wetting of leaf surfaces by dew, rain, or fog. As foliage grows at BCI, infection rates (defined here as the fraction of leaves with endophytic fungus) climb to almost 100% of leaves.

Endophytes were seen in more than 80% of Theobroma cacao leaves during 2 weeks of leaf emergence during the early wet season at BCI. Endophyte colonization is not affected by leaf toughness: both young and older leaves may be colonized with comparable frequency. Endophyte infections inside leaves are commonly assessed by calculating the fraction of tiny leaf pieces (normally about 2 mm2) that produce endophytes in culture. Endophyte colonization of leaf area varies by tropical locale and host species, but all tree species studied at BCI to yet exhibit consistently high densities of endophyte infection (>95% of tissue segments). Because the biomass produced by any individual infection is so minimal, each leaf represents a tightly packed mosaic of various endophyte species [4].

Mature leaves have a larger infection density than younger leaves, owing to the accumulation of multiple, independent infections as leaves age, as well as the differential proliferation of preferred species as leaves approach senescence. Arnold et al. discovered endophytes connected with just nine leaves from individual Theobroma cacao trees in Panama (i.e., 288 mm2 of leaf tissue). Interestingly, overall richness per tree did not vary substantially across individuals in agroecosystems, main forest, or secondary forest, despite the fact that endophyte species turnover was considerable in each location. Although leaves on the same tree share a subset of endophytes, each leaf has its own endophyte community, resulting in high rates of species turnover among leaves. Leaf pieces of a uniform size were utilized to survey growing leaf area on a single individual in a study of Laetiathamnia in Panama. The number of morph species accumulated as a function of cumulative leaf area with a coefficient of 0.504.

These and related research provide baseline data for understanding the variety of tropical endophyte ecosystems. However, three main difficulties must to be overcome before a complete picture of tropical endophyte diversity can emerge. To begin, coherent and physiologically valid species conceptions that include sterile (non-sporulation) fungi, which commonly dominate endophyte cultures, are required. Second, considerable sampling within sites is required to determine host affinity with confidence. Finally, comparative studies are required to evaluate spatial structure and beta-diversity. Although some studies have addressed one or more of these objectives, none have entirely met these requirements. Furthermore, there is uncertainty about the potential diversity of uncultivable species, the degree of overlap between endophytes and other fungal guilds, and the appropriate spatial scale for estimating species turnover. The number of endophyte species in tropical forests is still an open question, and it is more than academic as we try to grasp the ecological significance and possible uses of these cryptic symbionts.

Beyond alpha-diversity: host affinity and spatial structure

Tropical endophytes' host affinity and spatial heterogeneity are hotly disputed topics. The predominance of singleton species is one challenge: even large-scale surveys, such as those conducted at BCI, often recover 50-65% of species just once. It is hardly unexpected that evidence for host affinity and geographic structuring among endophytes has been inconsistent. Cannon and Simmons found no structure to endophyte communities in a non-quantitative research in Guyana, but Arnold et al. found substantial evidence for both host affinity and spatial organization of endophyte communities within and among forests in Panama. Suryanarayanan et al. discovered a significant degree of overlap across endophyte communities in many different hosts and forest types in India, whereas Arnold and Lutzoni discovered limited overlap in endophyte genotypes over a latitudinal gradient [5].

Some endophyte genotypes were separated from many hosts at BCI, independent of their phylogenetic location, leaf defenses, or phenology; nevertheless, others were detected in just one host species. Tropical endophyte communities seem to be a mix of genus- and host-specific species. The issue remains in inferring these ecological parameters for very rare taxa, as well as determining whether supposedly uncommon species are genuinely rare or merely compete poorly under certain culturing circumstances. Distribution statistics alone do not reveal the processes behind apparent host affinity. Because tropical tree leaves are effectively guarded against diseases, it is possible that chemical defenses of leaves impact endophyte host affinity. Arnold and Herre tested this theory by incorporating leaf homogenates as the nutrition source into water agar and measuring endophyte growth rates in vitro. When tested on plates containing extracts from each of three host species, 86% of endophytes from Theobroma cacao grew quicker on T. cacao extracts. cacao extracts were more effective than extracts from two co-occurring tree species. To be certain that this outcome did not represent a higher nutritional value in T. Arnold et al. cultivated endophytes from three host species on leaf-extract medium from all hosts, and discovered that endophytes developed faster on extracts of the host from which they were more commonly obtained in the wild. With the availability of novel technologies for producing sterile seedlings and inoculating them with endophytes, the ground is set for much-needed analyses of host affinity in planta.

Unfortunately, examining the spatial organization of endophyte communities - which is crucial for deter mining beta-diversity does not lend itself to such direct laboratory tests, but reciprocal transplant experiments might be instructive in this area. Fungal spores have long been assumed to disperse large distances as airborne plankton; for example, wheat leaf rust (Puccinia triticina) overwinters in Mexico and drifts north over the Great Plains of the United States in mid-April. It is unknown if endophytes travel on a comparable scale. As is established for many harmful fungi, genotype data are particularly useful for comparing fungal assemblages in various locations.

Given that plants in the dark forest understory are carbon constrained, why do they host such a huge number of obligatory heterotrophs in their leaves? Given that endophytes are often associated to infections and that tropical forest plants are effectively guarded against pathogenic fungi why can plants host such a diverse range of fungal species in their tissues? These concerns remain unanswered, since research into the ecological functions of tropical endophytes is still in its infancy. However, there are three primary ideas on the roles of endophytic fungi in general: they are neutral occupants, parasites, or mutualists of their hosts. Given the incredible evolutionary variety of tropical endophytes, endophytes as a whole are likely to comprise species capable of playing all of these functions, or of changing roles over time or under certain circumstances. Furthermore, it is possible that the most essential ecological responsibilities of endophytes are displayed in relation to insects or diseases that attack the plants they occupy. I offer data for and against these broad concepts of endophyte-host interactions as a basis for emerging debates about tropical endophytes' ecological functions [6].

