Nutrient and Water Management in Agricultural Soils

Shakuli Saxena

ALEXIS PRESS
JERSEY CITY, USA

NUTRIENT AND WATER MANAGEMENT IN AGRICULTURAL SOILS

NUTRIENT AND WATER MANAGEMENT IN AGRICULTURAL SOILS

Shakuli Saxena

ALEXIS PRESS

ALEXIS PRESS

Published by: Alexis Press, LLC, Jersey City, USA
www.alexispress.us

First Published 2022

A catalogue record for this publication is available from the British Library

Library of Congress Cataloguing in Publication Data

Includes bibliographical references and index.

Nutrient and Water Management in Agricultural Soils by *Shakuli Saxena*

ISBN 979-8-89161-295-2

CONTENTS

CHAPTER 1

UTILIZING CONSERVATION AGRICULTURE TO MANAGE WATER AND SOIL RESOURCES

Shakuli Saxena, Assistant Professor
College of Agriculture Sciences, TeerthankerMahaveer University, Moradabad, Uttar Pradesh, India
Email Id- shakuli2803@gmail.com

ABSTRACT:

Nature has given us the gifts of land, water, and plants. The lifetime of civilizations is determined by the sustainable management of these natural resources. By 2025, India's population, which is now estimated at 1050 million, should reach 1389 million. By 2025, it's expected that 37% of people would reside in urban areas. The demographic trends in India's various states will vary. About 75% of the total cultivated area, or 182.2 m ha, is already covered with food crops. There isn't much room for expanding the amount of land planted with crops to fulfill the rising demand. Instead, the area devoted to food crops is destined to decrease as rich fertile areas are diverted for non-agricultural uses including urbanization, highways, and industry, notably Special Economic Zones.

KEYWORDS:

Agriculture, Conservation, Management, Natural Resources, Soil Health, Sustainability, Water Conservation.

INTRODUCTION

The primary input for increasing the dependability and productivity of agriculture is irrigation. Agriculture uses about 83% of the water used in India, followed by industrial and home uses. The need for water for irrigation is projected to rise as a result of the growth in demand for food[1]. To reach partial self-sufficiency, it is predicted that India would need to produce 320 million tons of food grains by 2025 and 581 million tonnes by 2050. The current global water demand is estimated to be somewhat more than 700 billion cubic meters. According to Table 1, the need will probably rise to 1093 billion cubic meters by 2025. By 2050, it will have increased even further, reaching 1447 billion cubic meters[2].

Table 1. Illustrated the Tentative Assessment for Future Water Requirements.

Use	2000	2010	2025
Domestic	33	54	70
Irrigation	597	691	905
Industry	23	7	12
Energy	18	6	17
Others	32	52	76
Total	**712**	**738**	**1080**

There doesn't seem to be much room for expansion in the net planted area. Crop intensification, input utilisation, and irrigation coverage must all be raised in order to sustain self-sufficiency. Up from the present 80 million ha, there would be 107 million hectares of gross land irrigated by 2025. This would need 910 billion cubic meters of water, which may not be sustainable. We anticipate having a gross irrigated area of around 140 million hectares by 2050.

This clearly shows that by 2011–12, there will be less than 900 m3 of utilizable water available per person. On the other hand, it has been estimated that of the 1869 billion billion cubic meters of available water, only 1122 billion cubic meters may be utilised. Currently, around 29% of the total is used for rainwater conservation and utilization. More than 50% of irrigation is made possible by groundwater resources, which are fast running out. Clearly, from the perspective of the nation's water resources, there won't be enough water available for agriculture in the near future. The main surface irrigation systems in the nation seldom attain efficiencies of above 50%. Groundwater is more productive than surface water because it is constantly available, requires less transportation, and maximizes application efficiency. Farmers are liable for the cost of lifting[3].

The amount of arable land and irrigation water available is decreasing over time. This necessitates expanding the watered area's overall size. According to 25 years of study on long-term fertilizer experiments project in India and other long-term soil fertility experiments done in Indo-Gangetic Plains, rice yields in rice-wheat systems dropped in the majority of tests while wheat yields were more or less steady. However, it is uncertain if this stability in wheat yields will continue into the future. However, the results of two significant studies supported by the IRRI's Irrigated Rice Research Program showed declining trends in rice and wheat output. Furthermore, eight out of the eleven long-term rice-wheat trials that lasted longer than eight years showed a diminishing tendency in rice yields with time[4].

Soil, one of the most important natural resources, has seen over usage. The following issues with soil are currently a cause for concern: accelerated degradation brought on by physical, chemical, and biological stresses; declining organic matter and deteriorating quality; accumulation of heavy metals and nutrient imbalance; poor nutrient application efficiency; and specific micronutrient deficiencies. According to latest information on nutrient mining in India, nutrient inputs cannot keep up with crop nutrient loss[5], [6]. Previously balanced at 4:2:1, increased N, P, and K content has resulted in nutritional imbalance in general and the onset of micronutrient deficit in particular. These results suggest that careful attention to the sustainability of soil health is necessary to maintain agricultural productivity. According to CASA, the trends in resource degradation are reversible. This is made feasible through conservation agriculture, a practice that encourages cultivating crops without tilling the soil and leaving agricultural waste on the land's surface. The following are CA's primary traits: In order to maximize input advantages and minimize detrimental environmental consequences, little soil disturbance is achieved by the use of no-tillage, low traffic, leaving crop residues on the soil surface, crop rotation, and spatial and temporal crop sequencing[7].

Benefits to Farmers

Farmers may profit from conservation agriculture both now and in the future in a number of ways. This comprises:

- **a)** Lower cultivation costs due to labor, time, and farm power savings.
- **b)** Increased and steady yields with less water, fertilizer, and pesticide input.
- **c)** For mechanized farmers, fewer tractor repairs, longer tractor life, and less water, electricity, and fuel usage.
- **d)** Greater financial gains.

e) Lessened chance of extreme weather, such as drought, heat waves, and cold snaps[8].

Benefits to Natural Resources

Along with lower cultivation costs and greater economic returns, CA raises the standard of natural resources:

a) Lessening the effect of rainfall-related structure collapse, erosion, and runoff on the soil.

b) Surface wastes gradually decomposing, increasing organic matter and biological activity, which improves soils' ability to retain and control water and nutrient availability and delivery.

c) Increased biological variety and activity in the soil, including the presence of natural rivals and predators.

d) Chemical and pesticide contamination of surface and ground water is decreased as a consequence of more effective input utilization.

e) Reductions in the use of non-renewable energy and an increase in carbon sequestration[9].

Conservation Agriculture - Global Scenario

Current estimates indicate that CA systems are being implemented worldwide in around 80 million hectares, mostly in the rainfed regions, and that the area covered by CA is growing quickly. More than 18 million acres of land are presently covered by CA systems, which were first implemented in the USA. A combination of public pressure to stop erosion, a robust tillage and conservation-related research and education backbone, and public incentives to adopt reduced tillage systems has led to the expansion of CA in the US. Australia, Argentina, Brazil, and Canada are some nations that have long since embraced CA techniques on a large scale. In several Latin American nations, CA systems are quickly catching up. A formal strategy to encourage CA has been implemented by certain Brazilian states. A distinct Department of Conservation Agriculture has been established in Costa Rica. The fact that many of these nations' CA systems originated more from farmer- or community-led initiatives than through the typical research extension system efforts is one of its redeeming qualities.

Farmers who practice CA are well organized into local, regional, and national farmers' groups in several South American nations. These organizations are backed by organizations from both South and North America. In comparison to the above-mentioned nations, the spread of CA systems is significantly less pronounced in Europe. Even though substantial research conducted over the last 20 years in Europe has shown the potential advantages of CA, the development of practice there has lagged behind other regions of the globe, probably because of insufficient institutional backing. The two nations where CA is being used on around one million hectares of land used for annual crops are France and Spain. A regional lobbying organization called the European Conservation Agriculture Federation, or ECAF, has been founded in Europe. National associations from the UK, France, Germany, Italy, Portugal, and Spain are unified under this entity[10], [11].

Japan, Malaysia, Indonesia, Korea, the Philippines, Taiwan, Sri Lanka, and Thailand are among the nations in south-east Asia where conservation agriculture is being practiced to varied degrees. Another region where CA has potential is Central Asia. Systems for intensively farmed irrigated crops in South Asia would need to take into account the region's distinct edaphic requirements, rainfed systems with monsoon climatic characteristics, etc. Over the last ten years or more, the national research systems of the nations in the area and the coordinated efforts of the Rice-Wheat Consortium for the Indo-Gangetic Plains, a CG project, have led to an increase in the application of CA technology, mostly for the seeding of wheat crops. Recent estimates claim that no-till seed drills were used to grow wheat on more than two million acres of land[12].

Experiences from Pakistan shown that farmers were able to minimize diesel use by 50 to 60 liters per ha and save roughly Rs. 2500 per ha on field preparation expenditures by using zero-tillage technology. Zero tillage makes it possible to plant wheat on schedule, drill seeds uniformly, boost the effectiveness of fertilizer usage, save water, and, in certain situations, increase yield by up to 20%. In Pakistan, there were more than 5000 zero-tillage drills in 2003-2004, up from only 13 in 1998-1999. Additionally, farmers now cultivate rice, cotton, and wheat in beds. It has also been modified to get around issues with planting in wheat crop residue. Cotton is increasingly being planted in beds and furrows, which is popular among farmers owing to irrigation water savings and associated advantages such as better fertilizer usage efficiency, lessened soil crusting, etc. The widespread usage of laser field levelers increases planted area, decreases labor requirements, lowers irrigation, and boosts overall production. In Pakistan, over 225 laser land levellers were in operation in 2003–2004[13].

Conservation Agriculture - Indian Scenario

Although resource conservation methods have been adapted and promoted in India for over ten years, it has only been in the last four to five years that farmers have begun to quickly adopt the technology. The collaborative efforts of various State Agricultural Universities, ICAR institutions, and the CG-promoted Rice- Wheat Consortium for the Indo-Gangetic Plains have helped to create and disseminate conservation agriculture. In India, unlike the rest of the globe, technology is spreading in the irrigated areas of the Indo-Gangetic plains, where the rice-wheat cropping pattern is predominant. Other significant agro-ecoregions, such as the rainfed semi-arid tropics, the desert areas, or the mountain agro-ecosystems, have not yet explored or pushed CA systems[14].

Conservation Agriculture in Rainfed Semi-arid and Arid Regions

Rainfed semi-arid and arid areas are typified by erratic and unpredictable rainfall patterns, structurally unstable soils, and poor levels of overall production. The majority of research station studies' findings indicate that no specific benefits may be derived from zero or reduced tillage systems without crop residues remaining on the soil surface since a large portion of rainfall is lost as flow owing to the quick surface sealing nature of soils. Therefore, it would seem that no tillage on its own in the absence of soil cover is unlikely to become a preferred method. The use of residue as soil cover in arid and semi-arid areas is severely constrained by poor overall productivity, a lack of residue availability, and a high demand for the few residues that are available for animal feed.

The amount of rainfall, where it falls, and the types of soils vary greatly in semi-arid areas. In order to improve soil quality and the effective use of rainfall, it would seem that it is necessary to pinpoint circumstances where the availability of even a modest quantity of residues may be paired with decreased tillage. Without a doubt, maintaining zero-tillage systems takes more administration than controlling traditional crop production systems. Additionally, there is enough information to demonstrate that the advantages of CA mostly consist of reversing the deterioration process and that its advantage in terms of crop yield may only develop over time[15], [16].

Conservation Agriculture in Irrigated Ecosystems

The states of Punjab, Haryana, Uttar Pradesh, Bihar, and West Bengal are included in the Indo-Gangetic plains, where efforts to promote CA technology have mostly been concentrated in India. Although a variety of other crops are cultivated in different locations and at different times throughout the plains depending on agro-climatic variables, during the decades of the 1970s and 1980s, rice, followed by wheat, emerged as the primary cropping system covering more than 10 million hectares. The main driving forces behind the search for alternative technologies, particularly in the north-west region comprising the states of Punjab, Haryana, and western UP, are worries about stagnant productivity, rising production costs, declining resource quality, declining water table, and increasing environmental problems. The key issue in the eastern area, which includes eastern UP, Bihar, and West Bengal, has been finding and advocating solutions to overcome the obstacles causing the agricultural systems' persistently poor production[17]. The invention and use of zero-till seed cum fertilizer drill for planting wheat crop in the rice wheat system has been the key emphasis of creating and spreading CA practices.

The raised bed planting technique, land leveling assisted by laser equipment, residue management alternatives, a rice-wheat cropping system substitute in connection to CA technologies, and other interventions are also being tested and promoted. The amount of wheat planted with a zero-till drill has been rising quickly over time. According to research from the Haryana district of Kurukshetra, the area seeded with wheat went from 50 ha to 40,000 ha, and the number of zero-till cum fertilizer drills increased from 5 in 1997 to 1425 in 2003. The survey also revealed that farmers with modest holdings were also adopting this technology, in addition to those with vast holdings. Farmers adopted technology via specialized employment, while those with larger holdings bought seed drills. In a sample survey of farmers who were implementing zero-tillage, it was found that the area brought under zero-tillage in relation to the total area under wheat crop varied, with an overall average of 45% under zero till system. In a few of areas in Punjab and Haryana, zero tillage machines are used to seed the majority or all of the wheat harvest[18].

Other technologies being embraced by farmers in the area include raised bed planting and laser field leveling in addition to zero-till planting of wheat. Farmers who have used laser land levelers reported positive effects on crop establishment, uniformity of crop maturity, an increase in the area that can be farmed, improved efficiency of water application, and increased water productivity, all of which led to significant savings in irrigation water and improved use efficiency of applied nutrients. Precision land leveling may become a crucial first step in implementing CA systems as laser land leveling technology becomes more widely available. Table 2 compares fields that have been traditionally leveled with fields that have been laser leveled using trials that CSSRI has done on farmers' farms.

Table 2. Represented the Wheat yields and water productivity

Parameters	Conventionallevelling	LaserLevelling
Levellingindex	>1.5	<1.5
Irrigationdepth		
Paddy	110-115	90-95
Wheat	30-35	20-25

Pumpingrequirement		
Paddy	25-27	20-22
Wheat	15-17	9-11
Waterproductivity		
Paddy	0.37	0.47
Wheat	1.50	2.44
Profitoverconventional		
1styear	-	1000-1200
2ndyearonwards	-	4000-5000

DISCUSSION

Farmers are using raised beds more and more often to plant wheat and other crops. Farmers list a number of benefits, including lower costs for inputs like seeds and fertilizer, considerable water savings, and a decrease in the need for plant protection chemicals, at the expense of much higher labor demands. Crop yields and net returns rose overall. Additionally, bed planting technologies provided more scope for crop diversity and were compatible with crucial CA components like zero tillage and residues controlled on the surface. In the rice-wheat cropping combination, some attempts are also being made to adapt CA methods for the rice crop.

A Basmati rice on-station experiment was conducted at CSSRI, Karnal, to assess various tillage and crop establishment methods in the rice-wheat cropping system.Uncuddled transplanted rice had the highest output of rice, while standard puddled transplanted rice came in second. Uncuddled transplanted rice had a better yield due to increased biomass production and yield-attributing traits. When it came time for transplanting, direct seeded rice with sesbania co-culture as brown manure produced more than DSR and DSR. Due to brown manuring, it was seen that the weed population had significantly decreased[19]. In comparison to DSR without brown manuring, DSR co-cultured with sesbania produced more because there were less weeds, less N stress, and fewer cases of brown spot disease. There has to be further research into why direct seeded crops had a higher prevalence of the brown spot disease. This seems to be the likely cause of the DSR's lower yield than the previous year.

Furthermore, straight planted rice had low yield performance due to increased weed competition. Furthermore, rice replanted on raised beds produced less since there were fewer plants per unit area and more termites. Due to drier conditions at the top of the beds, which favored termite survival, bed-planted rice had a greater prevalence of termites. However, rice grown on raised beds had the highest levels of yield-contributing traits including panicle length, grains per panicle, and grain weight per 1000 grains[20]. Before making any conclusions, the findings need extensive testing over the course of a few more seasons. The direct seeded rice treatments had a better yield per unit of water usage than the other crop establishment methods, which led to the higher water productivity. Dry rice sowing followed by aerobic soil conditions minimizes the need for water overall by avoiding water application for puddle maintenance and submerged soil conditions. Due to greater water demand throughout the growing season, both puddled and uncuddled transplanted rice had poorer water productivity than DSR. The method that saved the most water when transplanting was DSR, followed by DSR+ Sesbania, DSR, and rice transplanted onto raised beds[20].

CONCLUSION

In summary, the adoption of conservation agriculture is a potential strategy for conserving soil and water resources. We can improve soil health, lower erosion, and increase water retention in agricultural landscapes by using conservation measures including minimum soil disturbance, crop residue retention, and diversified crop rotations. This improves agricultural yields, farmer livelihoods, and environmental advantages. However, a coordinated effort by farmers, researchers, politicians, and stakeholders is necessary for Conservation Agriculture to be implemented successfully. In order to encourage the broad adoption of conservation agriculture as a critical approach for attaining food security, protecting natural resources, and lessening the effects of climate change, it is crucial that we continue to invest in research, extension services, and policy assistance. By doing this, we can create the conditions for a more resilient and sustainable agricultural future.

REFERENCES:

[1] K. C. Abbaspour, S. A. Vaghefi, and R. Srinivasan, “A guideline for successful calibration and uncertainty analysis for soil and water assessment: A review of papers from the 2016 international SWAT conference,” Water (Switzerland). 2017. doi: 10.3390/w10010006.

[2] B. Ladeiro, “Saline Agriculture in the 21st Century: Using Salt Contaminated Resources to Cope Food Requirements,” J. Bot., 2012, doi: 10.1155/2012/310705.

[3] T. Qian, A. Tsunekawa, T. Masunaga, and T. Wang, “Analysis of the Spatial Variation of Soil Salinity and Its Causal Factors in China’s Minqin Oasis,” Math. Probl. Eng., 2017, doi: 10.1155/2017/9745264.

[4] N. Kumar, S. . Yamaç, and A. Velmurugan, “Applications of Remote Sensing and GIS in Natural Resource Management,” J. Andaman Sci. Assoc., 2015.

[5] W. G. M. Bastiaanssen, D. J. Molden, and I. W. Makin, “Remote sensing for irrigated agriculture: Examples from research and possible applications,” Agric. Water Manag., 2000, doi: 10.1016/S0378-3774(00)00080-9.

[6] V. Hakkim, E. Joseph, A. Gokul, and K. Mufeedha, “Precision Farming: The Future of Indian Agriculture,” J. Appl. Biol. Biotechnol., 2016, doi: 10.7324/jabb.2016.40609.

[7] D. Cillis, A. Pezzuolo, F. Marinello, and L. Sartori, “Field-scale electrical resistivity profiling mapping for delineating soil condition in a nitrate vulnerable zone,” Appl. Soil Ecol., 2018, doi: 10.1016/j.apsoil.2017.06.025.

[8] E. S. Jensen, L. Bedoussac, G. Carlsson, E.-P. Journet, E. Justes, and H. Hauggaard-Nielsen, “Enhancing Yields in Organic Crop Production by Eco-Functional Intensification,” Sustain. Agric. Res., 2015, doi: 10.5539/sar.v4n3p42.

[9] N. J. Doorenbos, “The Next Green Revolution. Essential Steps to a Healthy, Sustainable Agriculture,” Econ. Bot., 2002, doi: 10.1663/0013-0001(2002)056[0212:tngres2.0.co;2.

[10] C. Olson et al., “Agriculture and Rural Communities,” Impacts, Risks, Adapt. United States Fourth Natl. Clim. Assessment, Vol. II, 2018.

[11] S. K. Fortner, H. H. Scherer, and M. A. Murphy, “Engaging undergraduates in soil sustainability decision-making through an InTeGrate module,” J. Geosci. Educ., 2016, doi: 10.5408/15-106.1.

[12] V. Girijaveni, “Zeolites are Emerging Soil Amendments for Improving Soil Physical and Chemical Properties in Agriculture: A Review,” Int. J. Agric. Environ. Biotechnol., 2018, doi: 10.30954/0974-1712.12.2018.5.

[13] M. Jenrich, “Potential of precision conservation agriculture as a means of increasing productivity and incomes for smallholder farmers,” Journal of Soil and Water Conservation. 2011. doi: 10.2489/jswc.66.6.171A.

[14] A. Kesarwani, “A New Perspective of Agroecosystem in 21st Century,” Biomed. J. Sci. Tech. Res., 2017, doi: 10.26717/bjstr.2017.01.000137.

[15] B. F. Alemaw, T. R. Chaoka, and O. Totolo, “Investigation of sustainability of rain-fed agriculture through soil moisture modeling in the Pandamatenga Plains of Botswana,” Phys. Chem. Earth, 2006, doi: 10.1016/j.pce.2006.08.009.

[16] S. Mitra, “Groundwater Sustainability - A Brief Review,” Int. J. Ecosyst., 2015.

[17] D. Buttaro et al., “Irrigation Management of Greenhouse Tomato and Cucumber Using Tensiometer: Effects on Yield, Quality and Water Use,” Agric. Agric. Sci. Procedia, 2015, doi: 10.1016/j.aaspro.2015.03.050.

[18] L. S. Pereira, E. Duarte, and R. Fragoso, “Water Use: Recycling and Desalination for Agriculture,” in Encyclopedia of Agriculture and Food Systems, 2014. doi: 10.1016/B978-0-444-52512-3.00084-X.

[19] J. Zhou, G. Cheng, X. Li, B. X. Hu, and G. Wang, “Numerical Modeling of Wheat Irrigation using Coupled HYDRUS and WOFOST Models,” Soil Sci. Soc. Am. J., 2012, doi: 10.2136/sssaj2010.0467.

[20] M. M. Mansour, L. Wang, M. Whiteman, and A. G. Hughes, “Estimation of spatially distributed groundwater potential recharge for the United Kingdom,” Q. J. Eng. Geol. Hydrogeol., 2018, doi: 10.1144/qjegh2017-051.

CHAPTER 2

AN OVERVIEW OF THE IMPACT OF CONSERVATION AGRICULTURE PRACTICES

Praveen Kumar Singh, Assistant Professor
College of Agriculture Sciences, TeerthankerMahaveer University, Moradabad, Uttar Pradesh, India
Email Id- dr.pksnd@gmail.com

ABSTRACT:

As a sustainable method of contemporary farming, conservation agriculture has attracted a lot of attention lately. The study done to evaluate the effects of conservation agricultural methods on many areas of agriculture, the environment, and socioeconomic variables is briefly summarized in this summary. The study includes a thorough analysis of prior research as well as field tests and case studies from various agricultural contexts. The results show that conservation agricultural methods, which prioritize low soil disturbance, crop residue retention, and diverse cropping systems, have significant impacts on the fertility and health of the soil. These methods help to lessen the negative effects of climate change by improving water management, reducing erosion, and increasing carbon sequestration in agricultural soils. Additionally, the use of conservation agricultural techniques increases crop yields and overall farm production, which eventually helps farmers financially. This study also examines possible obstacles to the broad adoption of conservation agricultural methods, such as high upfront expenditures and poor information transmission. It is also examined how governmental frameworks and assistance programs might encourage and reward certain behaviors.