DISCUSSION

Over the last two decades, several writers have proposed that endophytes merely occupy their hosts without explicitly interacting. Endophytism, in this scenario, is an accidental aspect of the life cycle of fungi whose essential ecological importance rests elsewhere. Endophytes, on the other hand, preferentially colonize certain hosts, indicating a relationship between endophytes and host defenses and/or other features. Furthermore, during colonization, endophytes aggressively pierce leaf cuticles and very rarely enter leaves passively. Endophytes are metabolically active throughout the intercellular colonization phase, and they develop slowly but actively inside the host foliage after infection. Fungi release the organic compounds required for circular penetration and absorptive feeding at each of these phases. Given the tight evolutionary relationship between endophytes and diseases, tropical plants are likely to be susceptible to such exudates. Can endophytes avoid eliciting host defenses while invading? If this is the case, how can plants in the forest understory endure the consumption of carbon by these heterotrophic colonists? The potential function of endophytes as plant parasites has long been recognized, owing in part to the finding that endophytes feed on carbon from the host. The evolutionary link between endophytism and pathogenicity emphasizes endophytes' potentially negative effects. However, the presence or absence of endophytes had no effect on leaf area, plant growth rates, or total biomass in seedlings of tropical angiosperms such as Theobroma cacao, Gustavia superba, and Faramea occidentalis. Similarly, Arnold and Engelbrecht discovered that in well-watered circumstances, endophyte infection had no effect on leaf fresh weight, dry weight, or water content.

The effects on host water relations are most likely to be significant in highly seasonal tropical forests. As a result, advantageous benefits such as anti-pathogen protection may be more essential during rainy seasons or in ever wet forests. Similarly, illnesses that seem to be asymptomatic might have an impact on photosynthetic activity. Pinto et al., for example, discovered that infections with two endophytic Ascomycota impaired photosynthetic ability in maize and banana. Endo phyte infections may limit plants' ability to deal with damage since photosynthetic capability is connected with herbivory tolerance. The combined cost of lower photosynthesis and a reduction in damage tolerance may be particularly troublesome in the carbon-limited environment of the forest understory.

Endophytes as Mutualists

A third, non-exclusive theory is that the presence of endophytes in plant tissues benefits the plant. This concept has little support from evolutionary theory since extremely varied symbionts and infectious propagation are often linked with parasitic or harmful lifestyles. There are, however, many instances of varied, horizontally transmitted organisms that interact mutually with hosts. The ability of endophytes to promote host fitness in a host-specific way poses a number of concerns of interest to community ecologists. Herbivores and diseases are key density-dependent agents and have played an essential role in plant evolution, as shown by the diversity and variance in chemical and structural plant defenses in tropical plants. Through the host plants that they share, herbivores and diseases have the ability to interact intimately with foliar endophytes. Could endophytes offer a covert protection against predators?

Numerous writers have presented this theory in different versions, offering four options for how endophytes may contribute to host protection. Endophytes provide unique chemical defenses to hosts. Endophytes may provide plants with direct chemical protection by creating secondary chemicals that repel insects and suppress harmful organisms. Endophytic fungus's capacity to produce chemicals in vitro that hinder the development of other microbial species, including diseases, has led to the present interest in bioprospecting and biological control using endophytic fungi. This mode of defense is exemplified in the context of her bivory by the alkaloids produced by clavicipitaceous endophytes of temperate grasses, and has been demonstrated in a few horizontally transmitted endophytes of woody plants. Endophytes of tropical plants, according to Arnold et al., behave as acquired immune systems, working in tandem with intrinsic leaf defensive chemicals while young and in place of such defenses in adult leaves. However, the potential for these low-biomass diseases to produce significant chemical fingerprints in foliage has yet to be determined. One fascinating theory is that high amounts of chemical production per endophyte may not be required to protect host tissues [7].

Carroll proposed that endophytes protect hosts by creating a heterogeneous chemical environment inside and among leaves via a mosaic effect. As a consequence, portions of a genetically identical plant might vary unexpectedly in terms of palatability or quality for herbivores, as well as disease infectivity. This theory is intriguing but has yet to be investigated. Do endophytes interfere with host defenses? Although systemic acquired resistance in plants has long been recognized, there is presently no evidence for systemic protection of tropical plants as a result of endophyte infection. Arnold et al. grew endophyte-free seedlings, inoculated a subset of leaves on each seedling with endophytes, and then inoculated endophyte-infected and endophyte-free leaves with Phytophthora. The presence of endophytes in certain leaves did not protect other leaves on the same plants from severe pathogen damage in that investigation. That research did not look at pathogen damage in seedlings with no endophytes, so it's possible that some systemic defense occurred but was missed. However, field observations generally do not support the systemic defense hypothesis: new endophyte infections accumulate in tissues following initial colonization, and there is strong evidence that early colonists do not deter later infections. Instead, these findings suggest that endo phytes avoid or do not trigger plant defenses.

Endophytes may interact with diseases directly inside the leaves they share. When Arnold et al. discovered that endophytes' anti-pathogen effects were evidently limited to the leaves that bore those endophytes, they concluded that direct or indirect interactions between endophytes and the Phytophthora pathogen were responsible for limiting the pathogen's spread. The metaphor of "leaf as landscape" is appropriate in this scenario: either through direct or indirect competition, or perhaps mycoparasitism, a robust endophyte community may limit the ability of invadingpathogens to grow rapidly or extensively within leaves. Whether endophyte communities are more resistant to invasion when more diverse or more densely packed with individuals remains to be determined, and lends itself to simple experiments. Endophytes act as entomopathogens? Several significant insect pathogens, such as Beauveria bassiana, Aspergillus sp., as well as Paecilomyces sp. Endo phytes isolated from temperate and tropical plants.

Endophyte infections by Beauveria bassiana have been beneficial in limiting damage to maize by the European corn borer, a significant pest, in agroecosystems. In most cases, entomopathogenic infections of insects occur by cuticular penetration rather than through eating of infected plant tissues. Thus, plants with entomopathogenic endophytes benefit from the proliferation of fungal propagules on senescent tissues. The prevalence of entomopathogens in tropical endophytes has not been determined, but it is worth investigating using bioassays (to find new entomopathogens) and screening nameless cultures and leaf samples with particular primers to recover recognized species of entomopathogenic fungi. In general, the possibility of plants harboring entomopathogenics as symbionts is worth investigating in tropical forests [8].

Endophytes may protect plants from insects, but they may also function as folivore attractants and/or increase feed quality. Pathogen migration and/or infection success are directly linked to herbivorous insects. Garca-Guzman and Dirzo discovered a link between folivory and visible symptoms of pathogen dam age in Los Tuxtlas, Mexico: 43% of surveyed leaves were damaged by both herbivores and pathogens, 16% were damaged only by herbivores, and less than 2% were damaged only by pathogens. The scientists found that cuticular injury by insects is necessary for pathogenic fungus infection. Arnold (unpublished data) discovered that parts of Gustavia superba leaves damaged by hesperiid larvae had significantly higher rates of endophyte infection, higher endophyte species richness, and a different endophyte community than undamaged areas of the same leaves. Similarly, Faeth and Wilson surface-sterilized and then artificially herbivorized Quercus emoryi live leaves in Arizona, matching each herbivore-damaged leaf with an undamaged leaf of equal age and position. Endophytes were more numerous in damaged leaves and damaged sections of leaves at the conclusion of the growth season than in undamaged tissue. Leaf damage caused by chewing or scraping insects such as Lepidoptera, Orthoptera, Coleoptera, and Hymenoptera destroys the leaf cuticle, allowing environmental fungus to enter the leaf interior. Insects with piercing or sucking mouthparts are more typically connected with viral transmission than fungi, although there are exceptions.

Two aphid species, for example, may spread the fungal rust pathogen Puccinia punctiformis. Furthermore, sugar-rich exudates generated by piercing or sucking insects may enhance the frequency of fungus on leaf surfaces, improving infection success. For example, honeydew is an important nutrition source for Septoria nodorum, Uromyces vitis-fabae, and Botrytis fabae on their respective host plants, facilitating infection. The fact that folivory may boost endophyte colonization, along with the discovery that endophytic fungal propagules remain alive after transit through the orthopteran stomach, shows that folivory may benefit certain endophytes. This advantage would have two components: folivores would open new substrates by compromising leaf cuticles, and endophytes would be able to proliferate (from frass) more quickly than if imprisoned inside long-lived leaves. This accidental mycophagy should be investigated: can chemical changes in leaf tissues or the presence of fungal tissues make herbivores more appealing? Is the presence of fungal amino acids or other compounds beneficial to the quality of forage? Could endophytic chemicals have a role in shielding herbivores against parasitoids? In general, the significance of insect-mediated endophyte transmission in the tropics has received little attention, although it may be crucial for understanding the intricate interaction between endophytic and pathogenic fungus, herbivorous insects, and tropical plants [9], [10].

A vast array of fungal species may colonize live plant tissues in tropical woods. A plethora of species dwell within a landscape limited by just a few square centimeters of a leaf lamina, and leaves may function as provinces within the intricate geography of individual branches, trees, and forests. Because of the abundance and diversity of little-known endophytes, some authors have classified tropical plants as chimaera, in which plant tissue is interlaced with attendant fungal hyphae, or as "inside-out lichens", in which plants are functionally inseparable from the genetic, structural, and evolutionary contributions of their fungal symbionts. The ecological significance of these concealed symbionts are just now becoming clear, promising decades of study at the intersection of endophyte biology and tropical ecology. It has been estimated that the great majority of micro fungi in tropical forests are undescribed species, and some scientists have proposed that there may be up to 1 million endophytes. If current estimates are true, endophyte diversity is expected to be several orders of magnitude more than that of terrestrial plants. Why are there so many tropical endophyte species? The explanation may be buried in speciation and extinction rates, and, in the case of symbionts, a following complicated interaction of specificity and generalist that cannot yet be quantified accurately. According to Leigh, a more appropriate question may be: What circumstances promote the coexistence of such varied species? The diversity of species that share similar substrates in tropical forests may drive a constant process of character displacement in tropical endophyte communities. Furthermore, the practically limitless combinations of genotypes, chemical exudates, and interactions are expected to produce endophyte communities with different emergent features that are as varied as the fungi themselves.

CONCLUSION

Understanding the ecological functions of endophytic fungus is a continuing research topic. The variety, distribution, and roles of these fungus in tropical community ecology are being revealed by advanced molecular methods. More study is required to determine the precise methods by which endophytic fungus contribute to plant communities, interact with other species, and respond to environmental changes. Recognizing the significance of these invisible contributions is critical for fully comprehending tropical ecosystem dynamics and preserving biodiversity in these varied and important environments.

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CHAPTER 25

OPPORTUNITIES AND CONFLICTS IN WILDLIFE CONSERVATION IN AGROFORESTRY BUFFER ZONES

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ABSTRACT:

Conservation of wildlife in agroforestry buffer zones brings both possibilities and challenges. Agroforestry buffer zones are sections of land close to agricultural fields or plantations that are maintained to provide animal habitat and resources while also acting as a buffer between natural habitats and agricultural areas.In this chapter, we addressed Wildlife Conservation Opportunities and Conflicts in Agroforestry Buffer Zones.

KEYWORDS:

Area Limits, Buffer Zone, Agroforestry Buffer, Game Species, National Park.

INTRODUCTION

Conservationists increasingly realize the need of working outside of protected areas in order to preserve robust animal populations and large-scale ecological processes. Finding greater room for animals is tough given that many tropical forest parks and reserves are bordered by some type of agriculture. Too frequently, environmentalists create ambitious plans that extend wildlife corridors and buffer zones well beyond protected area limits, without taking into account the practical and political practicality of supporting wildlife in present land use regimes. Conservationists risk establishing paper buffer zones unless such maps are created with the involvement and input of local communities. By neglecting local sentiments toward animals, protected area manager's risk missing out on opportunities to form coalitions, or worse, antagonizing locals and turning them against conservation. In this chapter, we look at the potential and challenges of animal conservation in agroforestry buffer zones. We show how the local social and physical environment impacts the sustainability of wildlife management and the importance wildlife has for est farmers and protected area managers by drawing on many instances from around the tropics. We also demonstrate that the relative costs and advantages of wildlife in agroforestry buffer zones vary depending on the person [1].

A mountain gorilla grazing on fields outside a park, for example, may be a prized endangered species to conservationists but a dangerous problem to the local farmer. Sensitivity to local context and views is required to devise feasible solutions for gaining room for animals outside protected area limits. Managers must think imaginatively and form relationships with local groups in order to reduce conflict. They must also understand that their authority outside protected area limits may be questionable, emphasizing the need of including local inhabitants as planners and decision makers. 319 In the tropics, protected forest areas and agriculture intersect and interact in several ways. A tea plantation may be next to a towering stand of old growth, or a grove of fruit trees may gradually blend into secondary forest. As with the other chapters in this book, we employ a wide definition of agroforestry and define an agroforestry buffer zone as any land use system that combines trees with agricultural crops and is near to a park or reserve. Wildlife survival and local tolerance are influenced by the character of the park-agriculture interface.

Wildlife, for example, may not move far from a protected region surrounded by highly developed agriculture, but when it does, it generates considerable conflict. In contrast, in a sparsely populated extractive reserve, animals may roam over a forest-agriculture mosaic and be maintained as game by local farmers. The agroforestry system's wildlife access guidelines are also critical to understanding local sentiments. Farmers are likely to react differently to an animal that they are allowed to hunt than to one that is carefully protected. These physical and sociological elements, when combined, determine local views toward wildlife and its position as a problem or valuable resource. When a result, when we examine the costs and benefits of wildlife for various stakeholders, we explain how the local physical and social environment influences these assessments. In this approach, we want to give new insights on the feasibility of animal conservation outside the bounds of protected areas in various scenarios. Case Study Sites on a Continuum from Forest-Agriculture Mosaics to Hard Edges to identify key factors shaping the viability of wildlife management in agroforestry buffer zones, we describe human-wildlife interactions in three national parks, each from a different tropical region and each surrounded by a variety of agroforestry land uses [2].