KEYWORDS:

Agriculture, Conservation, Environmental Impact, Farming Practices, Sustainable Agriculture, Soil Health, Crop Yield.

INTRODUCTION

The foundation of human civilization, agriculture, has experienced substantial change throughout time. The need for sustainable agriculture practices is becoming increasingly urgent as global population expansion and climate change accelerate. Conservation agriculture (CA) is a concept that has gained traction in this environment. CA is an extensive contemporary farming philosophy that aims to balance agricultural requirements with the protection of natural resources. This introduction lays the groundwork for a thorough investigation of conservation agricultural practices' effects and provides information on the pivotal role they play in determining the future of agriculture, environmental sustainability, and socioeconomic well-being [1]. It is necessary to meet the increasing global population's need for food while simultaneously reducing the industry's harmful environmental consequences. Traditional agricultural methods often result in soil degradation, water depletion, and biodiversity loss due to heavy land plowing, excessive chemical inputs, and monoculture crops. These practices not only compromise ecological sustainability, but also imperil long-term food security. Contrarily, conservation agricultural practices advocate a significant change in our farming practices. Minimal soil disturbance is a crucial component of CA since it prevents erosion and maintains soil structure, moisture, and nutrients [2]. Keeping agricultural waste and using a variety of crops improves the management of water, soil organic matter, and carbon sequestration. After everything is said and done, the soil is refreshed and healthier, allowing for increased agricultural outputs and climate change resistance [3]. Conservation agriculture practices provide a number of economic advantages in addition to their ecological advantages. Since agricultural yields have increased, many small-holders farmers' standard of living has increased globally. Inputs like synthetic fertilizers, herbicides, and gasoline must also be used sparingly in order to potentially cut production costs and boost the profitability of agricultural businesses. It is also essential to regulate soil quality and protect water resources for long-term agricultural viability and the security of the food supply. California stands out as a beacon of optimism in the face of the effects of climate change as the rest of the globe suffers. Due to its innate ability to increase soil resilience and trap carbon, it is a crucial part of plans for coping with and adapting to climate change [4]. Agriculture contributes significantly to global greenhouse gas emissions, which might be decreased if CA methods are widely used.

However, making the switch to conservation agriculture is not without its difficulties. It calls for a change in farmers' perspectives, education, and access to resources in addition to advancing legislation and awarding awards from national and international organizations. To reach its full potential, CA must overcome these obstacles. We will go more into the many advantages of conservation farming practices in the parts that follow, relying on a variety of research publications, field experiments, and case studies. We will look at how they affect the management of water resources, carbon sequestration, agricultural production, and soil health. The socioeconomic repercussions of CA adoption will also be taken into account, and their influence on farmers' livelihoods and the sustainability of agriculture will be evaluated. Finally, we'll discuss the possibilities and problems that must be resolved in order for CA adoption to become widely accepted, with an emphasis on the need for information sharing and governmental assistance. In conclusion, the advantages of conservation farming practices go well beyond the confines of specific farms. It resonates with the whole agricultural ecosystem and presents a compelling vision for the future of environmentally sound farming, sustainable agriculture, and global food security [5].The swift adoption and spread of CA technology is due to a number of benefits, including zero-tillage for wheat. These include:

i. Reduction in cost of production:

This is a significant component in the quick uptake of zero-till technologies. According to the majority of research, the cost of producing wheat is decreased by Rs. 1500 to 2000 per hectare. Cost reductions are ascribed to lower prices for labor, fuel, and other inputs, notably weedicides.

ii. Reduced incidence of weeds:

When zero-tillage is used, which reduces the usage of weedicides, most studies tend to show a decreased incidence of Phalaris minor, a significant weed in wheat. Broad-leaved weed populations, however, tend to grow[6].

iii. Saving in Water and Nutrients:

Limited experimental findings and farmer experience suggest that zero-till planting, especially in laser leveled and bed planted crops, produces in significant nutrient and water savings.

iv. Increased Yields:

Wheat yields were consistently 4 to 6 percent higher in properly maintained zero-till planted fields than in conventionally prepared areas for the same planting date[7].

Environmental Benefits:

In Punjab, Haryana, and Western UP, more than 16 million tons of rice and wheat residues are burned each year, adding to the pollution burden on the environment. Significant quantities of N, P, and K are also burned during combustion and released as gas into the environment. Strategies that encourage the preservation of residues on the soil surface and their gradual decomposition during the growth season of the crop have the potential to produce nutrients in-situ for the crop to consume. Integrated nutrient management will greatly benefit from in-situ/ex-situ crop residue management solutions[8].Nutrient usage efficiency has been significantly increased by resource conservation techniques as zero tillage, furrow irrigated bed planting, laser land leveling, LCC, SPAD, and green seeker. After the harvest of the wheat, crops like pigeonpeas, soybeans, and cluster beans may be grown effectively with little to no fertilizer input and without tilling the soil. It is possible to reduce fertilizer consumption while maintaining yields by promoting conservation agriculture, which will improve the long-term sustainability of land resources. Crop residue burning, which produces significant amounts of greenhouse gases including CO_2, CO, N_2O, SO_2, and particulate matter, may be eliminated by conservation agricultural practices like zero-till and surface managed crop residue systems. Burning agricultural leftovers causes a significant loss of plant nutrients that, with good management, might be recycled. Crop residue burning on a large scale is also a severe health risk.

Crop Diversification Opportunities:

Crop diversification options are provided through conservation agriculture, which includes planting in raised beds. When used in the proper geographical and temporal patterns, cropping sequences/rotations and agroforestry systems may further improve natural ecological processes that support system resilience and decreased sensitivity to yield-reducing disease/pest concerns. A number of crops, including mustard, chickpea, pigeonpea, sugarcane, maize, soybean, and moong, may be advantageously suited to the new systems, according to the few research that have been done. However, comparative economic rewards, market accessibility, price support, post-harvest value addition, export evenness, etc. will significantly influence the success of diversification from the rice-wheat system. Future attempts at diversification should build on our prior successes with kinnow, grapes, winter maize, sunflower, and poplar-based agroforestry[9].

Resource Improvement:

The gradual decomposition of crop leftovers, particularly paired with surface-managed crop residues, initiates processes that enhance the structure of the soil and boost nutrient recycling and availability for plant growth. The advantages of tillage operationsmoderated soil temperatures, less evaporation, improved biological activity, and a more favorable environment for root growthare achieved by surface residues functioning as mulch[10].

Constraints in Adopting Conservation Agriculture Systems

a) Overcoming the limitations of the past and exploring the possibilities presented by conservation agriculture is a challenge for both the scientific community and the farmers. CA is currently seen as a path toward sustainable farming. Therefore, preventing the spread of CA will need significantly increased research and development activities.

b) The development, standardization, and promotion of high-quality machinery for a variety of crops and cropping sequences, permanent bed and furrow planting systems, harvesting operations to manage crop residues, etc. will need to be greatly accelerated in order to successfully adopt CA systems, even though significant successful efforts have been made in developing and promoting machinery for seeding wheat in no-till systems[10].

c) Conservation agricultural practices mark a significant divergence from conventional wisdom. This suggests that a wide variety of procedures, including as planting and harvesting, managing water and nutrients, controlling diseases and pests, etc., must be modified, assessed, and matched in the context of new systems.

d) Managing CA systems will be very knowledge-intensive. The ability of scientists to approach issues from a systems viewpoint, collaborate closely with farmers and other stakeholders, and expand knowledge and information exchange methods will need to be considerably increased in order to do this[11].

Conservation Agriculture-Implications for Technology Generation

The management of diversified, adaptable, and context-specific technology demands will necessitate an innovation system viewpoint for conservation agriculture, a new paradigm for crop production. The viewpoint on innovation system includes the organizations, groups of organizations, and people engaged in the production, dissemination, adaptation, and application of knowledge that has socioeconomic value, as well as the institutional structure that controls these interactions and processes. Research and development in conservation agriculture will thus need a number of novel characteristics to solve the issue. Understanding the system, developing a systems perspective, collaborations, connections, and networks, technology hurdles, site specificity, long-term perspective, adoption, and impact studies are a few of these. A strategy to strengthen the ecological foundation, which serves as the basis for sustainable agriculture, is via the adoption of CA systems across substantial regions. Therefore, it is crucial that the influence of the system on overall environmental performance or an improvement in the natural resources is included while evaluating CA. In order to overcome the difficulties, research and development for CA will need various novel characteristics[12].

Recommendations for Conservation Agriculture Research and Development

With declining factor productivity and falling cultivation costs, conservation agriculture provides a chance to halt and reverse the downward cycle of resource degradation, making agriculture more resource-use-efficient, competitive, and sustainable. While over the past ten years, research and development efforts have helped farmers accept zero tillage for wheat in rice-wheat cropping systems, this has also raised a number of institutional, technological, and policy-related questions about technology generation, adaptation, and further improvement, which must be addressed if CA practices are to be adopted on a sustained basis [13], [14]. Institutional procedures are needed to make sure that CA is promoted as a concept that goes beyond agriculture and that research and development efforts are effectively linked to it. In order to create conservation villages and promote employment in the places where it is implemented, conservation agriculture must focus on wide livelihood methods. However, attention must be used to prevent the general adoption of techniques; instead, it should be based on the site and production system.

A dramatic departure from conventional agriculture is implied by conservation agriculture. Policy assessments are required to comprehend how conservation technologies interact with other technologies, policy tools, and institutional configurations that encourage or inhibit conservation agriculture. Therefore, it is a challenge for both the scientific community and the farmers to go over their preconceived notions and investigate the possibilities offered by CA for sustainable agriculture. Therefore, preventing the spread of CA will need significantly increased research and development activities [15], [16]. The adoption of multiple-enterprise agriculture will pave the way for the development of CA by ensuring multiple uses of water, in-situ recycling of leftovers and byproducts from system components, lowering cultivation costs by switching to organic inputs instead of chemical ones, and lowering greenhouse gas emissions.

DISCUSSION

A significant subject in today's agricultural debate is the effect of Conservation Agriculture Practices (CAP) on current agriculture and the environment. This discussion part goes into the main conclusions and effects of CAP on several elements of agriculture, highlighting the significant impact it has on socioeconomic, soil, and agricultural production.

i. Fertility and Soil Health:

One of CAP's most important effects is its capacity to restore and maintain soil health. A core principle of CAP is minimal soil disturbance, which lowers erosion and compaction while preserving vital soil structure, moisture, and nutrients. Leaving crop leftovers on the field adds to the soil's organic matter level and boosts microbial activity, boosting soil fertility. Numerous studies have shown that CAP improves soil qualities, such as water retention and nutrient availability. Farmers that use CAP see less soil deterioration, more biodiversity in the soil, and long-term sustainability in their agricultural methods as a consequence [17].

ii. Crop Productivity

Crop production is directly and favorably influenced by CAP. Crops cultivated in CAP conditions are better able to tolerate environmental stresses, such as drought and harsh weather conditions, by maintaining healthier soils. Furthermore, varied systems encourage higher yields since there is less competition for nutrients and water across crops. It has been regularly shown through several case studies and field tests that CAP methods may boost agricultural yield, which is essential for solving issues with global food security. By raising yields and revenues, improved agricultural production also helps farmers maintain their financial stability.

iii. Environmental Sustainability

Conservation agriculture practices are essential for maintaining the ecosystem. By reducing soil erosion, water pollution, and greenhouse gas emissions, they assist in reducing the negative consequences of traditional agriculture. By minimizing tillage, CAP lessens soil erosion, protecting vital topsoil and preventing the sedimentation of water bodies. CAP is a useful instrument in the fight against climate change since crop residue retention and diverse cropping systems increase carbon sequestration in agricultural soils. Furthermore, the environmental impact of using agricultural chemicals is reduced by the decreasing dependence on synthetic fertilizers and pesticides [18].

iv. Socio-economic Consequences:

For smallholder farmers in underdeveloped countries in particular, CAP has significant socioeconomic effects. Farmers' earnings grow as a result of CAP's higher agricultural yields and decreased production costs. Furthermore, CAP helps agricultural communities maintain their economic resilience by lowering the need for costly inputs and the risk of crop loss due to adverse weather conditions. However, access to information, materials, and support systems are necessary for the effective adoption of CAP, which emphasizes the significance of extension services, instruction, and policy interventions to promote its wider adoption.

v. Obstacles and Proposed Courses of Action

Even while CAP has great potential, there are still certain difficulties. Farmers may first encounter obstacles including the price of implementing new methods and the need for education and training. In order to encourage and ease the implementation of CAP, policy support is crucial. Additionally, CAP's scalability and adaptation to diverse agroecological situations call for more investigation and development. To encourage CAP practices across various agricultural groups, comprehensive information dissemination and extension service strategies must be implemented [19].

The effects of conservation agricultural practices may be seen in many aspects of agriculture, including soil health, crop yield, socioeconomic well-being, and environmental sustainability. CAP stands out as a viable solution with the ability to solve urgent global concerns while ushered in a more sustainable and profitable age for agriculture and the environment as the globe struggles with the need for sustainable and resilient food production systems.

CONCLUSION

Conservation Agriculture Practices (CAP) have a significant and unmistakable influence on contemporary agriculture. It becomes clear that these techniques mark a crucial turn towards a more sustainable and resilient agricultural future when we consider the many varied effects of CAP on soil health, crop yield, environmental sustainability, and socioeconomic well-being. It is impossible to stress the fundamental importance of CAP in fostering and maintaining soil health. CAP improves soil structure, moisture retention, and nutrient availability by reducing soil disturbance, retaining crop leftovers, and diversifying cropping methods. Long-term agricultural sustainability is based on the rejuvenation of soils, which not only increases agricultural output but also protects against soil erosion and degradation. The advantages of CAP go beyond the boundaries of particular farms. The implementation of CAP is characterized by increased agricultural yields, which have the potential to solve issues with global food security. The capability of CAP to reinforce crops against environmental stresses is a glimmer of hope as our globe struggles with a burgeoning population and the unpredictable effects of climate change.

Furthermore, the socioeconomic effects of CAP are significant, especially for smallholder farmers in areas with limited resources. Farming communities may prosper in a changing agricultural environment with higher earnings, lower production costs, and increased economic resilience. Today's necessity for environmental sustainability has a supporter in CAP. The methods are a cornerstone of climate change mitigation and adaptation measures due to their capacity to reduce the negative environmental effects of traditional agriculture, such as soil erosion, water pollution, and greenhouse gas emissions. Agricultural practices are more in line with overarching environmental conservation objectives when crop leftovers are retained and synthetic inputs are used less. The path to achieving CAP's full potential, nevertheless, is not without its difficulties. Farmers could encounter obstacles when it comes to making early investments, sharing information, and getting access to resources. To overcome these challenges and promote the wider use of CAP, effective governmental support and educational measures are essential. In order to adapt CAP to various agroecological situations and increase its scalability, research and innovation will continue to be crucial.

REFERENCES:

[1] A. Gacar, H. Aktas, and B. Ozdogan, “Digital agriculture practices in the context of agriculture 4.0,” Pressacademia, 2017, doi: 10.17261/pressacademia.2017.448.

[2] J. M. Rodriguez, J. J. Molnar, R. A. Fazio, E. Sydnor, and M. J. Lowe, “Barriers to adoption of sustainable agriculture practices: Change agent perspectives,” Renew. Agric. Food Syst., 2009, doi: 10.1017/S1742170508002421.

[3] B. Mishra et al., “Adoption of Sustainable Agriculture Practices among Farmers in Kentucky, USA,” Environ. Manage., 2018, doi: 10.1007/s00267-018-1109-3.

[4] Y. Li, S. X. Chang, L. Tian, and Q. Zhang, “Conservation agriculture practices increase soil microbial biomass carbon and nitrogen in agricultural soils: A global meta-analysis,” Soil Biology and Biochemistry. 2018. doi: 10.1016/j.soilbio.2018.02.024.

[5] J. Peigné et al., “How organic farmers practice conservation agriculture in Europe,” Renew. Agric. Food Syst., 2016, doi: 10.1017/S1742170514000477.

[6] A. J. Alonge and R. A. Martin, “Assessment Of The Adoption Of Sustainable Agriculture Practices: Implications For Agricultural Education,” J. Agric. Educ., 1995, doi: 10.5032/jae.1995.03034.

[7] G. Nyamadzawo, P. Nyamugafata, M. Wuta, J. Nyamangara, and R. Chikowo, “Infiltration and runoff losses under fallowing and conservation agriculture practices on contrasting soils, Zimbabwe,” Water SA, 2012, doi: 10.4314/wsa.v38i2.8.

[8] K. Mazvimavi, P. V Ndlovu, P. Nyathi, and I. J. Minde, “Conservation Agriculture Practices and Adoption by Smallholder Farmers in Zimbabwe,” Proc. from Jt. 3rd African Assoc. Agric. Econ. 48th Agric. Econ. South Africa, 2010.

[9] N. Adnan, S. M. Nordin, I. Rahman, and A. Noor, “The effects of knowledge transfer on farmers decision making toward sustainable agriculture practices,” World J. Sci. Technol. Sustain. Dev., 2018, doi: 10.1108/wjstsd-11-2016-0062.

[10] M. Lubell, V. Hillis, and M. Hoffman, “Innovation, cooperation, and the perceived benefits and costs of sustainable agriculture practices,” Ecol. Soc., 2011, doi: 10.5751/ES-04389-160423.

[11] R. S. Alare, E. H. Owusu, and K. Owusu, “Climate Smart Agriculture Practices in Semi-arid Northern Ghana: Implications for Sustainable Livelihoods,” J. Sustain. Dev., 2018, doi: 10.5539/jsd.v11n5p57.

[12] N. K. Mahal, M. J. Castellano, and F. E. Miguez, “Conservation Agriculture Practices Increase Potentially Mineralizable Nitrogen: A Meta□Analysis,” Soil Sci. Soc. Am. J., 2018, doi: 10.2136/sssaj2017.07.0245.

[13] F. Magdoff, “Ecological agriculture: Principles, practices, and constraints,” Renew. Agric. Food Syst., 2007, doi: 10.1017/S1742170507001846.

[14] P. S. Ward, A. R. Bell, K. Droppelmann, and T. G. Benton, “Early adoption of conservation agriculture practices: Understanding partial compliance in programs with multiple adoption decisions,” Land use policy, 2018, doi: 10.1016/j.landusepol.2017.10.001.

[15] F. Cheng and Z. Cheng, “Research progress on the use of plant allelopathy in agriculture and the physiological and ecological mechanisms of allelopathy,” Frontiers in Plant Science. 2015. doi: 10.3389/fpls.2015.01020.

[16] M. Uddin, A. Dhar, and M. Islam, “Adoption of conservation agriculture practice in Bangladesh: Impact on crop profitability and productivity,” J. Bangladesh Agric. Univ., 2016, doi: 10.3329/jbau.v14i1.30604.

[17] C. A. Francis and P. Porter, “Ecology in sustainable agriculture practices and systems,” CRC. Crit. Rev. Plant Sci., 2011, doi: 10.1080/07352689.2011.554353.

[18] A. Indeche and F. Ondieki-Mwaura, “Determinants and challenges of applying sustainable agriculture practices among rice farmers in Mwea, Kirinyaga County, Kenya,” ASJ Int. J. Agric. Res. Sustain. Food Suffic., 2016.

[19] M. K. Hendrickson and M. Porth, “Urban Agriculture—Best Practices and Possibilities,” Univ. Missouri, 2012.

CHAPTER 3

AN EXPLORATION OF THE INDIAN WATER RESOURCES ENVIRONMENT AND IRRIGATED AGRICULTURE-RELATED WATER MANAGEMENT ISSUES

Sunil Kumar, Assistant Professor
College of Agriculture Sciences, TeerthankerMahaveer University, Moradabad, Uttar Pradesh, India
Email Id- sunilagro.chaudhary@gmail.com

ABSTRACT:

Water, a scarce renewable but finite resource on our earth, is essential to all life. Additionally, it is essential for the development and upkeep of local economies and food production. The importance of water may be recognized by the fact that the presence of water is originally taken into account as an indication of life on that planet while looking for alien life. The rise of civilization may be traced along the rivers. It wouldn't be overstating things to suggest, however, that civilizations were doomed not because of a lack of water, but rather because the water was abused, leading to an unsustainable use of resources that had a detrimental effect on both the quality of natural resources and human survival. The Aral Sea Basin serves as a contemporary illustration of how extensive failures in water management may have severe effects on agriculture, the environment, and people's general well-being.

KEYWORDS:

Resource Management, Water Agriculture Nexus, Water Environment Challenges, Water Management Issues, Water-Related Agriculture, Indian Water Resources.

INTRODUCTION

Water has always been a limited resource, and humans have a history of wasting it and seriously polluting the water sources. Rahim ji would not have spoken “Rahimanpanirakhiye, bin pani sab soon, Panigayenaubre, moti, manushchun" if such had not been the case. Through the "KaliyaMardan" episode, Lord Krishna attempted to educate the public about the pollution of surface water sources. Even now, our elders ask the kids to toss a few pennies into the river. However, as individuals now toss whatever penny that is in their pockets, this activity has evolved into a ceremony[1]. A penny made of copper, which is said to cleanse water, was always tossed earlier. According to current international standards, a place is considered to be water scarce if the amount of water available per person is less than 1000 m^3 year, and water stressed if it is less than 1700 m^3 annually. There is significant water shortage that is detrimental to everyone's wellness at 500 m^3 or below. Surface water availability per person in India was 2309 m^3 in 1991 and 1902 m^3 in 2001; by 2025 and 2050, these numbers are expected to fall to 1401 m^3 and 1191 m^3, respectively. As a result, efficient planning, development, and management of the nation's most valuable resourcesits water and landare necessary to raise the quality of life for millions of people, especially those who live in rural areas[2].

SurfaceWaterResourcesofIndia

India has been classified into 20 river basins in terms of surface water resources. These are made up of 8 composite river basins that effectively include all the other medium and small river systems and 12 big basins, each of which has a catchment area more than 20,000 sq km. These basins are estimated to have a combined water potential of 187.9 million hectares. When this resource is broken down, it is found that 105 million hectares are the runoff from rainfall that enters rivers, streams, reservoirs, and tanks[3]. A total of roughly 183 million hectares is obtained in additional water from sources including snowmelt, flow from outside of India, groundwater, and irrigated lands. The Ganga, Brahmaputra, Barak, and other rivers have a combined potential for water of 117 million hectares, followed by the Godavari and the west-flowing rivers from Tapi to Tadri, which each have an average yearly potential of more than 10 million ha. It is predicted that 69 million ha m of usable surface water resources will be used by the year 2025. This is due to the extreme variability in precipitation, which prevents the assured storage of all the water, the lack of storage space in hills and plains, evaporation losses, and water going to the sea and outside India. On full development, it is estimated that 76 million acres of land will be irrigated using surface water resources[4].