A1 plum + rape

A2 plum + passion fruit

A3 pear + potato

A4 pear + corn

A5 pear + bletilla

A6 pear + polygonatum

A7 tobacco + rape

Figure 1: Agroforestry planting patterns: Diagram showing the Agroforestry planting patterns (MDPI).

Bahuaja-Sonene National Park (BSNP), situated in the southeast Peruvian Amazon, is the most distant of the three locations. The BSNP is a one-million-hectare uninhabited park bordered by the 252,000-hectare Tambopata National Reserve (TNR). Adjacent to these protected areas is a 272,582-hectare buffer zone whose residents plant rice, cassava, and maize in shifting cultivation fields. GunungPalung National Park (GPNP) in West Kalimantan, Indonesia, is the second location. GPNP is a 90,000-hectare deserted park bordered by production forests and agricultural regions with various population densities, where locals raise lowland and highland rice, other grains, and fruits. The third location is the 76,000-hectare Kibale National Park in western Uganda. Kibale is an undeveloped park bordered by thickly populated terrain used for permanent cultivation (90-242 persons per square kilometer). Kibale is an example of a hard edge, with rapid changes in forest conditions and land use patterns near the park border. In addition to obvious differences in human population density and land use intensity, these three areas differ in terms of wildlife access laws, est resources, and cultural values of wildlife.

A hard edge, where forest conditions and land use patterns change suddenly at the park border, is described in detail in previous works. In addition to obvious differences in human population density and land use intensity, these three areas differ in terms of wildlife access laws, est resources, and cultural values of wildlife. Other publications provide detailed location descriptions for wildlife on their territory (Figure.1). Alternatively, they may like the presence of particular species but detest the presence of others. In the three case studies, we concentrate on the relative costs and advantages of animal presence in agroforestry landholdings outside parks to better understand the complicated perspectives among people of buffer zones. Wild species cross park borders at each of these locations to feed or hunt in the neighboring agroforestry zones. This border crossing results in both costs and advantages for many parties [3].

The conflicting viewpoints of these two stakeholder groups emerge in the conversation that follows. Bahuaja-Sonene National Park: Hunting Opportunities for Neighboring Farmers Among the three locations, BSNP offers the finest circumstances for long-term hunting in the buffer zone. BSNP sits in the Department of Madre de Dios, one of Peru's most isolated and biodiverse areas. Until the late 1800s, this lowland, wooded area was cut off from exterior markets. The entrance of 6,000 rubber workers gave birth to ribereo civilization (Amazonians of mixed lineage), while slavery and illnesses destroyed indigenous tribes. After the rubber business collapsed in the early 1900s, the local population remained constant until the mid-1960s, when a road was built into Madre de Dios. Gold, land availability, and economic incentives for ranching and farming drew Andean peasants to the area. Tambopata's population increased fivefold in 25 years, reaching 76,610 in 1997, with almost half of the population living in Puerto Maldonado. Despite fast population expansion, Madre de Dios maintains Peru's lowest population density (0.9 inhabitants per square kilometer) and the biggest stretches of unspoiled forest. The BSNP is huge and unpopulated. Large creatures that are endangered or uncommon elsewhere in the Amazon, such as white-lipped peccaries (Tayassu pecari), giant otters (Pteronurabrasiliensis), tapirs (Tapirusterrestris), and large-bodied monkeys, are numerous in the park. The majority of the park and nearby TNR is covered with intact primary forest. The buffer zone is dominated by forest, although it also contains logged forest, regenerated shifting agricultural fallows, and woodland under extractive use.

Around 3,000 farmers clear 0.5-ha shifting cultivation plots in the buffer zone to grow rice, maize, and cassava. Approximately 10% of the occupants of the buffer zone are indigenous Ese'eja people who live on communally held land. This case study focuses on ribereos, the buffer zone's major social group. Ribereo landholdings are typically 40 ha in size, including 21 ha of mature forest, 7 ha of fallow land, 5 ha of annual crops, and 5 ha of pasture (Alvarez 2001).

Agriculture is the most prevalent economic activity among local inhabitants, although they, like other Amazonians, engage in other economic activities (e.g., fishing, mining, gathering Brazil nuts [Bertholletiaexcelsa], and logging) in response to resource availability and boom and bust economic cycles. Approximately 20% of households in the buffer zone raise cattle (average 15 head per household), largely for financial purposes. The majority of individuals (more than 90%) grow small livestock for personal use (an average of 20 animals per household, including pigs, chickens, and guinea pigs).

Local inhabitants' exact salary numbers are unclear, however the minimum wage in 2000 was 5 soles. Approximately half of the population within the buffer zone hunt. In Peru, no single law governs hunting; rather, restrictions are linked to forestry and other legislation and may vary from year to year. Local locals and park guards are unsure about what animals may be killed where, especially in light of recent modifications in BSNP protected area limits. However, under Peruvian law, wildlife is designated as national treasure and the national government is responsible for its conservation. Except for 15 game species, all Amazonian animals are currently protected from hunting. Tapirs, pacas (Agouti paca), agoutis (Dasyprocta variegata), capybaras (Hydrochaeris hydrochaeris), armadillos (Dasypusnovemcinctus), turtles, and several game birds are among the game species. Hunting for these 15 game species is permitted in small settlements, including those in reserves and buffer zones, for sustenance and local market. Hunting is also permitted when wildlife poses a hazard to agriculture or cattle. Locals refer to this kind of hunting as cacera sanitaria especially when it comes to predator elimination [4].

The majority of hunters kill their game using shotguns. The capture of animals is unusual. Local Agriculturalists' Point of View Residents in the vicinity of BSNP frequently refer to animal species as presa ("game") or plaga ("pest"; Ascorra). Their categorization is based on the species' marketability and the possibility for major crop or animal losses. Individual views toward wildlife are also influenced by a species' local abundance and the farmer's skill and interest in hunting. Indigenous people and Ribereos are more likely to hunt than colonists, who lack the necessary comprehensive knowledge of the forest. Even in game-rich locations, colonists hunt less often than ribereos or indigenous people. Tambopata hunters are often more optimistic than non-hunters about having wildlife on their farms, especially high-value or big animals like pacas, brocket deer, tapirs, and white-lipped peccaries. Those who live near the park are lucky in that they may kill huge and valuable wildlife on their farms, easily compensating agricultural losses caused by this and other wild animals. Farmers who live more than 700 meters from the park's edge, on the other hand, are more likely to meet smaller, more adapted species such as armadillos, collared peccaries (T. tajacu), tayras (Eira barbara), and agoutis (Dasyprocta spp.). Agoutis do the most damage to maize and cassava in the buffer zone, and residents remark that this 4-kg rodent is "not even worth a bullet".