GroundwaterResourcesofIndia

Another significant source of water is groundwater, which supplies more than 45% of all irrigation in the nation as well as roughly 80% of household water needs. Precipitation is primarily the source of replenishable groundwater. Only 50 million hectares of the 400 million ha of rainwater that fall on the earth percolates into the ground and enters the groundwater or is usable. There would be a net increase of water via streams and irrigation, which is now estimated at 26 million ham, even though some of this water would regenerate into streams. An additional 11 million ha m are added by deep percolation. According to a recent assessment by the Central Ground Water Board, the state-wide groundwater potential is 43.2 million ha m. Estimates of groundwater potential by basin show that the Ganga basin has the highest potential and accounts for more than 38% of the total. At 5.9 million ha m, Brahmani and Baitarni are next. The potential available for irrigation is 36.03 million ha m after removing the allowance for home and industrial reasons. The estimated amount of groundwater that may be used for irrigation is 32.47 million ha m. In 2025, it's anticipated to reach 35 million hectares. An estimated 5–6 million ha m of water are stored, causing a rise in the water table and evaporation losses. The state with the greatest potential is Uttar Pradesh, which is mostly located in the Ganga basin. On the other side, Himachal Pradesh is the state with the least potential. The groundwater's irrigation potential has been updated and given a new area estimate of 64.05 million hectares [5].

Water Requirement in the Present and the Future

India's population is growing at a comparatively quicker pace, according to several authorities' assessments at different times in time. In a scenario with rapid population increase, the population in 2050 is anticipated to stabilize at 1581 million. Food grain output climbed from over 50 million tons in the 1950s to approximately 203 million tons in 1999-2000, and it has remained at or near that level ever since. India must thus devote its water resources to irrigation in order to feed its growing population. Additionally, it is impossible to ignore the rising demand in other industries. Agriculture is forced to rely on low-quality waters since other industries' demands are prioritized due to their ability to pay for them [6]. The following Table 1, is a reproduction of the predicted water consumption for several industries under low and high development scenarios from the National Planning Documents.

Table1. Illustrated theAnnualWaterRequirementforVariousUses

Itemofuse	**1997-98**	**2010**			**2025**			**2050**		
		Low	High	%	Low	High	%	Low	High	%

Irrigation	524	543	557	78	561	611	72	628	807	68
Domestic	30	42	43	6	55	62	7	90	111	9
Industries	30	37	37	5	66	67	8	81	81	7
Power	9	18	19	3	31	33	4	63	70	6
Inlandnavigation	-	7	7	1	10	10	1	15	15	1
Environment/Ecology	0	5	5	1	10	10	1	20	20	2
Evaporationlosses	36	42	42	6	50	50	6	76	76	7
Total	629	694	710	100	784	843	100	973	1180	100

ProblemsofWaterResourcesinIndia

Spatial and Temporal Distribution:

The Indian subcontinent receives 1200 mm of rainfall annually on average spanning both space and time. The northeastern state of Meghalaya's Mousinram in Cherrapunji had the greatest recorded rainfall at roughly 11,690 mm. Rainfall totals of up to 1040 mm per day have been seen in this area. The opposite extreme is seen in locations like Jaisalmer in the west, where the annual average rainfall is just 150 mm. Based on this, 400 million hectares of precipitation each year, including snowfall, is projected. More than 50% of the resource is produced in the zone with rainfall ranging from 1000 to 2500 mm, according to a distribution of this resource across various rainfall zones. Only 24.6% of the water resource is provided by the region with less than 1000 mm of annual precipitation, which makes up around 48% of the total geographic area. This resource generates around 300 million ha m from June to September and another 100 million ha m during the rest of the year. Another aspect of the rainfall is that, in many parts of the nation, just a few intense storms make up the majority of the yearly precipitation. Reduced rainfall would often be the result of no strong storms [7].

Conflicting goals for the development of water resources:

Major and medium-sized projects serve several purposes, including irrigation, flood control, and the production of electricity. For instance, the need for irrigation may change significantly over the course of a season or a year, but hydropower production may need a continuous delivery of water to accommodate all potential scenarios. Similar to how storage needs for hydropower and irrigation may outweigh flood management worries. Therefore, in order to achieve the majority of goals, operational elements of multipurpose projects must be improved. The least priority is paid to maintaining water quality, river regime, river environment, or other public demands [8].

Increasing sectoral rivalry between industries:

The demand situation for water is anticipated to vary significantly due to factors such as an expanding population, changing food habits, changing lifestyles, and a growing focus on travel, tourism, and the environment. Agriculture would lose out and would have to give up fresh water for the interests of other economic sectors, despite the fact that it already uses 83% of the developed water supply. Even though the total amount of water given to agriculture will rise, the demand would still outweigh supply. Agriculture must thus consider other sources, notably the so-called wastewaters produced by other industries after first use. Studies on the usage of these waters have already started in earnest [9].

Surface and groundwater resource pollution:

We are all witnesses to the excessive pollution levels of surface water bodies, particularly rivers, which become drains outside of monsoon season due to the untreated discharge of effluents from many municipal and industrial operations. Even more significant groundwater contamination goes undiscovered and is kept out of the public's gaze. Increased pollutant concentrations that are over the World Health Organization's recommended limits are the consequence of both point sources and non-point sources. Even more dangerous is the direct discharge of effluents in bore wells by disorganized communities and companies. It should be noted that remedial actions may be taken to clean up pollution in surface water bodies, but if the groundwater aquifers are polluted, it will be very difficult, if not impossible, to reverse the process [10].

Crop production and irrigating fields:

The country's rainfed regions see the greatest impact from rainfall on agricultural growth and productivity. The relationship between India's yearly food grain output and the summer monsoon rains is a notable example. When there is a shortfall in rainfall, output decreases, and when there is a surplus, production increases. Between the weak monsoon of 1974 and the following excellent monsoon of 1975, there was a difference in the nation's overall annual food grain output of roughly 20%. With significant geographical and temporal changes, the area that receives its yearly rainfall from rain is very irregular. As precipitation decreases, the coefficient of variation rises. In the arid, rain-fed area, it may reach as high as 61%, compared to 20% in the dry, sub-humid zone. Water isn't the only biophysical or socioeconomic limitation that lowers agricultural and animal yield. The majority of our agricultural land is used for rain-fed agriculture, although progress has been quite gradual in this area [11].

Water table paradox of growing and lowering levels:

In India, the majority of irrigation projects are not very efficient. It is evident that 60–65% of irrigation water is wasted during transportation or in the fields. This has caused the water table to rise in irrigation districts, especially in places with low-quality ground water subsurfaces. Since water logging and soil salinization are seen to be twin concerns, this has also led to those issues. A total of 6.73 million acres of agriculturally viable land have reportedly become infertile as a result of these two issues. Large regions can be generating less than they might. Such locations have not yet had an estimate prepared. Farmers have turned to intense irrigation via the development of groundwater as a result of the inadequate and unreliable nature of canal supplies. In Punjab, Haryana, and Western Uttar Pradesh, excessive groundwater use is causing a 0.2–1.0 m per year fall in water table. Additionally, 108 million acres, or nearly one-third of the whole geographic region, is at risk for drought and is home to 263 million people. This 26% of the population has a pronounced propensity for aggressive groundwater use, especially during drought years. Seawater intrusion is now causing issues in several coastal regions. Even in the state of Haryana, the gradient's reversal might result in the mixing of poor- and high-quality aquifers, which would be a serious setback for the state and the agricultural population [12].

Water:

The origin of the disputes: Whether there is war or not, there is still a chance that major disputes over water may arise. Water might be the source of conflict in 300 different conflict zones. Ten nations make up the catchment area of the Nile River. India has other such conflict zones closer to home, including those with Pakistan, Bangladesh, and Nepal. There may or may not be a global water war as predicted by policymakers, but there is currently a furious battle over water within Indian states, and there is no end in sight. Conflicts between Punjab, Haryana, and Rajasthan and Tamil Nadu, Karnataka, and Andhra Pradesh are all too well-known.

Water Resources

Can we overcome the obstacles: When one examines the numbers that are provided by the media, one starts to have serious doubts about the picture for the future. The sustainability of irrigated agriculture, socioeconomic progress, and environmental quality have all come under scrutiny. But let's be realistic. When our population was a small portion of what it is now, water was just as limited then. Both the lack of surface water bodies and their contamination caused concern in our ancestors. However, we have so far managed to survive. There are still many of chances to use our water supplies. Let's take a closer look at a few of these possibilities so that we may choose more wisely how to use these resources. According to estimates, a 10% growth in the agricultural sector may offset a 40% increase in home and industrial demand. The sections that follow explore a few of the difficulties [13].

Irrigation Improvement:

Various forums have produced suggestions for updating the current irrigation systems with better operation and maintenance, rationalizing water rates, methods for equitable water distribution, night irrigation, dynamic regulation through decision support systems, computer use, information technology, and advanced methods of communication. By moving water across basins, inadequacy and unpredictability are combated. It is gradually coming to pass. According to estimates, inter-basin water transfer will eventually increase the amount of irrigated area by 35 million hectares.

Irrigation management may benefit greatly from participatory irrigation management. Many people believe it to be the solution to every problem plaguing the irrigation system. The idea of PIM has already been hampered by this issue's overemphasis, and there are already calls for the irrigation system to be privatized in a participatory manner. The true meaning has not yet been revealed [14].

Dew:

Dew is the result of atmospheric water vapor condensing on surfaces of items exposed to night light. Dew observations in India began to be made regularly in 1968, and they have significantly increased since then. Despite the fact that dew may not significantly increase our water supply compared to other sources, it does accumulate in north and north-eastern India for a period of six months, from October to March, accumulating between 15 and 30 millimeters. Over Assam, the value is the highest. Dew might make up between 25 and 50 percent of the water shortage in South Punjab and Assam in January. This month's total water stress is estimated to be about 40 mm. It's not quite clear how important dew is in locations that are generally drier.

Integration of green and blue waters:

Approximately 50% of the entire water supply is made up of green water. Green water has not received nearly as much attention as blue water, which has had much too much development and utilization. Green water alone may produce around 230 million hectares m of water on a worldwide scale if its efficiency is improved. It could be possible to end the green and blue water syndrome. The production of irrigated farmland may rise simply due to green water's greater effectiveness [15].

Utilizing drainage water:

Back drainage waters were treated as wastewater not long ago. Analyses of water samples taken from surface drains revealed that the water present during the monsoon season is of acceptable quality and may be utilized in agriculture without harming the available land resources or crop yields. Farmers are fortunately aware of this fact, and this source is being fully used for the benefit of the country. The farmers pulling water out of depressions, borrow pits, and drains to irrigate their crops is a really promising sight. More than a kilometer of water is being carried by one pump. There would be a surge in the reuse of drainage water if Chinese pumps that are light in weight were made accessible.

Utilization of salty or acidic waters:

There would be many seminars where this topic will be covered. As a result, this lecture does not feature a discussion of this topic. It would be relevant to note, too, that in western Haryana and south-west Punjab, head-end to tail-end water conveyance and fresh water skimming are both quickly catching up [16].

Using water repeatedly:

We have spoken about the problem of using water that has been released from one sector for agricultural purposes after its first usage. To improve water production, however, it should also be applied to utilize water in diverse ways within the agricultural sector. Identification of consumption and non-consumptive activities is required for this purpose. One significant activity that combines aquaculture with agriculture is the use of value-added water from aquaculture to irrigate crops. Another example of numerous uses is the reuse of drainage water, which was covered earlier in this lecture.

The division between gray and black waters:

Urban areas will extract more freshwater, from a predicted minimum of about 15 BCM to a high of 60 BCM. Over 80% of this water would be returned to the environment. Grey and dark water would be discharged as a result. Grey water is the water that drains from sinks, baths, and kitchens, among other places. The lawns and kitchen gardens might be watered with this water since it is often of high quality. Black water, on the other hand, is sewage water. Because gray and dark waters are now mixed together, it is difficult to dispose of the vast amount of black water. Grey and black streams must now be kept separate in many nations. We are quickly approaching the day when we will need to implement such legislation in order to reuse greywaters and reduce disposal-related issues [17].

Technology advancements in agriculture:

Numerous sites where water might be conserved without harming crops have been identified through studies on water management. Both crop diversity and deficit irrigation might be used to accomplish it. A significant portion of water might be saved in agriculture by switching from crops with high water requirements to those with low water requirements. Water might be conserved by using resource conservation techniques such land leveling, zero tillage, bed and furrow planting of wheat, and dry or semi-dry seeding of rice. Improved irrigation methods like drip and sprinkler irrigation may increase production while saving water. Water production would thus significantly rise as a result.

.

DISCUSSION

Indian water resources environment and irrigated agriculture-related water management issues highlights a significant and intricate aspect of the nation's socioeconomic and geographical setting. In a country where agriculture is the foundation of the economy, the interaction between water resources, the environment, and irrigated agriculture takes essential significance. This session will go through the interconnected issues that these components raise. Due to its vast and varied geography, India has a complex network of water resources, including rivers, aquifers, lakes, and reservoirs.

For the environment's sake and to preserve agricultural production, effective resource management is crucial[18]. Due to the rising demand for water in irrigated agriculture, which often results in over-extraction and resource depletion, these resources are under a lot of stress. In this case, environmental forces take center stage. Agronomic imbalances including deteriorating soil quality, salinization of arable land, and groundwater table depletion may result from excessive irrigation water consumption. The biodiversity and aquatic ecosystems may be impacted by rivers' shifting flow patterns, exacerbating the environmental issues. In order to solve these issues, a comprehensive approach to water management is required[19].

To optimize the use of water in agriculture, implementing sustainable policies and practices is just as crucial as using cutting-edge irrigation techniques like drip irrigation. Water-saving techniques, such rainwater collection and watershed management, are crucial in minimizing irrigation's detrimental environmental effects. Additionally, to strike a balance between agricultural needs, environmental conservation, and the equitable distribution of water resources, effective governance and regulatory frameworks are required. India's water regulations must take into consideration the many and sometimes conflicting interests of various parties, including farmers, businessmen, and environmentalists.

Last but not least, the intricate web of Indian water resources environment and irrigated agriculture-related water management issues emphasizes the urgent need for putting into action thorough and long-lasting remedies. To strike a balance between the need of guaranteeing food security and environmental protection is a tough endeavor that requires the participation of governmental institutions, academia, and local residents[20]. India can only hope that such concerted efforts can ensure the country's water resources for present and future generations while safeguarding its fragile ecosystems.

CONCLUSION

In this section the author concludes this review and according to the author it captures the pressing need for an all-encompassing, equitable, and sustainable strategy to address the interconnected issues affecting India's water resources, environment, and irrigated agriculture. The intricate interactions between these elements highlight how important it is to make decisions that take into account the short- and long-term requirements of ecosystem health and agricultural productivity. To overcome these challenges, India must prioritize deploying cutting-edge, environmentally responsible irrigation techniques, as well as promoting water conservation measures and moral resource management. To provide equitable access to water resources and to protect the environment, it is essential to develop inclusive policies that take into consideration the requirements of all stakeholders. To solve the water management issues described in the title, cooperation between governmental organizations, academic institutions, farmers, and civil society is required. It demands a commitment to environmentally friendly practices that enhance the resilience of the nation's water supply as a whole, reduce the negative effects of irrigated agriculture on the environment, and maintain the vitality of water ecosystems. In the end, India's capability to provide food security, protect its environment, and save its people's lives will depend on its ability to solve these challenges. India can find ways to balance the competing demands on its water supply, assuring the nation's economic success and environmental sustainability, despite the fact that it is a difficult issue.

REFERENCES:

[1] M. Robert et al., “A dynamic model for water management at the farm level integrating strategic, tactical and operational decisions,” Environ. Model. Softw., 2018, doi: 10.1016/j.envsoft.2017.11.013.

[2] A. Kumar, “Building regulations related to energy and water in Indian hill towns,” J. Sustain. Dev. Energy, Water Environ. Syst., 2017, doi: 10.13044/j.sdewes.d5.0161.

[3] J. Buurman and D. Santhanakrishnan, “Opportunities and barriers in scaling up of 24/7 urban water supply: The case of Karnataka, India,” Water Policy, 2017, doi: 10.2166/wp.2017.191.

[4] P. Merlin Christy, L. R. Gopinath, and D. Divya, “A review on anaerobic decomposition and enhancement of biogas production through enzymes and microorganisms,” Renewable and Sustainable Energy Reviews. 2014. doi: 10.1016/j.rser.2014.03.010.

[5] P. Chinnaiyan, S. G. Thampi, M. Kumar, and K. M. Mini, “Pharmaceutical products as emerging contaminant in water: relevance for developing nations and identification of critical compounds for Indian environment,” Environ. Monit. Assess., 2018, doi: 10.1007/s10661-018-6672-9.

[6] A. K. Gosain, S. Rao, and D. Basuray, “Climate change impact assessment on hydrology of Indian river basins,” Current Science. 2006.

[7] K. Ibrahim-Bathis and S. A. Ahmed, “Rainfall-runoff modelling of Doddahalla watershed—an application of HEC-HMS and SCN-CN in ungauged agricultural watershed,” Arab. J. Geosci., 2016, doi: 10.1007/s12517-015-2228-2.

[8] I. Mukherjee and U. K. Singh, “Groundwater fluoride contamination, probable release, and containment mechanisms: a review on Indian context,” Environmental Geochemistry and Health. 2018. doi: 10.1007/s10653-018-0096-x.

[9] L. Taft and M. Evers, “A review of current and possible future human-water dynamics in Myanmar’s river basins,” Hydrology and Earth System Sciences. 2016. doi: 10.5194/hess-20-4913-2016.

[10] A. K. Gupta, P. Tyagi, and V. K. Sehgal, “Drought disaster challenges and mitigation in India: Strategic appraisal,” Curr. Sci., 2011.

[11] S. Mor, P. Negi, and R. Khaiwal, “Assessment of groundwater pollution by landfills in India using leachate pollution index and estimation of error,” Environ. Nanotechnology, Monit. Manag., 2018, doi: 10.1016/j.enmm.2018.09.002.

[12] V. M. Chowdary, D. Ramakrishnan, Y. K. Srivastava, V. Chandran, and A. Jeyaram, “Integrated water resource development plan for sustainable management of mayurakshi watershed, India using remote sensing and GIS,” Water Resour. Manag., 2009, doi: 10.1007/s11269-008-9342-9.

[13] K. V. Aneesh Kumar et al., “Functional approach reveals low niche overlap among common deep-sea fishes from the south-eastern Arabian Sea,” Deep. Res. Part I Oceanogr. Res. Pap., 2017, doi: 10.1016/j.dsr.2016.11.011.

[14] D. L. Fraser, G. Aguilar, W. Nagle, M. Galbraith, and C. Ryall, “The house crow (Corvus splendens): A threat to New Zealand?,” ISPRS Int. J. Geo-Information, 2015, doi: 10.3390/ijgi4020725.

[15] K. Bhattacharjee and B. Behera, “Forest cover change and flood hazards in India,” Land use policy, 2017, doi: 10.1016/j.landusepol.2017.06.013.

[16] R. R. Navalgund, V. Jayaraman, and P. S. Roy, “Remote sensing applications: An overview,” Current Science. 2007.

[17] B. Collin, A. S. Rehnstam-Holm, S. M. Ehn Börjesson, A. Mussagy, and B. Hernroth, “Characteristics of potentially pathogenic vibrios from subtropical Mozambique compared with isolates from tropical India and boreal Sweden,” FEMS Microbiol. Ecol., 2013, doi: 10.1111/j.1574-6941.2012.01471.x.

[18] T. Hassan, S. Parveen, B. N. Bhat, and U. Ahmad, “Seasonal Variations in Water Quality Parameters of River Yamuna, India,” Int. J. Curr. Microbiol. Appl. Sci., 2017, doi: 10.20546/ijcmas.2017.605.079.

[19] M. Yadav, “Towards A Healthier Nation: Organic Farming and Government Policies in India,” Yadav Dr. Manju; Int. J. Adv. Res. Dev., 2017.

[20] H. Chaturvedi, P. Das, and P. Kaushal, “Comparative study of different Biological Processes for non-segregated Municipal Solid Waste (MSW) leachate treatment,” Environ. Technol. Innov., 2018, doi: 10.1016/j.eti.2017.11.008.

CHAPTER 4

AN OVERVIEW OF SODIC WATER CHARACTERISTICS AND TECHNOLOGIES

Devendra Pal Singh, Assistant Professor
College of Agriculture Sciences, TeerthankerMahaveer University, Moradabad, Uttar Pradesh, India
Email Id- dpsinghevs@gmail.com

ABSTRACT:

Currently, agriculture uses 70% of all fresh water. Over the next 20 years, this is expected to fall by an additional 10 to 15%. Agriculture in the future would have access to water that was of somewhat lesser quality. Due to its low salt content and ability to be recovered with a calcium or acidic supplement, sodic water, also known as alkali water, has a great irrigation potential among the many different kinds of poor-quality fluids. Aquifers that contain sodic water are extensively dispersed over the states of Punjab, Haryana, Uttar Pradesh, Rajasthan, and Gujarat, claim Minhas and Bajwa. Due to either a lack of knowledge about the most recent technologies accessible to them or a fear of seriously harming the land and their crops, farmers now have few alternatives for utilizing these waters for irrigation. However, farmers are compelled to utilize them either because there is no other option or just out of need for their businesses. Therefore, by strategically and scientifically using them, the irrigation base and overall agricultural output of the area may both rise.

KEYWORDS:

Alkaline, Irrigation, Management, Soil, Salinity, Treatment, Water.

INTRODUCTION

Sodic waters often have low salt concentration and a far lower percentage of Ca and Mg salts than Na, which frequently makes up more than 70% of the total cations. These waters typically feature sodium bicarbonate as the main salt component and an RSC > 2.5 me l^{-1} with little calcium [1]. These waters were categorized into three subcategories by the CSSRl under the AICRP:

- **i.** Marginal alkali, EC 4 dS m^{-1}, SAR 10, RSC 2.5-4.0.
- **ii.** Alkali, SAR 10, RSC > 4.0, EC 4 dS m^{-1}.
- **iii.** High alkali, SAR > 10, RSC > 4.0, EC 4 dS m^{-1}.

High SAR saline waters are another group that is also known as saline-sodic waters and may sometimes cause sodic disorders [2]. The majority of naturally occurring sodic water has the following chemical characteristics:

- **a)** The pH of most liquids ranges from 7.2 to 8.5. Waters with a pH of above 8.5 often have a SAR of over 10. High RSC and a high carbonate to bicarbonate ratio are both seen in fluids with high pH [3].
- **b)** Low EC 2 dS m^{-1} and low SAR 10 are often seen in waters with RSC 4 me l^{-1}. However, their RSC and SAR both rise as EC increases. These waters often have a divalent cation ratio greater than 0.25. On the other hand, waters with RSC > 4 me l^{-1} have SAR > 10 and DCR 0.25. As compared to the first category, these fluids are more sedative [4].

c) The typical ratio of carbonate to bicarbonate ions ranges from 1:10 to 1:2. A high carbonate ion concentration suggests a low DCR (0.25) [5].

d) A lot of naturally occurring sodic fluids follow the anionic sequences HC03-Cl-S04, CI-HC03-S04, S04-Cl-HC03, and Cl- S04-HC03.

e) It is often discovered that ground fluids in the recharge zone have more calcium than magnesium, but those in the transitional and discharge zones have more magnesium than calcium [6].

f) B & F have a favorable relationship with HC03 waters.

DeleteriousEffects

Sodic soil conditions, such as a high exchangeable salt percentage and high pH, are created by irrigation with sodic water and negatively impact the physical qualities of soil, particularly soil tilth, water penetration, and soil aeration. High pH also lessens the soil's overall fertility, especially in terms of the availability of calcium, zinc, and nitrogen, and it may also make salt, chloride, and bicarbonates poisonous. Early on in a plant's development, particular toxicity signs including scorching and leaf burning are visible. The negative impacts of these fluids may vary depending on the soil type, water quality, crop intensities, and climatic conditions; nevertheless, in general, the negative effects are typically mitigated by the larger ratios of Cl: SO4 and Ca: Mg in water, the high status of soil organic matter, and the presence of calcium carbonate. The northwest regions of India have produced the majority of data on the sodication behavior of soils post irrigation with waters with significant residual alkalinity. According to these investigations, the effects of these fluids on the formation of soil sodicity varied depending on the water quality component and how it interacted with meteorological, soil, and crop circumstances[7], [8]. The following were the main deductions made from these studies:

a) Soil alkalinization occurred more quickly as residual alkalinity in irrigation waters of almost equal adj SAR increased.

b) Sodication relative to soil alkalization was slowed down when adequate Ca2+ was present in waters with high SAR and high RSC [9].

c) Compared to other upland crops including cotton, maize, and pearl millet grown in cycle with wheat, a rice-based farming system showed a fast rise of ESP and pH, particularly in the top soil layers.

d) The high RSC water was more sodicating than CI-S04 ones at a given adj. RNa. Rather than the SAR of water, RSC was linked to pH development.

e) In contrast to saline or sodic soils, where sodic water adversely affected plant development, saline-sodic soils are controlled by ECe, SAR, and pHs[10].

ManagementTechnologies

To develop methods for the secure use of sodic waters to cultivate agricultural products, consistent efforts have been performed at various research facilities around the nation. The fundamental concepts of soil-water-plant systems are now reasonably well known thanks to scientific advancements, and they support specific soil, crop, and irrigation management methods for avoiding soil degradation to levels that restrict agricultural yield [11]. Following is a discussion of some of these management techniques for preventing ESP buildup and preserving the physical and chemical characteristics of soils watered by sodic water:

Conservation of rainwater and land leveling:

The key requirements for maintaining land irrigated with sodic water are proper field leveling and the construction of 30-40 cm high, robust bunds for catching and keeping precipitation. By plowing the field in between downpours, it is possible to protect the surface soil from the pounding effect of rainfall. In addition to boosting the amount of rainwater consumed, this approach aids in reducing water waste due to weeds and evaporation. Additionally, these procedures encourage homogeneous salt leaching and self-reclamation by allowing soil calcium carbonate to dissolve [12].

Employing Amendments:

Sodic waters may be utilized in a safe and cost-effective manner after being treated with a calcium amendment, such as gypsum. Agricultural grade gypsum may be applied in water or to soil using specially made gypsum beds. The RSC of water and its negative effects may be neutralized with either technique. Both as a soil application and a pyrite bed, acidic amendments like pyrites may be employed to mitigate the harmful effects of high RSC water. The amount of gypsum that has to be administered is determined by the RSC of the water, the degree of soil degradation, and the water needs of the expected crops and cropping system; as a result, this information should be based on an examination of the water and the irrigated soil [13]. To further assist in determining the kind and amount of amendment needed for various sodic water usage scenarios, recommendations may be found below.

a) In a fallow-wheat cycle, gypsum is often not required on well-drained light textured soils. However, it has been observed that applying it with 25% to 100% GR of water during double cropping increases crop yields. According to this study, adding gypsum to a loamy sand soil at a rate of 50% of the recommended amount allowed for the growth of even delicate kharif crops like pearl millet, moongbeans, urdbeans, cowpeas, and cluster beans in the presence of 600 mm of rainfall.

b) In places with comparatively high rainfall, gypsum application corresponding to 50% of the annual gypsum water demand was adequate to support 8–9 Mg/ha of paddy and wheat yields, provided that the final pHs of the surface soil did not exceed 9.0 [13].

c) Applying gypsum sometimes at a rate of 1^{-2} tons per hectare before the rainy season is also advised to counteract the issues with infiltration brought on by salty water with a high SAR, especially on heavy-textured soils that are susceptible to infiltration declines.

Gypsum Requirement of Water

For each mel-1 of RSC, 90 kg ha-1 of agricultural grade gypsum must be irrigated at a depth of 7.5 cm. The RSC thereby estimates the amount of water needed for irrigation during a growing season or annually, as well as the amount of gypsum to be applied. For instance, if water from a tube well has an RSC of 10 me l-1 and is intended to be utilized for a wheat crop that requires five irrigations, the quantity of gypsum needed to neutralize this RSC would be 90×10x5, or 4.5 tons ha^{-1}.

If the soil has already been damaged by the use of sodic water, the amount of gypsum that is needed for the soil should also be assessed individually. During the first year, gypsum should be supplied based on both the soil and irrigation water. Gypsum would only be required in following years based on irrigation water [14].

Gypsum Application in Soil

Applying gypsum via water is more difficult than doing it in the soil. Gypsum powder may be spread in the necessary amount on a field that has already been leveled and mixed with a cultivator or disking to a shallow depth of 10 cm. Gypsum should be applied as soon as rabi crops have been harvested, especially in May or June if any recent rain has fallen. If not, delaying its application until after the first good monsoon rainfall is advised. Gypsum may also be used in standing water. Once the soil has reached the right level of soil moisture, it should be plowed. Gypsum added after a rabi crop is harvested will also significantly enhance the soil before the start of the kharif season. Additionally, pyrites have been utilized to mitigate the negative effects of high RSC waters. Pyrite application before to wheat planting has been shown to be more effective than split applications during irrigations or combining it with irrigation water. Pyrites treatment was discovered to be superior to gypsum, press mud, and FYM for paddy nursery development [15], [16].

Gymnastic Bed

The second method involves putting sodic water through a specially made chamber that is packed with gypsum clods. Water will be recycled in this manner before entering the field. The size of the gypsum chamber, which is made of bricks, cement, and concrete, is determined by the water's RSC and tube well output. On one side, a water fall box, and on the other, a water channel, are linked to this chamber. At a height of 10 cm from the base of the bed, an iron bar and wire mesh net are installed. The farmers may modify their waterfall chamber to become a gypsum chamber as well. Gypsum is put in a chamber, where sodic water coming from below dissolves it and recovers it. In research carried out at HAU, Hisar, it was stated that using this technique, the RSC of water could be decreased from 5. 5 to 1.9 me l^{-1} by passing it through a chamber with a size of 2.0 x 1.5 x 1.0 m and a tube well discharge of 6 l $sec.^{-1}$. The size of the chamber becomes too huge and the amount of gypsum needed to fill the chamber is too high in this situation, making this approach unsuitable for recovering water with a very high RSC. Additionally, it has been noted that the procedure for improving the water quality of gypsum beds may not dissolve more than 8 me l^{-1} of Ca. The effects of applying gypsum to the soil or running water through gypsum beds with a bed thickness of 7 and 15 cm are shown in relation to the growth of crops. Although crops in both paddy-wheat and sorghum-mustard rotations reacted to the application of gypsum in either of the techniques, total crop response was somewhat greater in the case of sodic water, which was improved after passing through gypsum beds. Therefore, it would seem that the gypsum bed approach might aid in the effective usage of gypsum [17], [18].

It is widely agreed upon that the addition of organic materials enhances sodic soils by increasing soil pCO2 and mobilizing intrinsic Ca2+ from CaC03 and other minerals. Na+ from the exchange complex is replaced by soluble Ca2+ in soil. It has been extensively documented that the addition of organic materials may restore barren alkali soils. However, there is significant debate in the literature about the short-term impacts of organic matter on the dispersion of sodic soil particles for soils that are being sodded. However, the bulk of the findings that are now available continue to point to FYM's overall favorable and helpful contribution to the enhancement of soil characteristics and crop yields. The kind of organic matter introduced affects how organic sources react as well. According to Sekhon and Bajwa, paddy straw is more effective than green manure and FYM. Additionally, by mobilizing Ca2+ during the breakdown of organic components, it is possible to significantly reduce the amount of gypsum needed to regulate the negative effects of irrigation with sodic water. So using organic materials sometimes should aid in maintaining crop yields that are watered with sodic water [19].

Selecting just those crops whose sodicity tolerance limitations are lower than the anticipated soil sodicity that will be created by using that water is the guiding concept for picking the proper sort of crops and cropping patterns suited for a certain sodic water. In fallow-wheat, millet-wheat, and rice-wheat cropping sequences, the predicted root zone sodicity may be estimated by 1.5 SARiw, 2.0 SARiw, and 3.0 SARiw, respectively, under typical water consumption circumstances. Thus, the appropriate crops may be selected from the list of sodicity tolerant crops offered depending on the anticipated development of ESP. It is advised to only use tolerant and semi-tolerant crops and their kinds with low water needs, such as barley, wheat, mustard, oats, bajra, and sorghum, etc., as the use of sodic water necessitates frequent treatment for gypsum. The list may be used to choose promising cultivars [20]. The following additional recommendations are relevant to choosing crops appropriate for sodic waters:

a) It is advised to leave the fields fallow during the kharif season in low-rainfall locations if there is no excellent canal water available. Only tolerant and partially tolerant plants, such as barley, wheat, and mustard, should be cultivated during rabi.

b) ower-wheat, guar-wheat, bajra-wheat, and cotton-wheat rotations may be used in locations with annual rainfall of more than 400 mm, provided that the kharif crops are sown using rainwater or high-quality canal water. Additionally, only two to three irrigations using sodic waters should be administered throughout the kharif.

c) Rotations of rice-wheat, rice-mustard, sorghum-mustard, and dhainacha-wheat may be used in parts of the rice-wheat belt of alluvial plains when rainfall exceeds 600 mm.

d) Switching between agricultural rotations that need a lot of water and those that require less water may slow down the development of sodicity in RSC waterways.

In the months of April through June, sodic waters should not be utilized for summer crop cultivation. To satisfy the needs of the crops, more nitrogen may need to be provided since sodic fluids increase soil pH, which results in increased nitrogen losses via volatilization and denitrification[21]. Similar to iron, zinc too has a limited availability owing to their precipitation as hydroxides and carbonates, respectively. Here are some other helpful hints for using fertilizer.

a) An additional 25% nitrogen application is required compared to typical circumstances.

b) Zinc sulphate should be applied at a rate of 25 kg per hectare, especially to the rabi crop.

c) On the basis of soil values, phosphorus, potassium, and other limiting nutrients may also be administered.

d) Some sodic waters may be rich in nutrients like potassium, sulfate, and nitrogen; in these cases, the waters should be evaluated and the fertilizer dosage of the relevant nutrient should be adjusted.

In addition to fertilizers, sporadic applications of FYM containing gypsum increase and maintain crop output when sodic water is used for irrigation.

DISCUSSION

The potential for the production of a thick subsoil layer rises as the sodality of the top soil grows, making the clay particles in sodic water irrigated soil more susceptible to dispersion and displacement. Additionally, these soils dry up to become exceedingly thick and hard. Poor crop yields are mostly attributed to both of these variables, which inhibit root multiplication.

Therefore, deep plowing or chiseling might be seen of as a temporary solution to get over physical obstacles in such soils [22]. The deep tillage of the wheat crop results in an average production increase of 0.2–0.4 Mg/ha. In many instances when groundwaters have significant salt content, there may also be restricted canal water supplies. The two alternatives for combining the use of low-quality waters and canal water are to mix the two sources to reduce the salinity and alkalinity below the level that is acceptable for crops, or to apply the two separately in a cyclical fashion.

Along with practical benefits, there is concrete evidence in favor of the latter, where salty irrigation is deferred until later development stages and the use of canal waters is encouraged during the germination and seedling establishment phases. The approach that would either decrease calcium precipitation or promote calcium precipitation dissolution would likely be preferable in sodic waters. According to Bajwa and Josan, irrigation with sodic water enhanced the pH and ESP of the surface layers of sandy loam soil while lowering its penetration rate to 14%. The yields of rice and wheat gradually fell over time and were, respectively, 62 and 57% of the potential yield, or the yield attained under canal irrigation over a six-year period. However, the yields of both crops were maintained at par with canal water when the sodic water was employed in cyclic mode, with the exception of the CW - 2AW mode. Soil sonication was reduced by the repeated application of two waters [23], [24]. Intriguingly, the ESP of the surface soil was 1.2–1.5 times higher after taking into account canal water and rainfall when evaluating the adj SAR as opposed to a factor of 1.8 seen with sodic liquids alone.

CONCLUSION

Given the difficulties that water sources with high salt and alkalinity provide, the author draws the conclusion in this part that the features and technologies of sodic water are essential. It is crucial to understand the special characteristics of sodic water and use the necessary technology as our planet struggles with growing water shortages and quality challenges. We now have a better understanding of the unique properties of sodic water, such as its high salt content, which, if handled improperly, may have negative impacts on the health of the soil and plants. We have also examined a variety of technologies and tactics, such as soil additives, enhanced irrigation systems, and cutting-edge water treatment methods, to help reduce these problems. Researchers, decision-makers, and managers of water resources may build on the information and understanding presented in this paper to solve difficulties with sodic water. We can decrease the negative effects of sodic water, improve the soil, increase agricultural output, and guarantee that there will always be clean, usable water supplies for future generations by employing the proper technology and management practices. If we are to guarantee the survival of our ecosystems and the security of our water supplies in the face of changing environmental stresses and climate change, it is essential that research and development in the area of sodic water characteristics and technology continue. With the problems of a changing global environment in mind, this information is a useful tool in our continuous efforts to promote ecologically responsible water management techniques.

REFERENCES:

[1] F. Sadegh-Zadeh, M. Parichehreh, B. Jalili, and M. A. Bahmanyar, "Rehabilitation of calcareous saline-sodic soil by means of biochars and acidified biochars," L. Degrad. Dev., 2018, doi: 10.1002/ldr.3079.

[2] T. Zhang, X. Zhan, J. He, H. Feng, and Y. Kang, "Salt characteristics and soluble cations redistribution in an impermeable calcareous saline-sodic soil reclaimed with an improved drip irrigation," Agric. Water Manag., 2018, doi: 10.1016/j.agwat.2017.11.020.

[3] E. Asensio, V. J. Ferreira, G. Gil, T. García-Armingol, A. M. López-Sabirón, and G. Ferreira, "Accumulation of de-icing salt and leaching in Spanish soils surrounding roadways," Int. J. Environ. Res. Public Health, 2017, doi: 10.3390/ijerph14121498.

[4] M. O. Dinka, W. Loiskandl, and J. M. Ndambuki, "Hydrochemical characterization of various surface water and groundwater resources available in Matahara areas, Fantalle Woreda of Oromiya region," J. Hydrol. Reg. Stud., 2015, doi: 10.1016/j.ejrh.2015.02.007.

[5] V. N. Chaganti and D. M. Crohn, "Evaluating the relative contribution of physiochemical and biological factors in ameliorating a saline-sodic soil amended with composts and biochar and leached with reclaimed water," Geoderma, 2015, doi: 10.1016/j.geoderma.2015.05.005.

[6] A. K. Singh, S. Arora, Y. P. Singh, C. L. Verma, A. K. Bhardwaj, and N. Sharma, "Water use in rice crop through different methods of irrigation in a sodic soil," Paddy Water Environ., 2018, doi: 10.1007/s10333-018-0650-2.

[7] T. Chernet, Y. Travi, and V. Valles, "Mechanism of degradation of the quality of natural water in the lakes region of the Ethiopian Rift Valley," Water Res., 2001, doi: 10.1016/S0043-1354(01)00002-1.

[8] A. Mishra, S. D. Sharma, and G. H. Khan, "Improvement in physical and chemical properties of sodic soil by 3, 6 and 9 years old plantation of Eucalyptus tereticornis biorejuvenation of sodic soil," For. Ecol. Manage., 2003, doi: 10.1016/S0378-1127(03)00213-5.

[9] E. Seedorff, M. D. Barton, W. J. A. Stavast, and D. J. Maher, "Root zones of porphyry systems: Extending the porphyry model to depth," Econ. Geol., 2008, doi: 10.2113/gsecongeo.103.5.939.

[10] É. Ács et al., "Nitzschia austriaca hustedt: A characteristic diatom of Hungarian inland saline waters including a morphological comparison with the type material," Phytotaxa, 2017, doi: 10.11646/phytotaxa.308.1.4.

[11] L. Borselli, D. Torri, J. Poesen, and P. S. Sanchis, "Effects of water quality on infiltration, runoff and interrill erosion processes during simulated rainfall," Earth Surf. Process. Landforms, 2001, doi: 10.1002/1096-9837(200103)26:3<329::AID-ESP177>3.0.CO;2-Y.

[12] I. D. S. Pereira, V. C. Silva, J. F. Duarte Neto, G. A. Neves, H. C. Ferreira, and R. R. Menezes, "Influence of the purification of bentonite clay from new deposits in the state of Paraíba-Brazil for use in water-based drilling fluids," Ceramica, 2018, doi: 10.1590/0366-69132018643722402.

[13] N. Rozeff, “sugarcane and salinity- a review paper,” Sugarcane, 1995.

[14] J. Akhter, R. Murray, K. Mahmood, K. A. Malik, and S. Ahmed, “Improvement of degraded physical properties of a saline-sodic soil by reclamation with kallar grass (Leptochloa fusca),” Plant Soil, 2004, doi: 10.1023/B:PLSO.0000016551.08880.6b.

[15] A. Guarnieri, A. Fabbri, and G. Molari, “Influence of sodicity and salinity on the mechanical properties of two italian soils,” Biosyst. Eng., 2005, doi: 10.1016/j.biosystemseng.2005.03.009.

[16] J. M. Nield et al., “Climate-surface-pore-water interactions on a salt crusted playa: Implications for crust pattern and surface roughness development measured using terrestrial laser scanning,” Earth Surf. Process. Landforms, 2016, doi: 10.1002/esp.3860.

[17] D. M. Arruda, C. E. G. R. Schaefer, and M. L. B. De Moraes, “Relações entre Atributos do Solo e Vegetações da Região Ecotonal do Médio Rio São Francisco, Brasil,” Rev. Bras. Cienc. do Solo, 2015, doi: 10.1590/01000683rbcs20150241.

[18] C. W. Rose, J. G. Shellberg, and A. P. Brooks, “Modelling suspended sediment concentration and load in a transport-limited alluvial gully in northern Queensland, Australia,” Earth Surf. Process. Landforms, 2015, doi: 10.1002/esp.3720.

[19] Z. Ladányi, V. Blanka, Á. J. Deák, J. Rakonczai, and G. Mezosi, “Assessment of soil and vegetation changes due to hydrologically driven desalinization process in an alkaline wetland, Hungary,” Ecol. Complex., 2016, doi: 10.1016/j.ecocom.2015.11.002.

[20] Elnaz Sabbagh Tazeh,“Effects of two organic amendments on EC, SAR and soluble ions concentration in a saline-sodic soil,” Int. J. Biosci., 2013, doi: 10.12692/ijb/3.9.55-68.

[21] J. M. Craine, F. Ballantyne, M. Peel, N. Zambatis, C. Morrow, and W. D. Stock, “Grazing and landscape controls on nitrogen availability across 330 South African savanna sites,” Austral Ecol., 2009, doi: 10.1111/j.1442-9993.2009.01978.x.

[22] J. A. Sánchez Navarro, P. Coloma Lpez, and A. Pérez García, “Saline wetlands related to groundwater flows from low permeability tertiary formations in the Somontano area of Huesca, Spain,” Hydrol. Process., 2001, doi: 10.1002/hyp.180.

[23] M. Hachicha, “Les sols salés et leur mise en valeur en Tunisie,” Sécheresse (Montrouge), 2007.

[24] N. W. Menzies, I. M. Fulton, R. A. Kopittke, and P. M. Kopittke, “Fresh Water Leaching of Alkaline Bauxite Residue after Sea Water Neutralization,” J. Environ. Qual., 2009, doi: 10.2134/jeq2008.0511.

CHAPTER 5

AN EXPLORATION OF THE MICRO-IRRIGATION FOR IMPROVING CROP YIELDS

Upasana, Assistant Professor
College of Agriculture Sciences, TeerthankerMahaveer University, Moradabad, Uttar Pradesh, India
Email Id- upasana35954@gmail.com

ABSTRACT:

This in-depth analysis focuses on how micro-irrigation systems may greatly increase crop yields and explores the crucial function that they play in the context of contemporary agriculture. Due to resource limitations, climate change, and the rising need for food from a growing world population, agriculture is now experiencing difficulties that have never before existed. The use of modern irrigation methods, including micro-irrigation, has gained popularity as a long-term response. The research starts by laying out the fundamental ideas and procedures of micro irrigation, emphasizing the efficiency and effectiveness with which it may provide crop roots with water as well as nutrients while reducing waste. It explores the myriad of parts and variations of micro-irrigation systems, such as sprinkler and drip irrigation, and offers insights into their potential applications in various crop kinds and geographical areas. The paper goes into great detail about the several advantages of micro irrigation systems, including improved water consumption efficiency, decreased needs for water and fertilizer, and reduced environmental effect. It also explores the potential financial benefits for farmers of higher agricultural yields and better product quality.

KEYWORDS:

Agriculture, Crop Production, Drip Irrigation, Farming Efficiency, Irrigation Technology, Precision Agriculture.

INTRODUCTION

Most of India's weather is monsoonal. More than 70% of the annual rainfall often occurs during the monsoon season which is June to August. Since the rest of the year will still be mostly dry, irrigation is essential for agricultural development. Since the dawn of time, irrigation has most often been accomplished by channeling a stream from the field's head into furrows or borders and letting it flow by gravity down the slope. Surface irrigation methods often only provide less than half of the water that is released to the plant. The conveyance losses from seepage and evaporation may be a contributing factor in this low efficiency[1]. Additional factors contributing to the losses include poor water distribution, inadequate soil preparation, and inefficient water application. Due to increasing demands on already-limited water supplies and the aim to lessen irrigation's detrimental environmental consequences, drip irrigation technology will unquestionably become even more important in the future. Drip irrigation, as seen in Figure 1, provides a variety of unique agronomic, water-, and energy-saving benefits that address a lot of the challenges that irrigated agriculture is now and will face in the future[2].