Just as the rewards of hunting are not uniformly spread in the local population, so are the costs of raiding. Residents in the buffer zone lose minor quantities of crops (maize, cassava, rice, and plantain) on average. A study of animal damage from 1998 to 2000 showed that wildlife damage aver aged less than 3% by area, or around $13 every planting season (for further information, see Naughton-Treves 2002), although average numbers disguise the uneven distribution of loss. Most farmers lost little to wildlife, while a few lost a lot (up to 47 percent). Losses to prime game species like pacas, tapirs, and peccaries are often handled better than losses to minor game like agoutis or nongame like tayras (a weasel family member that flourishes in agroforestry mosaics; Bisba). Residents who hunt in the buffer zone's changing cultivated fields or fallows (i.e., garden hunters) catch an average of 9 kg or approximately $14 of game meat per hunter throughout a planting season (about 5 months).

In reality, some hunters share the meat with their families, others sell it to neighbors, and still others illegally sell it to intermediaries for eventual sale in Puerto Maldonado. The average gains are roughly equivalent to the average crop losses to wildlife. However, thorough surveillance of 24 garden hunters in the surrounding area found that just three received more money from meat than they lost due to crop damage. These hunters resided near the reserve's line and were able to hunt tapirs and white-lipped peccaries in isolated places, including highly wooded buffer zone and reserve sections. Given the paucity of large game, it is more difficult for farmers farther from the reserve line to balance agricultural losses with hunting benefits. Furthermore, many hunters dislike hunting in brushy, hot fallows and fields with limited sight. They love to hunt in dense woodlands where they may take down bigger creatures [5].

Several hunters characterize agroforest hunting as a pastime for the elderly and infirm. Predators are the only sort of animal that is unanimously regarded as a problem in Tambopata. Predators such as jaguars (Panthera onca), pumas (Felis concolor), ocelots (Leopardus pardalis), and jaguarundis (Felis yagouaroundi) are not tolerated on hunters' or farmers' property. A random sample of 60 farmers in the buffer zone stated that the majority (75 percent) had lost poultry or pigs to wild predators. The most often accused wild species were ocelots (reported by 31% of farmers) and hawks (28%), followed by jaguars (5%). Tayras, jaguarundis, pumas, and bush dogs (Speothosvenaticus) were also mentioned. Farmers living near the area reported losing more domestic animals to a wider range of predators than those living farther away. The average value of cattle lost per farmer due to jaguar attacks was $118 per year (range $6-$294, SD = $121, n = 9). The average annual value of cattle lost to other predators was $49 (range $6-$194, SD = $54.3, n = 24). Jaguar assaults were recorded every 2.6 years among individuals who suffered losses, compared to every 1.1 years for other predators.

Hunters lost less domestic animals to predators than no hunters. In addition to direct advantages from hunting, animals may bring indirect benefits to people of buffer zones. Many of Tambopata's buffer zone inhabitants' economic worries are linked to Brazil nut farming. Approximately 20% of locals harvest Brazil nuts for commercial selling. Brazil nut plants need strong populations of euglossine bees to pollinate and produce plentiful fruit. These bees, in turn, rely on a healthy forest. As a result, the production of Brazil nut trees is linked to the health of local bee populations, which need a healthy forest. People, on the other hand, often shoot macaws and parrots that come to eat on ripening Brazil nuts. Biologists say that, contrary to popular opinion, parrots and macaws inflict no harm to Brazil's nut harvests, and they are currently spearheading an anti-macaw hunting campaign, arguing that killing macaws costs more in ammunition than it saves in fruits.

When the fruits ripen and fall to the ground, agoutis opens them and burys the nuts one by one, generally within 100 meters of the tree. Most seeds do not germinate because they are devoured by agoutis or other animals that locate the agoutis' stockpiles. Thus, Brazil nut trees need agoutis for seed dissemination, but an abundance of agoutis would likely hinder regeneration. Instead of protecting or controlling agoutis on their concessions, Brazil nut harvesters hunt them with shotguns or machetes whenever the chance presents itself. As a result, agoutis helps to meet the protein demands of Brazil nut harvesters. Brazil nuts are an example of how insects, trees, animals, and local people all work together in managed tropical forests. Finally, wildlife as an ecotourism attraction has the potential to generate revenue. The Tambopata area is seeing a surge in ecotourism. Tourists, on the other hand, often avoid populated areas, and their money goes to a small group of individuals who manage lodges in the buffer zone or reserve. Hunting, agriculture, and ecotourism cannot coexist in the same location.

The Esse'eja, an indigenous group in the buffer zone, struck a deal with a tour operator that promised them 60% of earnings and half the decision-making power in exchange for agreeing not to hunt or grow on 4,000 hectares of their property. This is more challenging for the individual landowner. Given that most individuals manage their property in 40-ha portions on their own, zoning must originate from higher representative entities (for example, a farmers' union). The Institute for Natural Resources (INRENA) of Peru is the official entity in charge of administering the BSNP and TNR. Its control over the buffer zone is uncertain. Buffer zones are not protected areas under Peruvian legislation, but INRENA personnel claim to have the last say in land use planning in the buffer zone. Given the enormous expanse of the territories and INRENA's modest budget, INRENA has little control over human activities in all three areas. The region has thus far been safeguarded mostly due to its remoteness [6].

Given these circumstances, the major management purpose of INRENA is to stabilize land usage along colonization fronts. To that purpose, it is collaborating with local stakeholders (e.g., environmental nongovernmental organizations, agricultural unions, indigenous federations, and tourist corporations) to create zones in the TNR where varied intensities of land use are permitted (Ascorra et al. in preparation). Managers see the park's bordering national reserve as a buffer zone where economic growth and biodiversity protection may coexist. They also consider the reserve and its surrounding buffer zone as a source of extra animal habitat. However, managers are concerned that hunters are already eradicating big and slow-reproducing species across the buffer zone.

Outside the park, large animal species, especially in sparsely populated regions, are already showing indications of overexploitation. In essence, the buffer zone serves as a sink for vulnerable species. In the long term, conservationists will tolerate this dynamic as long as the park's source regions are sufficiently big and effectively protected. Hill and Padwe estimate a source-to-sink area ratio of 7:1 for sink hunting to be viable. Conservation International-Peru, a non-governmental organization, has been working with two villages in the buffer zone to encourage more sustainable hunting methods. Urban demand for game meat and ambiguous property rights make sustainability difficult to achieve, although there are some encouraging instances of communities voluntarily establishing no-hunting zones and monitoring wildlife populations in their region. Despite the fact that a small number of ardent hunters endangers game species, they are the ones most engaged in wildlife conservation projects. Most farmers hunt only on rare occasions, if at all, and wildlife is not a valuable resource to them. These people generally support animal conservation projects, although they would prefer not to have wildlife visit their farms.

DISCUSSION

Over the last several decades, the wooded regions around the park have been logged or turned into agricultural fields, isolating the park. The settlements along the park's western side have been inhabited for generations, mostly by Islamic families, the majority of whom are of Malay descent, and by few families of Chinese heritage who relocated to the region in the early twentieth century. A number of trans migrants from Bali and Java have also moved in the region in recent decades. The park's inner villages are mostly populated by Dayak families. Residents of the park's western villages have created a complex land use system that includes farms, home gardens, forest gardens, and extractive areas from which they harvest rattan, specialty timbers, and other forest products in a gradient that leads away from the village and toward the park.

Key crops planted in forest gardens include durian, rubber, coffee, and other market crops (for more information on the structure and biodiversity of such complex agroforests. The major crops grown in agricultural regions are paddy rice, maize, and vegetables. The park's formal boundary with the communities on the park's western side is the bottom of numerous tiny hills within the park; there is no legally recognized buffer zone. Local villagers, on the other hand, have been progressively extending their forest gardens up the hill over the last several decades, taking over ground that is theoretically part of the park. As a result, this instance illustrates how the agroforestry buffer zone is encroaching into the park's forest areas. Religion was shown to be the most important element impacting attitudes toward wildlife in a study of forest garden owners' perceptions on wildlife. Although some families hunted larger deer (Cervus unicolor and Muntiacus spp.) and Balinese and Chinese families hunted pigs (Sus barbatus), the majority of village residents did not eat much bush meat, owing in part to Islamic religious prohibitions on eating wild animals other than deer. As a consequence, 332 IV may be seen often. Biodiversity as a Burden and Natural Capital gibbons, hornbills, and other big diurnal creatures in forest gardens near Islamic settlements. People hunted many types of animals in Dayak settlements on the park's northern perimeter, in contrast [7].

Langurs, long- and pig-tailed macaques, squirrels, rats and mice, pigs, and sam bar deer were among the most troublesome animals, causing moderate to severe crop damage. Weasels (Mustela spp.) and leopard cats (Felis bengalensis) allegedly destroyed the residents' poultry and ducks. Residents also assumed that the flying foxes ate the blossoms of the durian tree, failing to recognize their pollination function. Residents indicated that damage caused by all animals (including rats, mice, and flocks of small birds) cost them 9.0 percent (SD = 10.4 percent) of their gross income (the range was 0-50 percent). This statistic does not account for the time, effort, and equipment spent by people protecting crops before harvesting them. Residents, for example, slept in the fields for a week or two before harvest to save their rice crop from being devoured. A few people (mainly males who had spent a significant amount of time working in the forest) indicated interest or satisfaction in seeing and discussing what animals did.

Most inhabitants, however, exhibited mixed or even unfavorable opinions about the presence of animals. GPNP is home to a diverse range of wildlife, including indigenous proboscis monkeys (Nasalis larvatus) and the biggest surviving orangutan population in Kalimankan. It also has one of West Kalimantan's few surviving natural habitat corridors from the ocean to the cloud forest. Unfortunately, as previously said, the park is rapidly becoming into an island of woodland surrounded by agricultural plains. Furthermore, wood harvesting and land conversion to agricultural purposes are progressively clearing forest inside the park's borders. The national park administration has always maintained a poor presence on the ground around the park, like in most of Indonesia.

In reality, buffer zones were established on what were formerly park areas to cope with continued resource exploitation. Although less diversified than primary forest, these zones maintain forest cover and are hence preferred to monocultures. In other words, these buffer zones act as geographical buffers, increasing the distance between settlements and forest. The buffer zones also offer habitat for certain wildlife species and may aid in the creation of corridors for crucial animal movement. Kibale National Park: Conflict and Compromise on a Precipice Kibale National Park, located in western Uganda, is well known for its exceptional diversity and density of primates, including chimps (Pan troglodytes), eight monkey species, and three prosimians (Struhsaker 1997). Olive baboons (Papioanubis), red-tail monkeys (Cercopithecusascanius), bushpigs (Potamochoerusporcus), and elephants (Loxodonta africana), which have been reduced by more than 90% in Uganda over the last 30 years, are also present at Kibale. Although hunting is prohibited in Kibale, snares are often discovered throughout the park. Outside the park, citizens may only hunt "vermin" (baboons, vervet monkeys, and bushpigs) with permission from the Ugandan Wildlife Authority. Smallholder agriculture is practiced on about 54% of the area within 1 km of Kibale's perimeter. Agriculturalists in the region are divided into two ethnic groups: the Batoro, who arrived in the area in the 1890s, and the Bakiga, who arrived in the 1950s. Batoro leaders at the time gave immigrants land on the outside of their communities in the hope of protecting Batoro farmers from crop damage by wildlife [8].

Today, both communities cultivate a diverse range of subsistence and income crops, including bananas, maize, beans, and yams, coffee, and fruit trees. Farm sizes are tiny (1.4 hectares on average) and managed on an individual basis. Various animals feed on crops in this complex farming system, causing local producers to be frustrated and resentful of the park. In a 1992-1994 research, agricultural damage was reported within 200 meters of the park perimeter, with losses ranging from 4 to 7 percent by area every season. However, like with BSNP in Peru, the loss distribution was exceedingly unequal. Over half of the 334 IV.

All farmers within 500 m of the border lost no crops to wildlife, while 7% lost more than half their harvests. Certain settlements were especially susceptible to elephant destruction and incurred significant losses. Farmers enjoy the drinking water, fuelwood, and medicinal plants they collect from Kibale. Red tail monkeys, for example, visit many farms and may do more aggregate damage, but they do not destroy a whole field in a single raid; their damage is self-limiting. Elephants, on the other hand, harm fewer farmers but may create catastrophic damage and represent a physical danger. Only elephants are capable of inflicting such serious crop destruction that people in the Kibale area are forced to quit their farms. Farmers in the Kibale buffer zone differ in their ability to deal with crop loss due to animals. Guarding is by far the most prevalent defensive method (60 percent). Half of the farmers keep land fallow at the forest boundary, where there is a significant danger of loss. Farmers are hesitant to acknowledge to killing animals since it is prohibited, although snares or poison were found on 15% of farms along the border.