The usage of drip irrigation may be traced back to the traditional practice of maintaining a tulsi plant in the courtyard in certain regions of ancient India. The plant was watered throughout the summer by hanging a pitcher that contained water and had a little hole at the bottom to enable trickling.

Although, for a long time, the tribal farmers of Arunachal Pradesh in India employed a rudimentary sort of drip irrigation with the use of bamboo. It has been in use in India since 1970 in its current form. One of the newest irrigation techniques, drip or trickle irrigation, is gaining popularity in places with salt and water shortages.

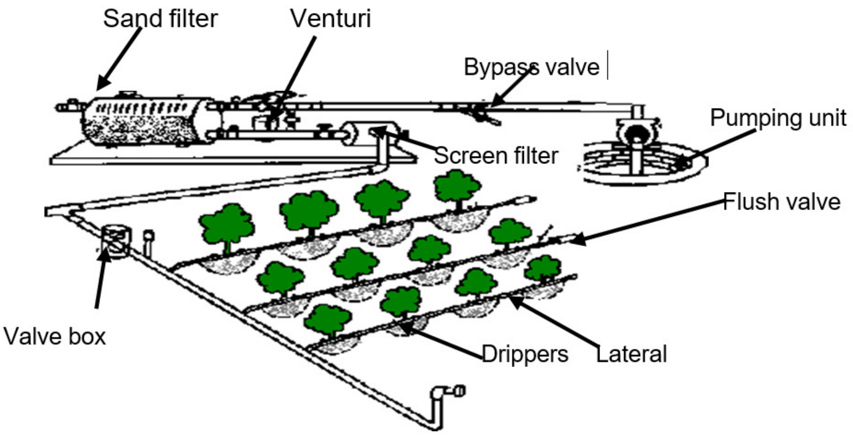

Figure 1: Illustrated the Typical Drip Irrigation System[3]**.**

In drip irrigation, a network of narrow-diameter plastic pipes equipped with emitters or drippers drips water into the soil at extremely low rates like 2-20 liters/hour. It is possible to confine irrigation to the plants' consumptive needs when water is supplied closely to the plants, wetting just a portion of the soil where the roots develop[4]. As shown in Figure 2, drip irrigation water offers a highly favorable high moisture level in the soil where plants may thrive since applications are made more often typically every 1-3 days than with other systems.

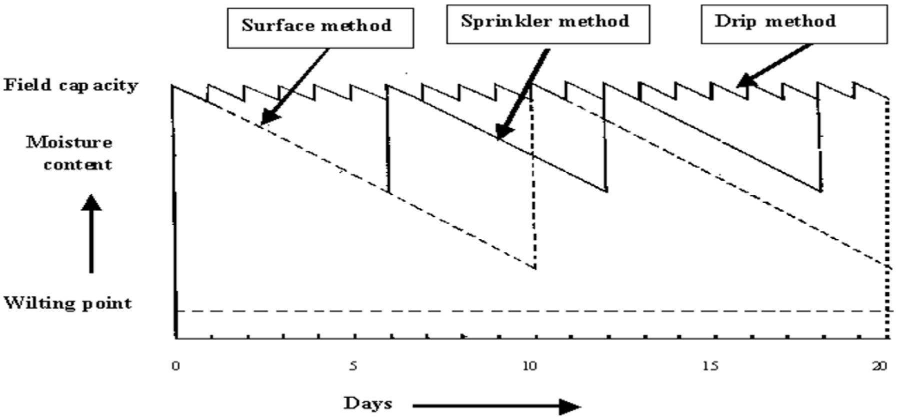

Figure 2: Illustrated the Moisture Availability for Crops in different Irrigation Methods[5]**.**

For terrain that is undulating, drip irrigation may be used. Most soil types may use it as well. To prevent surface water ponding and runoff in clay soils, water must be delivered gradually. Higher dripper discharge rates, however, will be required in sandy soils to achieve appropriate lateral soaking of the soil. In particular, drip irrigation works well with salty water of low quality. Since water is provided every day, salt is forced out of the moisture zone, or away from the crop's root zone. The following crops have been cultivated using a drip irrigation system:

i. Fruits and nuts from orchards, including grapes, citrus, apples, pears, peaches, apricots, and others; bananas; dates; olives; mangoes; and guavas.

ii. Tomato, green pepper, cucumber, lettuce, green pea, cauliflower, and okra are some examples of vegetables.

iii. Cotton, sugarcane, maize, groundnuts, and onions are examples of row and field crops.

iv. Additional obstacles, decorative plants, melons, alfalfa, and flowers like carnations, gladioli, and roses [6].

Application of Fertilizers through Drip Irrigation:

The most sophisticated and effective method of fertilization is called fertilization, or fertilization using a drip irrigation system. Water and nutrients, the two essential components of plant growth and development, are combined during fertilization. High production and quality depend on the proper balance of nutrients and water. Since it guarantees that nutrients are applied directly to the plant roots, fertilization is the most cost-effective technique of fertilizer application. To prevent wasteful leaching, fertilizer injections should be given in tiny, frequent dosages that fall within programmed watering intervals that match plant water needs. Prior to injection, the fertilizer solution has to be filtered. To capture any undissolved material, injection should happen after the pump and before the media or final screen filters. According to the "one-fourth" rule of thumb, fertigation should begin after one-fourth of the irrigation set time, injection should take place in the middle two-fourths, and the lines should be flushed with clean water in the last quarter. In general, injection rates shouldn't be more than 0.1% of the main system's water flow rate [7].

Advantages of Fertigation

a) Assures a consistent and regular flow of nutrients and water, which promotes faster plant development and greater yields and quality.

b) Provides more flexibility in fertilizer treatment timing to accommodate different crop needs. Fertilizers may often be administered regardless of the weather or the state of the field.

c) Increases the availability of nutrients and the roots' capacity to absorb them.

d) A safer application technique since there is no longer a risk of burning the plant's root system.

e) A quick and more practical application technique that conserves time, effort, and resources.

f) Growers may efficiently manage fertilizer programs by applying tiny, precise volumes of fertilizer at the right times directly to the root zone. This increases fertilizer usage effectiveness and lowers nutrient leaching below the root zone.

g) Reducing the compaction of the soil.

h) The possibility of lessening environmental pollution.

i) In general, fertigation application costs are around one-third less than those of traditional application techniques.

j) Reduces the amount of time operators handle, mix, and dispense potentially dangerous products.

k) Additionally, unintentional chemical drifts do not endanger humans or non-target crops.

SelectionofFertilizerApplicatorforFertigation

Application of fertilizer through a drip irrigation system necessitates the use of an extra component. In order to accomplish fertilizer injection in a timely manner without running the danger of over-watering, it is crucial to use a fertigation system with a drip irrigation system. Fertilizers are injected into irrigation systems using three main methods: fertilizer tanks, the venturi pump, and the injection pump. Fertilizers are introduced into irrigation systems using a variety of different procedures. For both the injection equipment and the fertilizer containers, non-corrosive materials should be utilized[8]. The next paragraphs outline the different fertigation systems' working principles, benefits, and drawbacks.

Factors Limiting Large Scale Adoption of Drip Irrigation System

Despite its economic and technological viability, India's large-scale adoption is not very promising. In a study of farmers conducted throughout all of India, the following variables were found to be the main causes of drip application delays:

i. Lack of awareness and poor understanding of the use, utility, manner of operation, and maintenance of drip irrigation and its theoretical potential.

ii. High starting costs and a lack of access to basic financing.

iii. Functional issues like:

  a) non availability of spares/micro-tubes

  b) high cost of component

  c) leakage due to damage of pipes/drippers

  d) blockage/clogging of drippers/micro-tubes

  e) improper after sales service

  f) lack of technical know-how like the quantity of water to different crops under different situations etc.

Growth Potential

i. Wasteland Development:

There are around 16.5 million hectares (mha) of cultivable waste land, and there are over 9.8 million hectares (mha) of "fallow lands other than current fallow" for a total area of 26.3 mha. They are being degraded more and more. On a small section of these fields, it would be beneficial to use drip irrigation techniques to put under tree crops of different sorts, including fruit trees.

ii. Hills and Semi-arid Regions:

Although water may be accessible, undulating terrain, rolling topography, and mountainous slopes cannot be irrigated by surface means. Such places may be irrigated using drip irrigation without spending money on leveling and shaping the soil. Drip irrigation methods may also be used in dry and semi-arid regions [9].

iii. Sandy coastal areas:

Shallow depths of quite excellent water, suitable for irrigation, become accessible in the coastal districts. With the right technology, these sandy regions may produce a broad variety of fruits, vegetables, and flowers. Under these circumstances, a drip system gives the best solution.

iv. Prospects and Potential

From a paltry 1500 hectares in 1985 to around 70,000 hectares in 1992 and an estimated 100,000 hectares in 1998, the country's drip irrigation area has grown significantly. Drip irrigation was being used in up to 35 nations across the globe in 1991, with India coming in seventh in terms of coverage area. In places where there is a severe lack of water as well as places where horticultural crops are cultivated, the drip irrigation method has become quite popular. In the real world, orchard crops with citrus as a main crop get about 54% of drip irrigation. Drip irrigation is used to grow over 1.5 lakh hectares of fruit and 2.5 lakh hectares of vegetable crops per year in India [10].

DISCUSSION

In the context of contemporary agriculture, the subject of micro-irrigation and its potential to increase crop yields are of the utmost significance. Numerous difficulties have been encountered by agriculture recently, such as the need for sustainable and effective agricultural methods, water shortages, and climate change. As a potential response to these issues and a means of raising crop output, micro-irrigation systems have gained popularity. One of the main benefits of micro-irrigation is its capacity to supply water precisely and steadily to the root zone of plants. Micro-irrigation, in contrast to conventional surface irrigation techniques like flood or furrow irrigation, reduces water loss due to evaporation or runoff since water is provided directly to the plants where it is most required [11]. This focused method guarantees that crops get a steady and appropriate amount of moisture, which is crucial for their growth and development, while also conserving water resources. Additionally, micro-irrigation systems may be modified to accommodate various crop varieties and field circumstances. For instance, spray irrigation may be used for a range of crops, including field crops and orchards, but drip irrigation is best suited for row crops like tomatoes and peppers. This adaptability enables farmers to maximize water use and modify irrigation plans in response to local climatic factors, reducing the negative effects of droughts or heavy rains on crop output. Micro-irrigation devices may increase the effectiveness of fertilizer delivery in addition to conserving water [12]. Farmers may better control the absorption of nutrients by crops and lower the danger of over-fertilizing or leaching nutrients into groundwater by applying water and fertilizer at the same time. By reducing the negative effects of agricultural operations on the environment, this precision agriculture strategy not only increases crop yields but also promotes environmental sustainability.

However, there are obstacles to the widespread use of micro-irrigation, such as high initial installation costs, ongoing maintenance expenses, and the need for farmer education and training [13]. Nevertheless, micro-irrigation is a desirable alternative for contemporary agriculture due to the long-term advantages of higher crop yields, water conservation, and sustainable farming methods. In a world where agricultural sustainability and food security are becoming more and more important, the introduction of micro-irrigation systems offers enormous potential for enhancing crop yields. These technologies help farmers maximize their output while addressing the problems caused by climate change and water shortages by effectively providing water and nutrients to crops. To guarantee that micro-irrigation becomes a crucial component of contemporary farming techniques and, eventually, contributes to a more resilient and productive agricultural sector, more research, funding, and education are required [14].

CONCLUSION

As a crucial agricultural breakthrough, micro-irrigation has the potential to significantly increase crop yields and sustainability. It eliminates waste, conserves water, and encourages effective nutrient absorption since it precisely delivers water and nutrients to the root zone of plants. Micro-irrigation is an essential tool in contemporary agriculture, despite short-term difficulties like initial expenditures and upkeep and longer-term positives like greater productivity, less environmental impact, and resistance against climate-related difficulties. Using micro-irrigation systems is becoming more and more essential as the globe struggles with the serious concerns of water shortage, climate change, and the need for food security. Continued research, funding, and farmer education are necessary for it to reach its full potential. Micro-irrigation may play a crucial part in defining a sustainable, productive, and resilient future for global agriculture with a coordinated push toward its adoption, guaranteeing that we can fulfill the food needs of a rising population while protecting our valuable natural resources.

REFERENCES:

[1] X. Li and T. J. Troy, "Changes in rainfed and irrigated crop yield response to climate in the western US," Environ. Res. Lett., 2018, doi: 10.1088/1748-9326/aac4b1.

[2] K. Frieler et al., "Understanding the weather signal in national crop-yield variability," Earth's Futur., 2017, doi: 10.1002/2016EF000525.

[3] E. Najafi, N. Devineni, R. M. Khanbilvardi, and F. Kogan, "Understanding the Changes in Global Crop Yields Through Changes in Climate and Technology," Earth's Futur., 2018, doi: 10.1002/2017EF000690.

[4] M. Y. Mkonda and X. He, "Climate variability and crop yields synergies in Tanzania's semiarid agroecological zone," Ecosyst. Heal. Sustain., 2018, doi: 10.1080/20964129.2018.1459868.

[5] A. Ceglar, M. Turco, A. Toreti, and F. J. Doblas-Reyes, "Linking crop yield anomalies to large-scale atmospheric circulation in Europe," Agric. For. Meteorol., 2017, doi: 10.1016/j.agrformet.2017.03.019.

[6] D. K. Ray, J. S. Gerber, G. K. Macdonald, and P. C. West, "Climate variation explains a third of global crop yield variability," Nat. Commun., 2015, doi: 10.1038/ncomms6989.

[7] A. L. Hoffman, A. R. Kemanian, and C. E. Forest, "Analysis of climate signals in the crop yield record of sub-Saharan Africa," Glob. Chang. Biol., 2018, doi: 10.1111/gcb.13901.

[8] M. M. Bakker, G. Govers, R. A. Jones, and M. D. A. Rounsevell, "The effect of soil erosion on Europe's crop yields," Ecosystems, 2007, doi: 10.1007/s10021-007-9090-3.

[9] J. H. Jeong et al., "Random forests for global and regional crop yield predictions," PLoS One, 2016, doi: 10.1371/journal.pone.0156571.

[10] F. Golzar, N. Heeren, S. Hellweg, and R. Roshandel, "A novel integrated framework to evaluate greenhouse energy demand and crop yield production," Renewable and Sustainable Energy Reviews. 2018. doi: 10.1016/j.rser.2018.06.046.

[11] M. Brückler, T. Resl, and A. Reindl, "Comparison of organic and conventional crop yields in Austria," Bodenkultur, 2017, doi: 10.1515/boku-2017-0018.

[12] D. B. Lobell, "The use of satellite data for crop yield gap analysis," F. Crop. Res., 2013, doi: 10.1016/j.fcr.2012.08.008.

[13] K. Guan et al., "The shared and unique values of optical, fluorescence, thermal and microwave satellite data for estimating large-scale crop yields," Remote Sens. Environ., 2017, doi: 10.1016/j.rse.2017.06.043.

[14] G. Luo et al., "Organic amendments increase crop yields by improving microbe-mediated soil functioning of agroecosystems: A meta-analysis," Soil Biol. Biochem., 2018, doi: 10.1016/j.soilbio.2018.06.002.

CHAPTER 6

MODELING AT THE REGIONAL SCALE FOR COMBINED WATER USE PLANNING

Ashutosh Awasthi, Associate Professor
College of Agriculture Sciences, TeerthankerMahaveer University, Moradabad, Uttar Pradesh, India
Email Id- ashuaw@yahoo.in

ABSTRACT:

Water is a limited resource that is essential for sustaining life, ecosystems, and economic activity. To ensure its equal distribution, conservation, and sustainable management, effective water consumption planning is essential. This paper stresses the importance, goals, and essential elements of water consumption planning while giving a thorough introduction to the idea. A thorough and dynamic process, water usage planning includes analyzing the present water supply, projecting future demand, and creating plans to make the most of the water that is already available. It covers a wide range of topics, including the distribution of water supplies among competing users, energy-saving techniques, the development of infrastructure, and policy design. It must also take into account any prospective impacts on water quantity and quality from population increase, industrialization, and climate change. Planning for water usage includes as its primary goals promoting water efficiency, protecting ecosystems, boosting resiliency to droughts and water shortages, and ensuring that everyone has access to clean, safe drinking water. In order to encourage sustainability and lessen disputes, it attempts to achieve a balance between the requirements of homes, industry, agriculture, and the environment.

KEYWORDS:

Resource Management, Sustainability, Water Efficiency, Water Policy, Water Quality, Stakeholder Engagement.

INTRODUCTION

The main user of water is agriculture, and joint surface and groundwater usage is often chosen to reduce supply uncertainty for irrigation water and to provide better financial results. In India, 60% of irrigated food production and roughly 50% of the total irrigated area rely on irrigation from groundwater wells, illustrating the significance of groundwater resources. The government of India's Central Ground Water Board estimates that the nation's yearly exploitable groundwater potential is 32.3 million ha m. Currently, 42% of the yearly exploitable groundwater potential, or 13.5 million ha m, is being used as groundwater. Irrigation uses up around 85% of the groundwater that is now being tapped[1]. According to groundwater quality assessments, 32 to 84% of the groundwater used for irrigation in arid and semi-arid parts of India is of low quality. An average amount of saline, sodic, and saline-sodic waters make up 20, 37, and 43% of these brackish water zones, respectively. Numerous more issues are caused by improper crop selection and concurrent usage practices at the field and regional levels without sufficient consideration of the climate, groundwater quality, groundwater depletion, terrain, irrigation system selection, and its management.

Waterlogging and irrigation-induced salinization or alkalization in irrigation systems are becoming obstacles in the sustainability of irrigated agriculture, and overexploitation of the groundwater is becoming a serious issue in groundwater irrigated regions[2]. These issues have taken precedence over the anticipated advantages of irrigation projects. In this work, regional scale distributed modeling was used to comprehend irrigation-induced salinization processes in the command of the Kheri distributary of the Bhakra system. The models used dealt with the movement of water and solutes under variably saturated circumstances. Taking into account the crop acreage and canal water supply, the CROPWAT was used to calculate the ET values of the crops, which were then used to calculate the pumping water[3]. The sustainability of the common practice of combining the use of low-quality groundwater with canal water was evaluated using interpretations based on regional water balance and distributed modeling. The availability of irrigation water and root salinity standards for the sustainability of the agricultural system were taken into account while suggesting adjustments to the current policy.

ModellingApproaches

i. Water balance for assessing sustainable water resources for irrigation:

The availability of all irrigation water in the irrigation command might be viewed as total when sustainable groundwater pumping and canal water are combined. The amount of groundwater that is accessible for sustainable pumping might be determined using the groundwater balancing analysis. Sustainable pumping might refer to pumping that stops the water table from rising or falling[4]. Long-term pumping was advised to be about equivalent to the typical groundwater recharge. The equation for the groundwater-balance is as follows:

$$\pm\Delta S = TGR_r - TGR_d$$

Inwhich,

TGR= Total groundwater recharge

TGR_d =Totalgroundwaterdraft

ΔS =Changeingroundwaterstorage

In the case of sustainable pumping, the storage change in Eq. is zero or insignificant. As a result, Eq. might be expressed as:

$$TGR_r = TGR_d$$

The availability of annual total irrigation water on a sustainable basis would be handled as the sum of sustainable groundwater pumping and canal water.

Simulation model for vadose zone solute transport:

The UNSATCHEM model's one-dimensional vertical transient unsaturated flow, which is described by Richard's equation, was numerically solved. The model was used to the simulation of regionally dispersed root zone salinity[5]. The following equation gives the one-dimensional advection-dispersion equation's description of the model's solute transport.

$$\frac{\partial \theta c_k}{\partial t} + \rho \frac{\partial \overline{c_k}}{\partial t} + \rho \frac{\partial c_k'}{\partial t} = \frac{\partial}{\partial z}\left(\theta D \frac{\partial c_k}{\partial z} - q_w c_k\right)$$

$k=1,2,,N_c$

k

whereθwasthevolumetricwatercontent[L^3L^{-3}],zwasspatialcoordinate[L],twastime[T],$c_k$wasthetotaldissolvedconcentrationoftheaqueousspeciesk[ML^{-3}],c wasthetotalsurfacespeciesconcentrationofaqueouscomponentk[MM^{-1}], c'_k was total solid phase concentration of aqueous component k [MM^{-1}], ρ was thebulkdensityofsoilmedium[ML^{-3}],Dwasthetortuositycorrecteddispersioncoefficientin the water phase [L^2T^{-1}], q_w was the volumetric flux [LT^{-1}] and N_c was the number ofprimaryaqueousspecies.Thesecondandthirdtermsontheleftsidearezerofor the species that do not undergo ion exchange or precipitation and dissolution [6].It needs to be computed for each of the major solute species present in the soil andinfiltrated water. Time dependent atmospheric and solute boundary conditions wereselectedforthetopboundary.Thepondingofwaterwasallowedwithoutsurfacerunoff.Free drainage conditions were assumed at the lower boundary as groundwater levelswereatsufficientlylowerdepthforallthesituationsconsideredforsimulations [7].

StudyArea

The command of Kheri distributary of the Fatehabad branch of Bhakra Main Line within the Bhakra system was the research area, situated in the Fatehabad district of Haryana, India, for regional water balancing and regional distributed modeling. The command was run by the BML tail system and was under the control of the Hissar-2 irrigation service circle. Most of the area's geography was rather level, with a gently sloping landscape that averaged 0.5 meters per kilometer of slope from northeast to southwest. The research region has a semi-arid climate. For the Fatehabad station, the yearly rainfall was 350 mm. The kharif and rabi seasons had rainfall totals of 290 mm and 60 mm, respectively. A 1650 mm annual potential evapotranspiration was estimated for the command. While the underlying strata' soil textures ranged from sandy clay loam to clay loam, the top soil's texture ranged from loamy sand to sandy loam. The Kheri distributary's CCA was almost 81 percent of its GCA. Through 88 outlets from the distributary and four minors using the warabandi system, water was delivered throughout the Kheri command[8], [9].

RegionalWaterBalance

Using various water balance components from 1985–1986 to 1995–1996 to analyze the availability of irrigation water, sustainable groundwater pumping was calculated. The inquiry was chosen for this time period primarily because of the significant increases in wheat and cotton crop regions within the command. Based on field research by the National Bank for Agriculture and Rural Development, found that groundwater models for the Lower Ghagger Basin may use 15% of the annual rainfall as the contribution of precipitation to groundwater recharging. As a result, the same assumption was used in this research to calculate how much rainfall contributes to groundwater recharge[10].

Given that flows in major canals, branch canals, and distributaries were maintained for 240 to 260 days per year, seepage from the conveyance system provided a consistent source of recharge. Taygi gathered hydraulic information from the irrigation department of Haryana's records, such as design discharge, daily discharge, number of running days, and length of conveyance system for each main and minor channel, and calculated the wetted perimeter and wetted areas for various channels. According to estimates, lined and unlined canals had seepage loss coefficients of 0.61 m3/sec/106 m3 and 2.44 m3/sec/106 m2, respectively, per million square meters of wetted area [11].

The water table won't receive all of the water that is lost via canals. The earth will hold some of it and some of it will evaporate. The recharge to a groundwater body was calculated as 80% seepage from major canals, 60% seepage from distributaries, and 40% from small canals. The main canal contributes more to the groundwater recharge since it is in operation for a longer period of time than smaller canals. Seepage loss for lined and unlined water courses was estimated to be 3.0 m3/sec/106 m2 and 7.53 m3/sec/106 m2, respectively, based on hydraulic data gathered for water courses and field measurement by HSMITC. Because watercourses flow for a shorter period of time, seepage was assumed to account for 40% of the recharge to groundwater bodies. Additionally, it was estimated that 30 to 40 percent of the water provided at the farm gate was lost owing to seepage and other reasons from irrigated areas when application was made using a canal supply. In the case of irrigation using tube wells, this loss was estimated at 25%. For the research region, the recharge rate was estimated using each of these presumptions [12].

Based on the intensities of the wheat and cotton crops as well as irrigation deficits throughout the cropping seasons, the pumping rates in the Kheri command were projected for the years 1985 to 1995. While the intensity of cotton grew from 30 to 60%, it climbed from 30 to 75% for wheat. During the rabi season, the irrigation intensity rose from 50% to 100%. The intensity of the kharif season has risen from 40% to 80%. The primary crop rotation was wheat and cotton. Therefore, pumping estimates for these two crops were performed. The canal supply and rainfall were thought to be sufficient to meet the irrigation needs of the crops of pearl millet, sorghum, and oilseeds during the kharif season and the rabi season, respectively. Therefore, the command for these crops did not experience any notable pumping. In the Kheri command, the long-term viability of a wheat-cotton crop rotation based on irrigation water availability was evaluated taking into account crop ET requirements, canal water supply, groundwater pumping, and groundwater recharge [13].

RegionalDistributedSalinityModeling

Root-zone Salinity Modeling: For long-term simulations related to regional scale salinity modeling with distributed data on soil, irrigation supply, its quality, and crop rotation for the Kheri command of the Bhakra system, a one-dimensional unmatched model was used. This model was calibrated and validated with micro-plot experiments. Crop evapotranspiration needs were calculated using the cropwat model, while soil water retention parameters were estimated using the RETC model. On the basis of criteria for root zone salinity and the availability of irrigation water, regional modeling was utilized to identify key regions in the command. The data from a saline water micro-plot experiment served as the basis for the calibration and validation of the unmatched model. To examine the crop responses and salt buildup in soils for cotton and wheat crops under mixing and cycling modes of the saline and non-saline waters, the experiment was carried out on field plots with a sandy loam soil. When calibrating and validating the model, the input files of the Unsatchem were created, and simulated salinity profiles of corresponding irrigation treatments at the time of wheat harvest were compared with observed salinity profiles. Saturation extracts of soil samples were used to calculate the observed soil salinity levels. As a result, soil salinity values for saturation extract were converted from simulated soil water salinity values. By modifying the dispersitivity value and assuming a linear root water uptake pattern, the excellent agreement between these profiles was achieved. Simulated salinity profile during validation was obtained without any further adjusting of parameter values apart from irrigation water quality. The salinity profiles of the actual and simulated data showed good agreement. It demonstrated the accuracy of the model and the calibration's presumptions. The model was used to regional modeling after calibration and validation[14], [15].

Six separate typical places in the command had distributed soil samples taken from their profiles at depths of 0–15, 15–30, 30–50, 50–80, 80–120, 120–145, and 145–175 cm, respectively. The mechanical composition of the soils was used to establish layer-by-layer textural classifications for the profiles, and the profiles were divided into three primary categories. The profiles from Sirhan, Kirhan, and KhabraKhurd, which had textural classes ranging from loamy sand to sandy loam, comprised the first group. Sand concentration ranged from 52% to as high as 89% in the bottom strata of profiles from KhabraKhurd and

Kirhan, respectively, whereas the silt + clay proportion of the soils did not surpass 34%. The profiles from Khabra Kalan and Dayar are in the second category. In these profiles, the proportion of silt plus clay rises from 37.7 to 40.6% in the lower layers. The profile from Dhabi represented the third group. This profile has a silt + clay proportion ranging from 53.5 to 65.9%. The heterogeneity in soil textural properties is explained by the soil composition at six profiles[16].

CROPWAT simulations

Variations in the weather parameters were disregarded since the command was minimal. The rotation of wheat and cotton crops from the wheat crop of 1985–1986 to the wheat crop of 1995–1996 was suggested based on long-term simulations using the UNSATCHEM model. For these simulations, the model needed evapotranspiration from various wheat and cotton crops. Using meteorological information from adjacent weather stations Fatehabad and Hisar, the CROPWAT model was used to determine the reference evapotranspiration values of crops. The crop coefficients were estimated to be 0.35, 0.44, 0.84, 1.11, 1.07, and 0.59, respectively, for the various growth phases of the wheat crop. The crop coefficients for cotton crop development stages were also estimated to be 0.35, 0.78, 0.78, 1.2, 1.2, and 0.9, respectively. Wheat and cotton crops' annual evapotranspiration needs were calculated and used to plan their irrigation schedules. The CROPWAT model was also used to predict daily soil evaporation and root water uptakes as required by the UNSATCHEM. For both crops, a non-linear root uptake pattern was indicated[17].

It was projected that there would be enough distributed irrigation for six typical areas in the Kheri command. The typical sites get canal water from several exits that are either on the main distributary or its lesser tributaries. The projected canal water supply for the 1985–1986 growing seasons of wheat, cotton, and pearl millet was 18, 20, and 15 cm, respectively, taking into account the canal rotation in the BML tail system, crop times, cultural command areas beneath outlets, and outlet discharges. Within the Kheri command, all representative places received almost identical canal supplies.The quality of the groundwater in the Bhakra system determined the spatial variability in canal water supply. The Kheri command's groundwater quality was salty, and the canal management now allots around 33 cm for wheat cultivation. The research used the assumption that the canal supply at the wheat crop's outflow had risen linearly over time from the initial 18 cm to 33 cm. Additionally, it was pre-summated that the cotton crop received almost the same quantity of canal water supply as the wheat crop. The likely groundwater pumping amounts inside the Kheri command for wheat and cotton crops were evaluated taking into account irrigation intensities, cropping intensities, evapotranspiration needs, canal water supplies, and rainfall amounts[18].

Long-term simulations:

The calibrated and verified UNSATCHEM model ran long-term simulations for six sample sites, spanning the wheat crops of 1985–1986 and 1995–1996 in order to provide a root zone salinity scenario for the current conjunctive water usage strategy for wheat–cotton crop rotation. With 10.5 years of simulation time, it was anticipated that the simulated root zone salinity profiles would be more similar to natural conditions. For regional validation, simulated salinity levels were contrasted with actual salinity values. On the basis of the threshold salinities of these crops, the simulated results were also utilized to evaluate the viability of a rotation of wheat and cotton crops.

DISCUSSION

The crucial topic of the regional scale for integrated water use planning has to be thoroughly examined. This approach to regional water resource management offers a lot of promise for addressing the growing issues with water scarcity, quality, and sustainability. The integration and coordination of water use across several sectors, including agriculture, industry, urban areas, and the environment, within a specific geographic region is at the core of regional-scale planning. This approach recognizes that water resources transcend political boundaries and that a more all-encompassing and collaborative strategy is needed to ensure the efficient and sustainable use of this vital resource.

One of the key benefits of regional-scale water planning is its ability to optimize water distribution across various sectors while minimizing disagreements and negative environmental consequences[19]. The interdependencies of water usage may help decision-makers allocate and manage water resources more effectively. This tactic encourages the development of innovative solutions that might increase the water supply's efficiency, including programs for water recycling and reuse.Additionally, regional planning enables a more thorough analysis of the potential impacts of climate change on water supplies. Climate patterns are changing and becoming more unpredictable, requiring regions to adjust their water management strategies.

This includes measures to decrease the consequences of extreme events like floods, droughts, and other calamities as well as plans to ensure that water quality remains within acceptable standards.There are challenges with a regional scale for combined water use planning, however[20], [21]. It is necessary for several parties to collaborate closely, including governmental institutions, water utilities, companies, and environmental groups. Additionally, it requires the extensive collection and analysis of data on water availability, use, and environmental conditionseach of which may need a significant number of resources.

It is important to create efficient governance structures and legal frameworks in order to ensure that decisions on water planning are transparent, egalitarian, and accountable. The Regional Scale for Combined Water Use Planning is an effective method for tackling the complex and interconnected issues associated to water resource management. Despite its challenges, this method has the potential to improve water sustainability, efficiently distribute resources, and be climate change resistant[22]. Regional planning should be a part of any comprehensive water management strategy since it promotes collaboration, creativity, and wise use of this important resource.

CONCLUSION

In conclusion, the Regional Scale for Simultaneous Water Use Planning is a critical and progressive strategy for addressing the complex issues related to water resource management. This approach has the potential to change how we approach water shortage, quality, and sustainability by placing an emphasis on coordination, integration, and a holistic viewpoint. The advantages it provides outweigh the challenges it presents and the cooperation it necessitates among many parties. It can improve water distribution, lessen disputes, and support creative solutions like water recycling and climate-adaptive measures via regional-scale planning. Additionally, this strategy promotes a greater comprehension of the complex interactions between different water users and the ecosystem, opening the door for more well-informed and responsible choices. Adopting a Regional Scale for Combined Water Use Planning is not just a choice; it is required as the globe struggles with escalating water issues. It promotes careful management of this priceless resource, preserving its accessibility to both the present and future generations. We must adopt this all-inclusive, team-based strategy and continue to develop and use it in other parts of the globe in order to protect the future of our water resources. By doing this, we make a big step toward ensuring sustainable water supplies and a future that is more robust for our people and the environment.

REFERENCES:

[1] K. K. Deshmukh, “Assessment of ground water quality in Sangamner area for sustainable agricultural water use planning,” Int. J. Chem. Sci., 2011.

[2] A. Montazar, H. Riazi, and S. M. Behbahani, “Conjunctive water use planning in an irrigation command area,” Water Resour. Manag., 2010, doi: 10.1007/s11269-009-9460-z.

[3] L. Scodanibbio, “Opening a policy window for organisational change and full-cost accounting: The creation of BC Hydro’s water use planning program,” Ecol. Econ., 2011, doi: 10.1016/j.ecolecon.2010.12.022.

[4] X. Wang, “Integrating water-quality management and land-use planning in a watershed context,” J. Environ. Manage., 2001, doi: 10.1006/jema.2000.0395.

[5] A. M. Lerner, H. C. Eakin, E. Tellman, J. C. Bausch, and B. Hernández Aguilar, “Governing the gaps in water governance and land-use planning in a megacity: The example of hydrological risk in Mexico City,” Cities, 2018, doi: 10.1016/j.cities.2018.06.009.

[6] J. K. Mutiga, S. T. Mavengano, S. Zhongbo, T. Woldai, and R. Becht, “Water Allocation as a Planning Tool to Minimise Water Use Conflicts in the Upper Ewaso Ng’iro North Basin, Kenya,” Water Resour. Manag., 2010, doi: 10.1007/s11269-010-9641-9.

[7] R. Gregory, L. Failing, and P. Higgins, “Adaptive management and environmental decision making: A case study application to water use planning,” Ecol. Econ., 2006, doi: 10.1016/j.ecolecon.2005.07.020.

[8] T. Vairo, M. Quagliati, T. Del Giudice, A. Barbucci, and B. Fabiano, “From land- to water-use-planning: A consequence based case-study related to cruise ship risk,” Saf. Sci., 2017, doi: 10.1016/j.ssci.2016.03.024.

[9] I. Vandecasteele et al., “The Water Retention Index: Using land use planning to manage water resources in Europe,” Sustain. Dev., 2018, doi: 10.1002/sd.1723.

[10] M. Bravo and I. Gonzalez, “Applying stochastic goal programming: A case study on water use planning,” Eur. J. Oper. Res., 2009, doi: 10.1016/j.ejor.2008.04.034.

[11] M. J. Kaledhonkar and A. K. Keshari, “Regional Salinity Modeling for Conjunctive Water Use Planning in Kheri Command,” J. Irrig. Drain. Eng., 2006, doi: 10.1061/(asce)0733-9437(2006)132:4(389).

[12] C. S. Dyckman and K. Paulsen, “Not in my watershed! will increased federal supervision really bring better coordination between land use and water planning?,” J. Plan. Educ. Res., 2012, doi: 10.1177/0739456X11426877.

[13] B. Mitchell, “Integrated water resource management, institutional arrangements, and land-use planning,” Environ. Plan. A, 2005, doi: 10.1068/a37224.

[14] R. C. Peralta, R. R. A. Cantiller, and J. E. Terry, “Optimal Large-Scale Conjunctive Water-Use Planning: Case Study,” J. Water Resour. Plan. Manag., 1995, doi: 10.1061/(asce)0733-9496(1995)121:6(471).

[15] R. M. Cowling et al., “An operational model for mainstreaming ecosystem services for implementation,” Proceedings of the National Academy of Sciences of the United States of America. 2008. doi: 10.1073/pnas.0706559105.

[16] D. Fotakis and E. Sidiropoulos, “Combined land-use and water allocation planning,” Ann. Oper. Res., 2014, doi: 10.1007/s10479-012-1080-y.

[17] H. W. Lu, G. H. Huang, Y. M. Zhang, and L. He, “Strategic agricultural land-use planning in response to water-supplier variation in a China’s rural region,” Agric. Syst., 2012, doi: 10.1016/j.agsy.2011.10.007.

[18] K. Wang and E. G. R. Davies, “Municipal water planning and management with an end-use based simulation model,” Environ. Model. Softw., 2018, doi: 10.1016/j.envsoft.2017.12.024.

[19] R. G. Sales, “The perception of water in the in the land use planning. Small cattle producers of Mendoza-Argentina,” Bitacora Urbano Territ., 2018, doi: 10.15446/bitacora.v28n3.72169.

[20] A. Ahmadi, M. Karamouz, A. Moridi, and D. Han, “Integrated Planning of Land Use and Water Allocation on a Watershed Scale Considering Social and Water Quality Issues,” J. Water Resour. Plan. Manag., 2012, doi: 10.1061/(asce)wr.1943-5452.0000212.

[21] S. N. Lieske, D. M. McLeod, and R. H. Coupal, “Infrastructure Development, Residential Growth and Impacts on Public Service Expenditure,” Appl. Spat. Anal. Policy, 2015, doi: 10.1007/s12061-015-9140-8.

[22] D. Beckwith, “Integrating land use and water planning,” J. Am. Water Works Assoc., 2014, doi: 10.5942/jawwa.2014.106.0131.

CHAPTER 7

AN OVERVIEW OF THE PRECISION AGRICULTURE

Anil Kumar, Assistant Professor
College of Agriculture Sciences, TeerthankerMahaveer University, Moradabad, Uttar Pradesh, India
Email Id- anilsingh2929@gmail.com

ABSTRACT:

Modern agricultural practices like precision agriculture utilize cutting-edge technology and data-driven strategies to increase crop productivity while minimizing adverse environmental consequences. In this abstract, the key concepts, benefits, and challenges of precision agriculture are briefly discussed. Recent years have seen a rise in the popularity of precision farming as farmers search for more efficient and sustainable ways to manage their operations. This approach incorporates a range of technologies, including GPS, remote sensing, drones, and data analytics, to collect and assess data on soil, weather, and crop conditions. By using this wealth of data to guide their decisions on planting, irrigation, fertilizer, and pest management, farmers may boost output and resource efficiency. Precision farming offers a number of important benefits, including greater productivity, cheaper input costs, and better environmental management. By modifying agricultural practices to specific field conditions, farmers may improve resource allocation and boost crop yields and profitability. The production of sustainable food is also aided by the judicious use of inputs, which reduces waste and the environmental effect of agriculture.

KEYWORDS:

Crop Management, Data Analytics, Farm Automation, GPS Technology, Precision Farming, Remote Sensing, Sustainable Agriculture.

INTRODUCTION

The use of technology advancements largely created for other sectors has improved agricultural production systems. Agriculture was mechanized and given synthetic fertilizers throughout the industrial era. Automation and genetic engineering became available in the technological era. Precision agriculture has the ability to incorporate technology advancements because to the information age. Since ancient times, people have recognized the factual basis of PA the spatial and temporal variability of soil and agricultural elements within a field. Prior to the development of agricultural technology, farmers could manually change treatments due to the small size of the fields. However, it has gotten more and more difficult to account for within-field variability without a revolutionary advancement in technology as fields have become larger and more heavily mechanized [1].

The idea of PA is to redesign the whole agricultural system in order to transition it to a low-input, high-efficiency, sustainable agriculture. The Global Positioning System, geographic information systems, miniaturized computer components, automatic control, in-field and remote sensing, mobile computing, advanced information processing, and telecommunications are just a few of the technologies that have emerged and come together to form this new approach. The agricultural sector may now collect more detailed information on production variability across time and place. The aim of PA has evolved into the desire to react to such variability on a fine-scale. After more than ten years of research, PA has come to a fork in the road where most of the required technology is available but the environmental and financial advantages have not yet been shown [2]. Although there have been many technical advances, the establishment of agronomic and ecological principles for optimal input recommendations at the localized level has often lagged behind. Many farmers are unsure whether or not to use PA technology on their operations. Strict environmental regulations, public concern over excessive agrochemical usage, and financial benefit from decreased agricultural inputs and increased farm management efficiency may all serve as drivers for the broad adoption of PA technology. After all, the economic and environmental benefits will be used to judge the effectiveness of PA technology [3].

Spatial and Temporal Variability

There are six categories of variables that have a substantial impact on agricultural productivity.

i. Variability in yield Distributions of past and current yields.

ii. Field topography includes elevation, slope, aspect, and terrace; field border and stream vicinity; and other factors.

iii. Soil diversity N, P, K, Ca, Mg, C, Fe, Mn, Zn, and Cu make up the soil's fertility, which is also given by manure. The soil's physical characteristics include its texture, density, mechanical strength, and moisture content. Computers and Electronics in Agriculture 36 113/132 ph, organic matter, salinity, and CEC; soil plant-available water-holding capacity and hydraulic conductivity; and soil depth [4].

iv. Variability in crops crop nutrient stress for N, P, K, Ca, Mg, C, Fe, Mn, Zn, and Cu; crop density; crop height; Crop water stress, crop biophysical characteristics (such as the leaf-area index, biomass, and intercepted photosynthetically active radiation), crop leaf chlorophyll concentration, and crop grain quality.

v. The fluctuation of abnormal factors Infestation with weeds, insects, nematodes, and diseases, as well as damage from wind and hay.

vi. Management inconsistency Crop hybrids, sowing rates, crop rotations, fertilizer and pesticide applications, and irrigation patterns are all examples of tillage practices. While the majority of these variability categories are recognized as independent variables, yield variability is often regarded as the most dependent variable of them. Soil nitrogen fertility level has been the independent variable that has been investigated the most to date. In actuality, nitrogen fertilizer applicators have been used to create the majority of variable-rate technology for chemical applications [5].

Both spatial and temporal variability is prevalent in many different phenomena. An example would be a weed invasion. During the crop-growing season, the patterns of the weed patches may shift in space. The majority of climatic parameter variations are temporal in character. To help with decision-making for fertilizer applications, thorough precipitation monitoring throughout fields is also crucial.

Managing Variability

Two methodsthe map-based method and the sensor-based method can be used to manage variability. The map-based strategy is often simpler to apply given the technologies of GPS, remote sensing, yield monitoring, and soil sample that are already accessible. In order to use this method, you must first grid sample a field, then analyze soil samples in the lab, create a site-specific map, and then use that map to operate a variable-rate applicator. For this method, a positioning system like a GPS is often needed. The sensor-based technique, on the other hand, uses real-time sensors in an "on-the-go" manner to measure the required qualities, such as soil and plant parameters, and then uses the results to regulate a variable-rate applicator. The sensor-based technique does not necessarily need a positioning device [6].

Since most on-the-go sensors for tracking the field, soil, and field variability are either too costly, insufficiently precise, or not accessible, the majority of experimental precision-agriculture systems are map-based systems. Through the integration of maps produced by remote sensing, soil sampling, yield monitoring, and different sensors, spatial databases have been created utilizing a variety of GIS systems. The geographical and temporal variability is analyzed using sophisticated geostatistical techniques. Utilizing crop modeling approaches, yield potential maps have been created as the foundation for fertilizer prescription. Based on anticipated meteorological conditions, these maps may be used to forecast variability in crop growth and crop disease. Therefore, PA offers a perfect instrument for assessing agricultural risk and organizing logical farm activities [7].

Management Zone

By separating a field into smaller management zones that are more homogenous in attributes of interest than the field as a whole, site-specific uses of agricultural inputs may be applied. One rate of a certain crop input is suitable for a management zone, which is described as "a portion of a field that expresses a homogenous combination of yield-limiting factors." Therefore, management zones within a field may vary for various inputs, and the delineation of management zones for a particular input only takes into account the variables that have a direct bearing on how well that input performs in accomplishing certain objectives. Additionally, a management zone may be defined by a number of distinct agricultural inputs. In this scenario, just one rate is used for all of the distinct inputs included inside a zone. The size of the field, its dimensions, and other management parameters all influence how many different management zones there are in a given field[8].

The capacity of the farmer to manage fields' various zones differently sets a minimum size for a zone. There appears to be no need for limitations on the geometry of the zone if a GPS is used to direct or control the implement. However, while defining the management zones, it is important to take into account the way that the application equipment moves throughout the field. The idea of a management zone may be seen as a step backward from the original PA idea of "farming by foot." Management zones, however, are easier to put into practice. Spatial filtering is used to define management zones in order to lessen the impact of noise on factor measurements. The geometries of the zones are made simpler and the need for VRT equipment is decreased by the removal of extraneous features in within-field variability. Researcher evaluated several methods for categorizing nutrient management zones[9]. Zhang and Taylor presented techniques for morphological and spatial filtering to create management zone boundaries.

Impact of Precision Agriculture

Two effects of PA technology on agricultural productivity are anticipated: producer profitability and public benefits to the environment.

i. Profitability:

PA enables accurate monitoring and fine-tuning of agricultural output. Due to the geographical and temporal variability in a field, PA technologies provide farmers the chance to alter the distribution and timing of fertilizers and other agrochemicals. In order to accurately estimate risk, farmers might do economic analyses based on the variability of agricultural output in a field. A farmer may, for instance, confirm that, for 70% of the time, 75% of the barley planted in a field will produce 3.8 tons. Farmers may determine the cash return over the expenses for each acre by understanding the cost of inputs. It is possible to identify certain areas of a field that consistently produce below the breakeven point in order to create a site-specific management strategy [10].