Some farmers are able to reduce danger by establishing buffer zones on their properties. For example, wealthy landowners may utilize pasture or cultivate coffee or tea to separate their food crops from the forest. However, the owner of a small farm may have limited options for arranging crops of varying palatability to animals and may end up growing maize straight on the border. Similarly, more prosperous farmers may hire others (typically other people's children) to protect their fields, but poorer farmers must either risk crop loss without a guard or forego other chances, such as education, to leave a kid guarding crops. An additional expense of guarding is increased malaria exposure, since most raiding happens at dawn or dark, when Anopheles mosquitoes are active. Most farmers believed these passive defensive tactics to be expensive and only partly successful.

Although farmers in Kibale do not work together to safeguard their crops, an individual's susceptibility is impacted by his or her neighbors' activities. A farmer, for example, who lives in a community where others hunt in their fields is likely to incur less bush pig damage, even if he or she does not hunt (Naughton-Treves 1998). Finally, a farmer's greatest protection against wildlife damage is to put a neighbor's crops between his or her farm and the forest, so that the damage occurs on the neighbor's field rather of his or her own. Some big landowners (over 8 ha) take advantage of this protection by leasing plots to other farmers along the forest border. Researchers in other parts of Africa have shown that a tightly packed belt of farms is the strongest barrier against animal intrusions deep into agricultural regions. Aside from regional patterns of danger, Kibale's tolerance to wildlife is affected by the political situation. Many buffer zone inhabitants angrily refer to crop-raiding animals as "the government's livestock" and feel the government should assist guard, slaughter animals, or erect a barrier. Farmers often compare the government to a nasty neighbor who allows its "livestock" to destroy other people's crops. They point out that farmers are required by customary law to reimburse their neighbors for any harm caused by their cattle [9].

They seldom highlight how many farmers graze their cattle and goats illegally in the park. Clearly, traditional local social contracts about grazing rights and reparations for animal crop damage do not exist between farmers and Kibale National Park administrators. Some people's worries about animals are exacerbated by their overall dislike of the area. When Kibale was elevated from a reserve to a national park in 1993, hundreds of people were forcefully relocated from the Kibale game corridor. Residents who remain in the neighborhood are concerned that any park intervention on their property may result in more evictions. Crop losses of 4-7 percent in a restricted band of farmland seem to be a modest price for conserving endangered animals and est habitat, according to park managers. Indeed, in Kibale, the zone of greatest agricultural loss (approximately 200 m outside the forest border) may be deemed 3,000 hectares of additional animal habitat.

However, roughly 4,000 disgruntled farmers live in this additional habitat and are passionately opposed to the use of their land as a "park for grazing wild animals," putting coalitions between environmentalists and local inhabitants at risk. Most managers, however, recognize that there is no other option except to reach out to local communities. Wild animals will unavoidably breach park borders, leaving them vulnerable to snares and poison. Up to 20% of one monkey colony in Kibale had lost a foot or hand to snares they gathered up while foraging in 336 IV. Outside the border, biodiversity as a burden and natural capital crops. More generally, Uganda is evolving toward decentralized resource management, driven by both donor focus on community engagement and financial constraints in government institutions. All of these considerations make it even more critical to increase public support for wildlife.

Managers have experimented with growing no palatable crops such as soybeans, sunflowers, tobacco, tea, and Mauritius thorn (Caesalpinia decapetala) along the park boundaries. A cultivar must be lucrative, unappealing to animals, and planted across a big enough region to lower the attraction of crops beyond to be effective as a buffer. The majority of farmers in Kibale have modest landholdings (1.4 ha) and do not collaborate with neighbors on crop selection, planting, or upkeep. This restricts the effectiveness of buffers. Baboons effortlessly crossed over his neighbor's fallow field to reach the maize when a single farmer planted tea on the woodland border and corn 100 meters beyond. Given the modest landholding on the outskirts of Kibale, a buffer is only a realistic choice if neighbors work together to plant it [10].

Collective attempts to plant Mauritius thorn barriers along the border have yielded better outcomes. Tea is a popular buffer crop in highland Africa since no animal species devour it. A tea buffer, on the other hand, must be planted continually and substantially, as well as trimmed on a regular basis. Such a planting regime is beyond the capabilities of a single farmer and would need communal or corporate ownership. The area removed to establish tea buffers around Kenya parks came from the national park, a substantial sacrifice considering the limited and isolated character of most highland parks. Many Kenyan park administrators have resorted to using an electric fence as a barrier. Many of Kibale's neighbors, especially those who live in areas vulnerable to elephant incursions, have requested a fence. Fences, on the other hand, are expensive and anathema to conservation biologists working to integrate ecosystems and eliminate species population separation. Kibale management have also created tourist revenue-sharing schemes to increase local tolerance for animals. Kibale receives around 1,000 visitors each year, each of whom pays US$10 for a guided forest walk that includes the chance to observe chimps. To far, 5 of Kibale's 27 bordering parishes have engaged in income sharing schemes. Over a three-year period, they got $3,000 in tourist earnings to fund schools and clinics. Despite the little fee, park managers had stronger interactions with inhabitants from beneficiary areas. It is unclear if these communities who get community money hunt less than those that do not, however recipient groups cooperated in the apprehension of mountain gorilla poachers in a nearby park. Surprisingly, several participants viewed income sharing as a larger benefit of having a park.

Conservation of Wildlife in Agroforestry Buffer Zones 337 is more important than obtaining access to non-timber forest resources. Aside from generating large cash, identifying the suitable community in the buffer zone to benefit from tourist revenue sharing is a big difficulty, mirroring common quandaries in integrated conservation and development project (ICDP) design. Managers aiming to promote wildlife survival in agroforestry landscapes beyond protected area boundaries must carefully consider the social and physical parameters of their site and tailor their approach to local context. Managers may support the maintenance of wildlife habitat by encouraging sustainable hunting among local residents when animal populations are quite numerous and human population densities in adjacent buffers are low (e.g., BSNP). Although this hunting may increase the local value of wildlife for hunters, it is vital that game access laws (e.g., who gets to hunt which species and where) be well stated and enforced, or else wildlife as an open access resource would likely be depleted. Managers must also recognize that hunting possibilities in a buffer zone are not fairly distributed, and persons who live near to a park and have ecological understanding will be best equipped to exploit animals.