PA's economic advantages, however, have been hard to quantify. For the application of phosphorus on a rice and soybean cycle. compared VRT with uniform-rate technology and found that the profitability of VRT was extremely sensitive to both residual P and soil clay concentration. Changing from URT to VRT within a 10-year planning horizon may not be appropriate, even when VRT was proven to be economical on silt loam fields, since higher yields do not always offset the expense of VRT deployment. PA technology may be useful for enhancing profit potential and lowering hazards if a whole-farm strategy is used that takes into consideration all agricultural operations and resource restrictions [11].

ii. Environment:

There are strict environmental laws in nations including the United States, Australia, the United Kingdom, Denmark, and Germany. Directives from the European Union may be adopted soon that will compel farmers in member nations to considerably cut their use of agrochemicals. PA offers the tools for accurate and targeted application, meter-scale recording of all field treatments, operation-to-operation monitoring, and transmission of recorded data with harvested goods, all of which would help with law enforcement. Even though the environmental advantages of PA have not been scientifically and statistically assessed, certain studies have shown encouraging results. In potato cropping systems, nitrate leaching has been a significant issue, particularly in soils with a coarse texture. Computers and Electronics in Agriculture 36 113/132 117 did research in two neighboring fields, one treated with URT for nitrogen fertilizer and the other with VRT, which showed the impact of VRT in minimizing ground water pollution. The relationship between tillage and soil/water erosion may be studied with the use of topographic data for areas where PA technologies have been used, leading to a decrease in erosion [12].

Engineering Innovations

While agronomists are driving PA research, engineers have worked hard to create the tools required to put PA techniques into effect. The development of sensors, controllers, and remote-sensing technologies are engineering advances for PA.

i. Sensors:

For the implementation of different PA technologies, reliable, inexpensive, and ideally real-time sensor systems are required. Some sensor types now have commercially available products. Others are presently being created.

Yield Sensors

Four different kinds of yield sensorsimpact or mass flow sensors, weight-based sensors, optical yield sensors, and g-ray sensorsare used to monitor grain yields. For their combine harvesters, the majority of significant agricultural equipment manufacturers provide optional yield-mapping systems. The development of yield sensing methods for important crops is almost complete. A displacement sensor, a load cell, a capacitance-controlled oscillator, and an optical sensor have all been investigated as yield monitors for fodder crops. During the cropping seasons, a red and NIR optical sensor was utilized to measure spectral radiance in order to estimate yield and direct nitrogen fertilizer VRT. To create yield maps for hand-harvested crops, a simple, inexpensive, and automated yield mapping method was created. To gather spatially variable yield data for tomatoes in real-time, a continuous mass-flow type yield sensing system incorporating load cells, a vibration-resistant angle transducer, and a DGPS was created[13].

Field Sensors

Most farmers in affluent nations may now afford commercial GPS signal receivers and processors. GPS receivers on handheld devices provide location accuracy of 9/100 m. With differential GPS, the inaccuracy is reduced to 9/2m. The inaccuracy is reduced to a sub-centimeter level using a relative positioning GPS. A real-time kinematic GPS can maintain this precision for moving vehicles. Researcher created field maps during field scouting using a geo-referenced audio recorder with speech recognition capabilities. Users using this system may walk or ride an ATV around a field while recording visual observations on crop growth, weeds, illnesses, or other abnormalities. Field activities were utilized to map performance metrics that were then used to examine the topology, soil type, and soil moisture content variations in the field to pinpoint problem regions[14].

Soil Sensors

In order to estimate the organic matter and moisture contents of surface and subsurface soils, a near infrared soil sensor monitored soil spectral reflectance within the waveband of 1600–2600 nm. At a ground speed of 3.6 km/h, an online, real-time soil spectrophotometer detects the spectral reflectance of the soil in the visible and NIR wavebands. Field investigations showed that reflectance at certain wavelengths and different soil characteristics, such as soil organic matter and moisture content, had linear connections. In non-saline soils, a soil electrical-conductivity sensor based on a four-electrode technique has been successful in identifying a number of yield-limiting variables. An eight-rolling-electrode sensor that can detect soil EC at three different depths was developed in France. Soil subsurface may be mapped by combining an automated penetrometer with a soil EC probe. An electromagnetic-induction-based soil EC sensor is a non-contact sensor. A soil productivity index that takes into account the impacts of bulk density, water-holding capacity, salt, and pH and measures EC showed good correlation with that index. Plant-available-water-holding capacity may be connected to EC measured before to planting. Soil penetration resistance, moisture content, and organic matter were all assessed using a penetrometer with a near-infrared reflectance sensor. Soil hardpan may be measured using a penetrometer and a soil EC sensor. Different physical concepts, such as time-domain reflectivity, standing-wave ratio, and laser light depolarization, were used to create soil moisture-content sensors. A contour map was created using a ground-penetrating radar to show the location of clay lenses, which control the speed and direction of ground-water flow[15].

Crop Sensors:

A field spectral-imaging system in cotton and peanut fields with a configurable liquid crystal filter. Vegetative-indices were mapped using a near-ground scanning radiometer placed on a tractor. An electromechanical sensor for counting maize plants was created by researchers. Infrared laser beams and mechanical fingers were used to measure the height of cotton plants. Oil content and grain protein sensors are presently being developed. A halogen lamp and an NIR light were used to produce a cotton mass-flow and strength sensor. To regulate irrigation events, a canopy temperature thermometer was utilized to measure the temperature. To determine the moisture content of forage, several sensors including a capacitance sensor, a sensor measuring power needed at the PTO shaft, a microwave sensor, and an NIR sensor were evaluated. It was anticipated that advancements in agricultural plant gene engineering would make it possible to differentiate between these distinct forms of stress. An infrared plant-temperature transducer was created by researchers. to detect temperature variations in plants brought on by water stress. To map nitrogen stress in maize, employed a DGPS in conjunction with a chlorophyll meter. In order to identify crops under salt stress, a multispectral radiometer was used. In order to measure ionic nutrients, Rial and Han investigated the effectiveness of a commercial complicated permittivity sensor[16].

Anomaly Sensors

There are several commercially available weed sensors. To accurately detect weed-infested zones, researchers created an autonomous sensing and spraying system. A weed sensor was created. utilizing an image spectrograph. Based on research of the spectrum properties of weeds, crops, and soil, created an optical weed sensor. Plant temperature fluctuations brought on by a greenbug infestation were detected using an infrared plant-temperature transducer created.

DISCUSSION

Precision farming, often known as precision agriculture, has developed as a cutting-edge technique for modernizing and enhancing agricultural operations. This subject covers the fundamentals, implications, and prospective results of precision agriculture. One of the fundamental elements of precision agriculture is its reliance on cutting-edge technology and data-driven methods. Today's farmers may get the most recent information on crop health, weather, and soil quality by using a number of tools, including GPS, remote sensing, drones, and sophisticated data analytics software. Due to the abundance of information available, farmers are better able to make decisions on planting, irrigation, fertilizer, and pest control[15]. By adjusting their activities to the specific field conditions, farmers may increase resource efficiency, increase crop yields, and enhance resource allocation.Numerous benefits come with precision agriculture. Increased productivity is probably the major advantage. By properly managing their operations, farmers may boost yields and profitability.

Additionally, precision farming promotes sustainability by reducing the negative effects of farming on the environment. Precision in the application of inputs like water and fertilizer lowers waste and runoff, assisting in effective resource management. This is crucial right now, when worries about resource scarcity and climate change are intensifying.Adoption of precision agriculture, however, is not without its challenges. High upfront costs may be a hurdle for some farmers, limiting their access to this technology. The need for particular knowledge and skills in data analysis and technology usage may also result in a high learning curve. Ensuring data privacy and security is a high responsibility as the administration of sensitive agricultural data becomes crucial to the process.To put it mildly, precision agriculture has a promising future in the agricultural industry. There are possibly many more cutting-edge tools and techniques in the works as a consequence of continuing research and development. The use of artificial intelligence and machine learning, which is anticipated to greatly enhance decision-making processes, will lead to farming being even more productive and sustainable[17].

Policymakers and industry partners must work together to remove the obstacles to precision agriculture adoption and make technology beneficial and available to farmers of all sizes and locations. Precision agriculture represents a fundamental shift in the way we think about farming since it provides a means to boost production, sustainability, and resilience in the face of shifting agricultural issues.

CONCLUSION

One outstanding example of innovation in the contemporary agricultural industry is precision agriculture. Agriculture might change as a result of modern technology and data-driven strategies, making agriculture more productive, efficient, and successful in the future. The advantages of precision agriculture, which include better environmental management, lower input costs, and higher agricultural yields, are undeniable. However, in order to ensure equal access and broad adoption, issues including up-front investment costs, the need for specialist expertise, and data privacy concerns must be addressed.The potential for further growth of precision agriculture is significant. Additional study and development will probably result in even more honed tools and methods that will help farmers navigate an ever-changing agricultural environment more precisely and easily. The use of machine learning and artificial intelligence to agricultural operations has the potential to improve resource allocation and decision-making. To guarantee that all farmers, regardless of their size or location, can profit from precision agriculture, the international agricultural community must also work together on regulatory and educational measures.Precision agriculture provides some promise in the face of resource depletion, climate change, and the need to feed a growing world population. By combining data-driven choices with technologically based solutions to solve the problems confronting contemporary agriculture, it provides a practical and effective road ahead. As we embrace the age of precision agriculture, where the objectives of food security, environmental responsibility, and economic viability can all be attained concurrently, we set out on a path to a more resilient and profitable agricultural future.

REFERENCES:

[1] F. J. Ferrández-Pastor, J. M. García-Chamizo, M. Nieto-Hidalgo, J. Mora-Pascual, and J. Mora-Martínez, “Developing ubiquitous sensor network platform using internet of things: Application in precision agriculture,” Sensors (Switzerland), 2016, doi: 10.3390/s16071141.

[2] C. Yang, “High resolution satellite imaging sensors for precision agriculture,” Frontiers of Agricultural Science and Engineering. 2018. doi: 10.15302/J-FASE-2018226.

[3] K. Jensen, M. Larsen, S. H. Nielsen, L. B. Larsen, K. S. Olsen, and R. N. Jørgensen, “Towards an open software platform for field robots in precision agriculture,” Robotics, 2014, doi: 10.3390/robotics3020207.

[4] R. Martínez, J. Á. Pastor, B. Álvarez, and A. Iborra, “A testbed to evaluate the fiware-based iot platform in the domain of precision agriculture,” Sensors (Switzerland), 2016, doi: 10.3390/s16111979.

[5] G. Bucci, D. Bentivoglio, and A. Finco, “Precision agriculture as a driver for sustainable farming systems: State of art in litterature and research,” Qual. - Access to Success, 2018.

[6] M. S. Allahyari, M. Mohammadzadeh, and S. A. Nastis, “Agricultural experts’ attitude towards precision agriculture: Evidence from Guilan Agricultural Organization, Northern Iran,” Inf. Process. Agric., 2016, doi: 10.1016/j.inpa.2016.07.001.

[7] D. Murugan, A. Garg, and D. Singh, “Development of an Adaptive Approach for Precision Agriculture Monitoring with Drone and Satellite Data,” IEEE J. Sel. Top. Appl. Earth Obs. Remote Sens., 2017, doi: 10.1109/JSTARS.2017.2746185.

[8] J. L. Aleixandre-Tudó, L. Castelló-Cogollos, J. L. Aleixandre, and R. Aleixandre-Benavent, “Bibliometric and social network analysis in scientific research on precision agriculture,” Curr. Sci., 2018, doi: 10.18520/cs/v115/i9/1653-1667.

[9] M. Zude-Sasse, S. Fountas, T. A. Gemtos, and N. Abu-Khalaf, “Applications of precision agriculture in horticultural crops,” European Journal of Horticultural Science. 2016. doi: 10.17660/eJHS.2016/81.2.2.

[10] S. Tohidyan Far and K. Rezaei-Moghaddam, “Determinants of Iranian agricultural consultants’ intentions toward precision agriculture: Integrating innovativeness to the technology acceptance model,” J. Saudi Soc. Agric. Sci., 2017, doi: 10.1016/j.jssas.2015.09.003.

[11] A. Hernandez, H. Murcia, C. Copot, and R. De Keyser, “Towards the development of a smart flying sensor: Illustration in the field of precision agriculture,” Sensors (Switzerland), 2015, doi: 10.3390/s150716688.

[12] G. Morota, R. V. Ventura, F. F. Silva, M. Koyama, and S. C. Fernando, “Big data analytics and precision animal agriculture symposium: Machine learning and data mining advance predictive big data analysis in precision animal agriculture,” J. Anim. Sci., 2018, doi: 10.1093/jas/sky014.

[13] E. C. Leonard, “Precision Agriculture,” in Encyclopedia of Food Grains: Second Edition, 2015. doi: 10.1016/B978-0-12-394437-5.00203-5.

[14] Y. Huang, Z. xin CHEN, T. YU, X. zhi HUANG, and X. fa GU, “Agricultural remote sensing big data: Management and applications,” Journal of Integrative Agriculture. 2018. doi: 10.1016/S2095-3119(17)61859-8.

[15] S. M. Say, M. Keskin, M. Sehri, and Y. E. Sekerli, “Adoption of precision agriculture technologies in developed and developing countries,” Online J. Sci. Technol., 2018.

[16] P. C. Robert, “Precision agriculture: A challenge for crop nutrition management,” Plant and Soil. 2002. doi: 10.1023/A:1021171514148.

[17] P. Bosilj, T. Duckett, and G. Cielniak, “Connected attribute morphology for unified vegetation segmentation and classification in precision agriculture,” Comput. Ind., 2018, doi: 10.1016/j.compind.2018.02.003.

CHAPTER 8

STRATEGIES FOR MITIGATING SOIL SALINITY, WATERLOGGING AND ALKALINITY IN IRRIGATED AGRICULTURE

Kusum Farswan, Assistant Professor
College of Agriculture Sciences, TeerthankerMahaveer University, Moradabad, Uttar Pradesh, India
Email Id- kusumfarswan.14feb@gmail.com

ABSTRACT:

It is crucial to address alkalinity in irrigated agriculture since it has a big impact on crop yield and the sustainability of the soil. This abstract examines the problems caused by alkalinity in irrigated areas and possible solutions. It draws attention to how common alkalinity-related issues are in numerous agricultural contexts, particularly how they affect the quality of the soil, nutrient intake, and plant development. The abstract also covers the significance of selecting crop genotypes that are alkalinity-resistant and putting good soil management methods in place. Overall, it offers a succinct summary of the complex problem of alkalinity in irrigated agriculture and the need for proactive steps to solve this mounting issue.

KEYWORDS:

Soil Management, Soil Quality, Soil Salinity, Soil Sustainability, Water Management, Waterlogging.

INTRODUCTION

In irrigated regions all around the globe, salinity and alkalinity are significant and growing issues. 3.3 million ha, or 10% of the total, of the 34.3 million hectares of irrigation potential developed by big and medium projects in India by the end of 1990 are affected by irrigation-induced salinity. The sustainability of agricultural output in irrigated areas is being threatened by the twin issues of waterlogging and soil salinity, which are severe throughout most of North-West India and many other regions of the nation. Highly productive agricultural land is under danger as a result of the worrisome increase in the water table[1]. Because of the rising water table and brackish or salty groundwater in a large portion of the vulnerable region, the threat is becoming worse. There will be severe effects on the region's agricultural economy, which supports around 80% of the people. In both older systems, like the Western Yamuna Canal, as well as more recent ones, like the Bhakra Canal system or the Ukai-Kakrapar project, waterlogging and soil salinization are frequent. In Haryana, brackish groundwater is present in 65 percent of the region. Groundwater levels had risen as a consequence of the extensive use of canal irrigation. Currently, waterlogging and salinity are problems in around 0.5 million acres, or about 10% of the state's agricultural land, primarily in the central and northwestern regions. The issue is just as terrible, if not worse, in Punjab, where a sizable portion of the South-West Punjab, which includes the districts of Ferozpur, Faridkot, and Bhatinda, is plagued by brackish groundwater, waterlogging, and salt issues[2].

The water table rose as a result of insufficient drainage and the extensive use of canal water for agriculture. Because of this, water and salts have been progressively building up over time. In addition to causing additional environmental issues, any loss of land in the irrigation commands or decline in productivity affects our ability to reach food production objectives. Given that India has the greatest net irrigated area in the world and has invested more than Rs. 50,000 crores directly in the irrigation industry, the issue is taking on severe dimensions. To stop the rapidly deteriorating of these lands and to meet the goal of producing 109 million tons of wheat by 2018 AD, the waterlogging and salt concerns in India must be addressed right now[3]. Preventing additional declines in soil productivity and reclaiming the soils already made waterlogged and salty are important to enhance and maintain the agricultural output of the regions affected by waterlogging and soil salinity. Reclaiming the waterlogged lands, integrating water management, and implementing the proper cropping system for its avoidance and control are all part of the solution to the waterlogging issue. Although it is cost-effective, reclamation of wet, salty soils appears out of reach for farmers in terms of initial expenditure. A proper cropping strategy must be used, with a focus on crops and types that use less water and are tolerant of these circumstances.

The amount of wheat produced must rise by 40 million tons by the year 2018 AD in order to meet expected population growth, and this increase must occur at a rate of 1.8% each year. Since there is limited room to expand the land, more output must be produced through raising per-hectare productivity. The primary focus becomes preserving the productivity of the already productive and irrigated areas by avoiding salinization and waterlogging. Studies of the interplay between salt and alkalinity and waterlogging might provide insight on the challenge of developing cereals with greater yields on such challenging soils. Until cultivars with resistance to simultaneous salinity/alkalinity and hypoxia, which causes extremely substantial increases in salt intake, are created, it is probable that there won't be much improvement[4].

The majority of research on the effects of waterlogging on plants has been conducted in lab settings with brief interruptions in the plants' oxygen supply. The use of such artificial systems is predicated on the idea that an oxygen deficit in wet soil is the main cause to which plants react. The adoption of such too simplistic systems ignores the defenses against free radicals that operate in natural situations. However, during periods of natural floods or waterlogging, the oxygen that has been dissolved in the soil water gradually disappears over a period of hours to days, with the length of time dependent on the soil temperature and the respiration rate of the roots and other soil organisms. In nature, roots typically undergo hypoxia prior to anoxia, which enhances their performance when confronted with anoxic circumstances. Therefore, we must carry out this research in real salinity-waterlogged/submergence circumstances or attempt to imitate them in a lab setting by exposing roots to sub-ambient O_2 concentrations prior to anoxia[5].

We are aware that there are several genotypes of wheat that are more or less resistant to salt or alkalinity, and these genotypes have been created and disseminated. Second, the tolerance of cereals to hypoxia varies. According to certain publications, there is variation in the resistance of wheat genotypes to waterlogging, salt and waterlogging, and alkalinity and waterlogging. Rapid screening techniques for large populations of young plants that are segregating will be required to create wheat varieties that are resistant to saline and waterlogging stressors. This can be accomplished by choosing plants that can continue to absorb O_2 by developing aerenchyma-like tissue in the root cortex and stem base as well as the development of nodal roots under these stresses. These plants should also be able to maintain desirable levels of growth and metabolism, nutrient uptake, preventing the buildup of higher concentrations of Na^+ and Cl^-, and stopping the leakage of cell metabolites and ions. Equally crucial is the capacity to handle the effects of repeated exposure to O2 in the medium. Identification of cultivars with these desired traits is necessary for either direct cultivation or potential use as tolerant donor parents[6], [7].A good range of genotypic resistance to salt and alkalinity stressors is present in wheat, rice, Indian mustard, chickpea, and pigeon pea, according to studies undertaken over the last three decades. There have been different reports of intra-specific variation in these crops' susceptibility to salt and alkalinity stressors. All of these efforts have resulted in the production of lines and varieties of these crops that are resistant to salt and alkalinity stressors. Waterlogging wheat crops in alkali fields for 1, 2, 4 and 6 days at the 25-day stage resulted in 8, 17, 27 and 39 percent less plant growth and production, respectively. Waterlogging hindered root development, lowered ion uptake, particularly of N, P, K, Ca, Mg, and Zn, and increased the absorption of Na, Fe, and Mn. Results for barley were almost same[8].

According to research done at CSSRI, water stagnation in previously salinized plants decreased plant growth and yield in wheat genotypes and was also associated with a decline in net CO2 assimilation rates, but did not influence stomatal conductance. Intercellular CO2 concentrations and Na+ and Cl- absorption both rose in response to the decrease in photosynthesis. These reactions varied between the two genotypes. In comparison to PBW 343, genotype KRL 3-4 was shown to be more resistant to salt, waterlogging, and the combination of both.

Understanding the physiological processes underlying tolerance to salty and waterlogged stressors is facilitated by genotypes with varying salinity and waterlogging tolerance. For agricultural crops, further improving tolerance necessitates expanding the germplasm pool and discovering alternative variation after screening the present commercial varieties. The alternative strategy to diversify the range of tolerance in situations where there is little to no diversity across types will be to create divergent populations in these crops utilizing cutting-edge genetic and molecular biology methods. Screening ecotypes or taking use of plant-to-plant diversity for tolerance within variations will also need to be taken into consideration[9], [10].

Toxicities of Microelements in Waterlogging

Key mechanisms of resistance to sodicity or alkalinity and water logging are shown by critically essential physiological data on the growth of Na+, B, Al and some other microelements in shoots of plants cultivated in various soils with varying levels of sodicity. Increased amounts of B and Al were found in several genotypes of wheat under sodicity and waterlogging under neutral and sodic circumstances in pot trials, according to an analysis of plant samples by ICP. Ten genotypes of wheat were examined, and differences in these elements' uptake were found. Waterlogging occurred at neutral and higher pH in all genotypes, and varied responses were seen across the ten genotypes. B and Al concentrations rose with increases in pH from 8.2 to 9.6. In the pH 8.2, pH 8.2 +Waterlogging, pH 9.6, and pH 9.6 +Waterlogging treatments, B mean values were 5, 22, 44, and 59 ppm, respectively. Al also showed similar results, with levels of 47, 147, 217, and 261 ppm, respectively. The genotype HD 2189, which performed the best at pH 9.6 and waterlogging treatment, had the least rise in Na, Al, and B under both higher pH and waterlogging, while HD 2009, the genotype with the lowest performance, demonstrated a greater absorption of Na, Al, and B. When the experiment was replicated in micro plots with the same soils, similar findings were also attained[11].

The importance of toxicities for Al and B accompanying Na in determining the response of wheat genotypes in alkali soils with or without waterlogging has likely never been shown before. These results contribute to the understanding of why various mechanisms of tolerance are significant in various soils susceptible to waterlogging and why the germplasm ranking for tolerance differs in various soils. Since the plants are still exposed to toxic Na, B, and Al concentrations even after recovering from waterlogging, the observed increased concentrations of the microelements appear to have serious implications for plants growing in alkali soils and when exposed to waterlogging. This exacerbates the stress situations for the plants. These findings support the discovery of significant genetic variability in wheat for the elements Na, B, and Al[12].