Many farmers, on the other hand, have little interest in hunting (for example, new colonists with no expertise or experience in tropical woods). Hunting is seldom a communal, organized activity for rural people in the same way that other non-timber forest products (such as rattan, Brazil nuts, or firewood) are. Furthermore, the ecological feasibility of hunting in agroforestry buffer zones is dependent on the size and growth rate of source game populations in the park, as well as the intensity of hunting in the surrounding buffer zone. Interior species and large-bodied species are likely to be depleted in agroforestry zones unless hunting is strictly prohibited culturally or legally. Some species that are adaptive and have strong reproduction rates may flourish in agroecosystems. Smaller, more widespread species include agoutis, bush pigs, baboons, cane rats (Thryonomys spp.), and macaques. In regions where parks and forests are becoming more isolated islands, such as GunungPalung, agroforestry methods may be implemented in buffer zones to offer spatial buffering for the protected area and, in principle, create corridors to link forest areas. However, the usefulness of these areas is heavily dependent on how well farmers can be protected from crop-raiding animals and wildlife from local hunting pressure. Given the endangered status of certain crop raiders and circumstances of land scarcity and poverty along the protected area edge, there is less space for maneuver in high-conflict, high-risk settings like Kibale. Interventions such as revenue-sharing programs, buffer crop planting, land buyouts, and fencing may be acceptable at such locations. Compensation and insurance schemes have a poor track record in most tropical countries due to corruption, administrative inefficiency, and other issues, but they merit consideration, particularly in areas where highly endangered species are present and conservation funding is available.

Compensation is a standard technique in the United States and Europe for preserving wildlife beyond protected area limits, and it has been used to generate political support for protecting animals that endanger livestock and crops, such as timber wolves and bears. Kibale is also a challenging location due to the prevalence of elephants. Elephants and other megafauna (animals weighing more than 1,100 kg, such as hippos and buffalo pose unique challenges in buffer zones because they may cause catastrophic agricultural damage and endanger human lives. Large predators pose comparable difficulties. Conservationists should not expect farmers to accept these animals unless they are compensated for their losses. Farmers use obstacles even in acclaimed cases of community-based wildlife management. For example, 20 percent of safari hunting money in the CAMPFIRE (Communal Areas Management Programme for Indigenous Resources) program is spent on electric fences around farms. Enclosing farmland is preferable than enclosing wildlife from a conservation viewpoint, but this is seldom politically or financially possible. Conclusions Human-wildlife interactions vary greatly between and within the three areas examined in this chapter. As a result, there are no blanket guidelines for employing agroforestry to support animal protection. However, there are a few fundamental notions that managers should bear in mind while deciding if this technique would be effective in their specific situation. Distance from Natural Forest Is Important In all three sites, the population farming closest to the protected area boundary pays the most and obtains the most wildlife benefits. In the case of Peru's BSNP, many protected area neighbors enjoy big game hunting on their farms, easily balancing agricultural losses to wildlife.

Hunting is a crucial variable that determines both local attitudes toward wildlife and the effect local people have on wildlife at all three locations. Indigenous tribes and ribereo populations in BSNP are more likely to cherish wildlife than recent colonists, who seldom hunt and have little experience of the area. However, although local hunters may cherish wildlife, many species are overexploited. Wildlife is an open access resource surrounding BSNP, and wildlife will remain vulnerable in the buffer zone and accessible portions of the reserve until there are widely recognized laws limiting access to wildlife. Religion is a crucial element in deciding who hunts and who does not in Indonesia. Although hunters may put a higher importance on wildlife, bigger quantities of animals may be found in towns where hunting is banned. At Kibale, tight hunting bans exacerbate local sentiments of vulnerability to crop loss, leading to anger of the "government's livestock." The small size and individual character of farms around Kibale further restrict people's choices for mitigating damage. Although collective animal losses for buffer zone people are limited, the potential of catastrophic individual loss due to elephant raiding and animosity for park evictions of corridor communities have resulted in generally unfavorable attitudes. Negotiating hunting laws and refuges is vital if game species are to persist in agroforestry systems, according to the experience at all three locations.

Another difficulty for those encouraging wildlife in agroforestry buffer zones is the possibility of collective action by buffer zone inhabitants. Biodiversity as a Burden and Natural Capital unless hunting restrictions are agreed upon and enforced, wildlife will be exposed to overexploitation by private hunters. Similarly, individual farmers cannot successfully defend themselves against wildlife raids, notably from elephants. Managers should safeguard and promote collective land management methods in order to construct effective barriers or guarding regimes. Individuals in forest farming communities have varying capacities to benefit from the presence of these species or to manage with pests. Affluent farmers with bigger landholdings may better reduce their risks from animals, despite the fact that they are often the worst complainers and may wield more political power.

Agroforestry farmers in all three locations were concerned about environmental protection. They understood that natural forests and agroforestry offer critical environmental services such as soil and water protection, firewood and building materials, and medicinal plants. Farmers, on the other hand, were less likely to recognize the significance of animals in supporting ecosystem function via pollination, seed dissemination, and predation. Recent rainforest colonists are unlikely to be aware of these indirect functional responsibilities. Long-term residents may understand complex plant-animal interactions in rainforests, but if they are so poor that they cannot meet their subsistence needs, they are unlikely to be concerned about long-term declines in tree species or the other consequences of removing wildlife from forests. Knowledge local tolerance and the feasibility of animal conservation in buffer zones requires a knowledge of both culture and politics. Local communities are diverse, and their members' values for wildlife are likely to vary depending on the level of gain they get from hunting and the agricultural and other losses they experience. Other stakeholders will continue to have different values and may use their political clout or actively interfere to affect the composition and quantity of animals in agroforestry regions. Overall, it is obvious that protected area managers and local residents may have quite divergent views on the importance of wildlife in buffer zone regions.

To improve animal survival in agroforestry buffer zones, protected area managers and conservationists must abandon alluring but unrealistic conceptions of smallholder agriculturalists inviting all species on their fields. Neighboring farmers may accept the overall goal of wildlife conservation, but they will most likely react to wildlife on their farms based on their own economic requirements and cultural beliefs. Hunters may be the most tolerant of animals, but they also have the most direct influence on wildlife numbers. As a consequence, managers must collaborate closely with local people in order to devise solutions that benefit both animals and humans. The sharing of knowledge is a vital first step toward collaborative wildlife management in agroforestry settings. Park managers must be informed on the pressing economic requirements and specific environmental goals of farmers on their property. If agroforestry farmers and park managers work together, they may be more willing to accommodate wildlife.

CONCLUSION

Addressing these problems and capitalizing on wildlife conservation potential within agroforestry buffer zones requires a comprehensive and collaborative strategy. It entails taking into account ecological, social, and economic factors, collaborating with local people and stakeholders, using adaptive management measures, and encouraging sustainable land-use practices that benefit both animal conservation and human well-being.

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