Assessment of Wheat Germplasm for Waterlogging Tolerance Under Alkalinity

Only 29 of the 1344 wheat cultivars or lines evaluated by CIMMYT in North-West Mexico were able to set seed after experiencing waterlogging from tillering to maturity. The length of the waterlogging therapy, however, seems excessive and could not be applicable to the real stress being experienced in India and other nations. This paper, along with others, offers strong proof that wheat and other dry land cereals are capable of withstanding waterlogging. Even with a small number of genotypes, several recent Australian studies suggest genetic variation for wheat waterlogging resistance. The Mexican types that were tested in Australia and shown to be waterlogging resistant performed moderately to poorly. This discovery supports the idea that testing plant materials for certain target conditions is necessary[13].

Numerous investigations have been made into the processes of damage or adaptation, the effects of salt and alkalinity on all types of plants, particularly crop plants, and the screening of wheat and other crop germplasm. There are, however, a relatively limited number of research available that discuss the combined impacts of salt and waterlogging stressors, the processes of harm or adaptation, and genotype screening of wheat and other crops. Furthermore, such research must be tailored to the requirements for the crops and the environment. By concurrently introducing genes for salt and waterlogging tolerance, researchers also shown that there is a good chance of increasing the performance of wheat in saline and waterlogged conditions. The amphiploid hybrid of Chinese spring and Th. The studied genotype elongatum showed to be the most tolerant, however it had a poor absolute yield[14].

For a basic understanding of plant biology and a better understanding of the effects of salinity and waterlogging, as well as the mechanisms of tolerance to O2 deficiency, is required. This will allow for the enumeration of a wide range of desirable physiological traits. Plant breeders attempting to increase crops' tolerance for waterlogging may benefit from these features. The discovery of sensitive and tolerant genotypes will help us better understand the mechanisms and processes of adaptation, which will encourage the use of these genotypes in genetic and molecular biology research.

Screening for Germination

There is a lack of information on wheat seed resistance to waterlogging, despite the fact that this feature is important. The mechanisms for waterlogging tolerance during the seed stage are not well understood. This information is crucial to help with varietal selection in situations where farmers frequently experience early-season land flooding, where significant crop losses result from unseasonal rains or seepage from canals, and especially in alkali soils with lower permeability and hydraulic conductivity. The problem-ridden, highly productive irrigation command regions will see a delay in the loss of production of the prime agricultural lands due to the identification and/or creation of crop varieties resistant to salty, alkaline, and waterlogged conditions and their cultivation. Most of the time, superior genotypes will aid in full production recovery in locations where waterlogging is temporary and marginal. They will aid in lowering yield losses in the most seriously impacted cases[15].

This often results in inadequate field preparation, poor stand, or delayed wheat planting, which causes the crop to mature under hot circumstances and reduce output. This issue is prevalent across Eastern India as well as the rice-wheat region of North India. By permitting timely seeding of wheat, good crop stand growth, and avoiding heat stress during grain filling phases under such circumstances, the identification and development of wheat lines resistant to waterlogging and salt would provide greater yields. A systematic laboratory procedure was developed to test wheat genotypes for resistance to waterlogging during germination under normal and alkaline conditions. The standard treatment period for the screening of additional genotypes was determined by the germination percentage plot with time, which revealed that a 60% drop in germination was seen after 4 days of waterlogging.Sodic soil that wasn't wet had a lower redox potential than neutral soil. The redox potential of both soils decreased as the duration of the waterlogging increased from 0 to 1, 2, 4, 6, and 8 days. After 8 days of waterlogging, the redox potential in neutral and alkali soils decreased from 364 to 119 mV and 329 to 80 mV, respectively. As a result, damp soils had considerably lower redox potential values, which might indicate microelement toxicities and a decline in soil oxygenation. As a result, soil loss happened quickly and was greater in cases of saturated sodic soil than in those with neutral soil[16], [17].

Thus, water logging under neutral and sodic circumstances inhibited germination of several kinds to diverse degrees, with the drop in germination percentage ranging from 5-84%. When it came to germination under water logging under normal and alkalinity conditions, Ducula-4, the wheat genotype thought to be the most water logging resistant at the entire plant level, performed poorly. When waterlogged in neutral and alkaline circumstances, its germination was slowed down by 84% and 76%, respectively. The findings show that there are genetic variations in the germ plasm, and tolerant and non-tolerant checks were also found. During germination, the genotypes D 2-13 and Krichauff showed the greatest tolerance, whereas Ducula-4 and HD 2009 showed the most intolerance. These tolerant lines and cultivars may be used as tolerant donors in improvement projects as well as for planting in soggy situations. We examined 150 double haploid lines of the Ducula 4/2* Brookton cross and significant wheat varieties from Western Australia, India, and Australia for waterlogging at germination. According to the findings, 25 out of 150 DH lines may survive 67% longer in wet alkali soils than their superior performing parent Brookton. The DH lines have artificially improved their ability to tolerate waterlogging, and substantial genetic variety has also been shown[18].

Although there is a strong correlation between germination in waterlogged neutral soils and alkali soils, certain lines performed differently in neutral and alkali environments. Varieties that are suited for the particular circumstances must thus be identified independently. These tolerant lines and cultivars may be used as tolerant donors in improvement projects as well as for planting in soggy situations.Data indicate that when seeds are soaked in soil from the target habitats, there is an up to 10-fold variation in the genetic diversity for waterlogging tolerance during the germination/emergence stage. Important findings from physiological research on plants' endurance to waterlogging

a) According to the current theory, wheat's ability to withstand waterlogging is a result of its resistance to anaerobiosis and to particular, native microelements in the target environment, or the combined effects of low oxygen levels and microelement toxicities in different soils.

b) The capacity to recover after waterlogging, resistance to microelements, and tolerance to seed waterlogging are important adaptive features.

c) Significant variation has been found in wheat for a number of features, including microelement toxicity and its relationship to waterlogging. Future breeding efforts and possible parents should be more targeted as a result of this knowledge, especially in order to combine tolerance for waterlogging with the capacity for recovery[19], [20].

d) Tiller number and biomass after waterlogging are the rapid visual selection criteria for waterlogging tolerance.

DISCUSSION

The issue of alkalinity in irrigated agriculture is very relevant in the context of modern agricultural practices. Alkalinity in irrigation-based agriculture is a subject with a wide range of ramifications. First off, crop output may be significantly harmed by high pH alkaline soils. Alkaline conditions that decrease the availability of essential minerals like iron, manganese, and phosphorus might hinder plant development. Therefore, this may lead to lower crop yields and worse agricultural productivity, which would hurt farmers' finances and cast doubt on the safety of the local food supply.Water management and soil salinity are extremely closely connected to alkalinity in irrigated agriculture [21].

Alkaline soils with high salt concentrations exacerbate the negative impact on plant growth and may finally deteriorate the soil. Alkalinity issues need appropriate water management strategies since inefficient irrigation practices may lead to salt accumulation in the root zone, a problem that is exacerbated. Alkalinity has a detrimental effect on agricultural land; thus it must be sustainably controlled using strategies like improved drainage and targeted watering.In an effort to tackle the issues that are brought on by alkalinity, research has been focused on the discovery of crop genotypes that are alkalinity-resistant. Developing crop varieties that can thrive on alkaline soils is an effective way to ensure food security in places with alkalinity issues. In order to boost nutrient availability and adjust the pH of the soil, soil treatments and amendments may also be applied, which will improve the soil's suitability for crop development. The usage of organic material or specific chemicals are a few of examples of these therapies.As a result, regulating alkalinity in irrigated agriculture requires a multifaceted approach that takes into account managing the soil, the water, and developing crop varieties that can survive alkalinity[22]. Since the impact of alkaline soils on crop output and food security cannot be overstated, agricultural communities, researchers, and politicians must work together to find long-term solutions to this challenging issue.

CONCLUSION

Alkalinity is a severe issue in irrigated agriculture that needs concerted action and strategic solutions. By limiting nutrient availability and inhibiting plant growth, high pH alkaline soils have the potential to dramatically lower agricultural production. These undesirable results might jeopardize food security and make farming unprofitable. However, by using effective soil and water management techniques, we may mitigate the consequences of alkalinity. By using organic amendments, improved drainage systems, and other sustainable agricultural practices, alkalinity management and soil health may be accomplished. A further promising development for ensuring agricultural sustainability in alkalinity-prone locations is the development and adoption of crop genotypes resistant to the acidic condition. Due to the interdependence of alkalinity, soil salinity, and water management, it is essential that agricultural stakeholders, researchers, and policymakers collaborate to find innovative solutions. We can address the issue of alkalinity in irrigated agriculture, safeguard crop yield, and enhance global food security with the right strategies and financial investments. By putting strong and sustainable farming practices first, we can thrive in the face of issues caused by acidification and secure a more prosperous agricultural future.

REFERENCES:

[1] I. N. Daliakopoulos et al., “The threat of soil salinity: A European scale review,” Science of the Total Environment. 2016. doi: 10.1016/j.scitotenv.2016.08.177.

[2] S. Dasgupta, M. M. Hossain, M. Huq, and D. Wheeler, “Climate change and soil salinity: The case of coastal Bangladesh,” Ambio, 2015, doi: 10.1007/s13280-015-0681-5.

[3] H. Yu, M. Liu, B. Du, Z. Wang, L. Hu, and B. Zhang, “Mapping soil salinity/sodicity by using Landsat OLI imagery and PLSR algorithm over Semiarid West Jilin province, China,” Sensors (Switzerland), 2018, doi: 10.3390/s18041048.

[4] A. Allbed, L. Kumar, and P. Sinha, “Mapping and modelling spatial variation in soil salinity in the Al Hassa Oasis based on remote sensing indicators and regression techniques,” Remote Sens., 2014, doi: 10.3390/rs6021137.

[5] S. U. Laiskhanov et al., “Dynamics of soil salinity in irrigation areas in South Kazakhstan,” Polish J. Environ. Stud., 2016, doi: 10.15244/pjoes/61629.

[6] W. Jingwei, B. Vincent, Y. Jinzhong, S. Bouarfa, and A. Vidal, “Remote sensing monitoring of changes in soil salinity: A case study in inner Mongolia, China,” Sensors, 2008, doi: 10.3390/s8117035.

[7] Y. Wang, C. Deng, Y. Liu, Z. Niu, and Y. Li, “Identifying change in spatial accumulation of soil salinity in an inland river watershed, China,” Sci. Total Environ., 2018, doi: 10.1016/j.scitotenv.2017.11.222.

[8] A. Allbed and L. Kumar, “Soil Salinity Mapping and Monitoring in Arid and Semi-Arid Regions Using Remote Sensing Technology: A Review,” Adv. Remote Sens., 2013, doi: 10.4236/ars.2013.24040.

[9] E. Scudiero, T. H. Skaggs, and D. L. Corwin, “Regional-scale soil salinity assessment using Landsat ETM+ canopy reflectance,” Remote Sens. Environ., 2015, doi: 10.1016/j.rse.2015.08.026.

[10] M. Hardie and R. Doyle, “Measuring soil salinity,” Methods Mol. Biol., 2012, doi: 10.1007/978-1-61779-986-0_28.

[11] G. Aredehey, H. Libsekal, M. Brhane, K. Welde, and A. Giday, “Top-soil salinity mapping using geostatistical approach in the agricultural landscape of Timuga irrigation scheme, South Tigray, Ethiopia,” Cogent Food Agric., 2018, doi: 10.1080/23311932.2018.1514959.

[12] R. M. A. Machado and R. P. Serralheiro, “Soil salinity: Effect on vegetable crop growth. Management practices to prevent and mitigate soil salinization,” Horticulturae. 2017. doi: 10.3390/horticulturae3020030.

[13] T. Gorji, E. Sertel, and A. Tanik, “Monitoring soil salinity via remote sensing technology under data scarce conditions: A case study from Turkey,” Ecol. Indic., 2017, doi: 10.1016/j.ecolind.2016.11.043.

[14] A. Sidike, S. Zhao, and Y. Wen, “Estimating soil salinity in Pingluo County of China using QuickBirddata and soil reflectance spectra,” Int. J. Appl. Earth Obs. Geoinf., 2014, doi: 10.1016/j.jag.2013.06.002.

[15] Z. Wang, B. Zhou, L. Pei, J. Zhang, X. He, and H. Lin, “Controlling threshold in soil salinity when planting spring wheat and sequential cropping silage corn in Northern Xinjiang using drip irrigation,” Int. J. Agric. Biol. Eng., 2018, doi: 10.25165/j.ijabe.20181102.3621.

[16] M. Zhang, B. Dong, Y. Qiao, H. Yang, Y. Wang, and M. Liu, “Effects of sub-soil plastic film mulch on soil water and salt content and water utilization by winter wheat under different soil salinities,” F. Crop. Res., 2018, doi: 10.1016/j.fcr.2018.06.010.

[17] J. Chen and V. Mueller, “Coastal climate change, soil salinity and human migration in Bangladesh,” Nature Climate Change. 2018. doi: 10.1038/s41558-018-0313-8.

[18] M. Elhag, “Evaluation of Different Soil Salinity Mapping Using Remote Sensing Techniques in Arid Ecosystems, Saudi Arabia,” J. Sensors, 2016, doi: 10.1155/2016/7596175.

[19] M. A. Casterad, J. Herrero, J. A. Betrán, and G. Ritchie, “Sensor-based assessment of soil salinity during the first years of transition from flood to sprinkler irrigation,” Sensors (Switzerland), 2018, doi: 10.3390/s18020616.

[20] X. Fan, Y. Liu, J. Tao, and Y. Weng, “Soil salinity retrieval from advanced multi-spectral sensor with partial least square regression,” Remote Sens., 2015, doi: 10.3390/rs70100488.

[21] D. D. Alexakis, I. N. Daliakopoulos, I. S. Panagea, and I. K. Tsanis, “Assessing soil salinity using WorldView-2 multispectral images in Timpaki, Crete, Greece,” Geocarto Int., 2018, doi: 10.1080/10106049.2016.1250826.

[22] F. Wang, X. Chen, G. P. Luo, J. L. Ding, and X. F. Chen, “Detecting soil salinity with arid fraction integrated index and salinity index in feature space using Landsat TM imagery,” J. Arid Land, 2013, doi: 10.1007/s40333-013-0183-x.

CHAPTER 9

OPTIMIZING CROP PRODUCTION IN SALINE AND SODIC IRRIGATED SOILS

Kuldeep Mishra, Assistant Professor
College of Agriculture Sciences, TeerthankerMahaveer University, Moradabad, Uttar Pradesh, India
Email Id- mishraypikuldeep@gmail.com

ABSTRACT:

Inadequacy of water for irrigation is often a major factor limiting crop production in arid and semi-arid regions. Groundwater is being increasingly exploited to meet the water requirement of crops or to bridge the shortfall of water available from other sources viz-a.viz the water required by the crops. However, 32-84 % of the groundwater aquifers especially in the states of Rajasthan, Haryana and Uttar Pradesh are considered unfit for irrigation, as their use is likely to build-up salinity, sodicity or toxicity in the soils. The use of marginal and poor-quality waters is not considered safe for irrigation since the continuous use of such water causes salinity and sodicity hazards in the soils. It is now known that with appropriate techniques, the waters that are conventionally considered unfit be profitably used for crop production.

KEYWORDS:

Agriculture, Farming, Harvest, Irrigation, Planting, Soil Fertility.

INTRODUCTION

Addition of amendment to neutralize the exchangeable sodium in sodic water irrigated soils and leaching of soluble salts from the root zone profile in case of a saline water irrigated soil are the essential pre-requisites for successful crop production. In situations, where the development of soil salinity is due to shallow groundwater table, lowering of water table to a safe depth will be the first step in the reclamation of such soils. Therefore, special agronomic and cultural practices are required to minimize the harmful effect of salts and to restore good physical condition of the soil for better crop growth. The research works have proved that the optimum yields of selected crops can be obtained from the poor-quality irrigated soils where nothing used to grow or very poor yield obtained in the past[1]. In this lecture, it is proposed to highlight the important cropping systems and improved cultural practices for sustainable production of crops in sodic and saline irrigated soils.

Management of Saline Irrigated Soils for Crop Production Choice of crops and cropping sequences

The selection of crops and cropping sequences for saline irrigated soils is of paramount importance, since crops vary in their tolerance to salinity and are either too sensitive or semi-tolerant to tolerant to a given level of salinity.

The selection of the first crop will hence depend upon the degree of soil salinity after the basic reclamation measures are implemented. Since complete reclamation may not be attainable in practice, the improvement of the soil is gradual. Hence, crops that are tolerant and can cope up with salinity are preferred in the early phase of reclamation. Appropriate cultivation practices and growing of suitable crops help in leaching of salts and the crop cover prevents re-salinization due to evaporation[2].

Principal Scientist

In the saline irrigated soils of arid and semi-arid areas of India, cotton, sorghum, pearl millet, cluster bean and moth bean could be grown during kharif, and during rabi wheat, barley, mustard, safflower and sugarcane could be grown depending upon the availability of water. The crop production as a function of soil salinity under field conditions has been studied at CSSRI and it was found that threshold tolerable soil salinity levels for wheat, barley and mustard are 4, 7 and 6 dS/m, respectively. After solving the salinity problem in the affected area, wheat, barley and mustard yields can be increased by 28, 30 and 13 percent, respectively. Further it was reported that pearl millet and cotton could be grown in saline soils up to ECe of 6.5 and 7.5 dS/m, respectively without significant reduction in yield[3].

The cultivation of crops having low evapotranspiration and/or high tolerance is one way of compensating for water deficiency. The recommended cropping sequences for saline soils are pearl millet-barley, pearl millet-wheat, pearl millet-mustard, sorghum- wheat or barley, sorghum-mustard, cluster bean-wheat or barley and cotton-wheat or barley. From the long-term experiments on cropping sequences in saline soils, it was observed that pearl millet-wheat, pearl millet-barley, pearl millet-mustard, sorghum -wheat and sorghum -mustard cropping sequences were more remunerative in saline soils. Cotton based cropping sequences were not much beneficial since the yield of following rabi crops were drastically reduced. In water scarcity areas mustard could replace wheat since its water requirement is low as compared to wheat[4].

Improved Agronomic Practices

Establishing a good crop stand in saline irrigated soils is a challenging task. Unlike normal soils, the agronomic practices for crop production in saline irrigated soils are different. An ideal package of cultural practices besides soil fertility and irrigation water management can ensure a good crop stand vis-à-vis good yield.Pre-sowing irrigation: In saline soils, salt often accumulate in the top few centimeters of the soil during non-crop periods. Where high water table exists, fallowing may result in excessive salt accumulation in the root zone particularly in arid and semi-arid regions. Under these conditions both germination and yields are adversely affected. A heavy pre-sowing irrigation to leach the accumulated salts from the root zone is very useful and essential to improve germination and early growth. Wherever available, pre-sowing irrigation should be given with good quality canal water. Deep tillage and inversion help to reduce salinity hazard[5].

Seed rate and spacing:

Due to inhospitable soil environment, germination is adversely affected. Mortality of young seedlings and poor tillering of the crops are common in saline soils. The plant growth is hindered compared to normal soils. Higher seed rate and closer spacing are advisable to counter these effects. For cotton, pearl millet, sorghum, wheat, barley, mustard 25% higher over the recommended seed rate for normal soils ensures good crop stand. In case of transplanted crops, the number of seedlings per hill should be increased.Treatment of seeds/seedling: The chemical treatment of seeds and seedlings has been reported to induce salt tolerance. In a field experiment on saline soils, irrigated with saline water, the highest yield of wheat was obtained when seeds presoaked in 3 percent sodium sulphate solution were used[6].

Practices for sowing/planting:

Sowing/planting practices can often be modified to obtain a more favourable salt distribution in relation to seed location or growing roots. Since salt tends to accumulate on the ridges under furrow method of irrigation, furrow planting may help to obtain better crop stand and yield under saline conditions. The sowing of sugar beet on one side of the ridge half way between top and bottom, opposite to the sun direction gave significantly higher yield than flat and ridge sowing. The salt concentration in the root zone under this method of sowing was comparatively less owing to more accumulation of salts on southern face of the ridge due to direct and intensive solar radiation on this face. Similarly in case of sugarcane, trench method of planting gave significantly higher yield than flat planting attributable to low concentration of salts, as salts move to the top of the adjoining ridges. Moreover, the seeds should be sown in lines at an optimum depth with bullock or tractor driven seed drills. Seed-cum- fertilizer drill should be preferred to ensure uniform placement of seeds and fertilizers at the optimum depth and early emergence of seedlings. If seed drill is not available, sowing should be done by kera or pora method[7].

Irrigation Water Management

In saline soils, evapotranspiration needs of crops are modified by the presence of soluble salts. The water availability decreases with increasing salinity of the soil. In this case both matric potential and osmotic potential must be considered while deciding irrigation scheduling in crops. Light and frequent irrigations have to be adopted to keep the soil-water potential at low levels. Successful operation of field application must supply water to the plants at the right time in appropriate quantity and quality withminimum waste and at the place where the plants need it for optimum growth. On-farm water management technology includes proper land leveling and shaping, efficient design and layout of irrigation methods, scientific scheduling of irrigation under both adequate and deficient water supply conditions, irrigation management under high water table depths and crop planning for optimum water use[8], [9].

Selection of suitable irrigation method is of vital significance to efficient operation of an irrigation project. The selected method should aim at regulating soil moisture and meeting the crop requirement with a minimum potential of creating drainage or salinity problem without any adverse effect on soil or crop. The irrigation methods are generally of three types, surface, subsurface and sprinklers/drip. Surface method includes free flooding, check basin, border strip, furrows and corrugations. The subsurface method is used only under specialized conditions and therefore, the choice is limited to the surface and sprinklers/drip. Drip method of irrigation is relatively a recent development. Leaching of saline soil with irrigation water is reported to be more efficient when the soil is maintained in unsaturated condition and the rate of water flow is kept relatively slow. Therefore, flood method of irrigation is inferior to sprinkler and trickle methods in leaching of saline soils. The drip method of irrigation is also suitable for saline water irrigation and helps in maintaining a zone of low salt concentration and higher moisture content resulting in favorable condition for crop growth[10].

The important concepts that are adopted in scheduling irrigation are depth interval soil moisture depletion crop growth stage plant symptoms andclimate. The time, frequency and quantity of irrigation depend largely on water requirement of crops, climatic conditions, and soil characteristics including texture, infiltration rate, moisture- tension relationship, irrigation methods, water quality and water table. Sorghum, pearl millet, cotton, guar, moth, wheat, barley and mustard cannot tolerate standing water and also relatively wet moisture regime whereas linseed and sugar beet will perform better with such a regime. Enough moisture should be present at the time of flowering and seed development stage.

Proper scheduling of irrigation if water table remains high within certain limits and underground water is of good quality could affect substantial saving in irrigation water. The depths of critical water table, beyond which the yield is reduced significantly, depend upon the crop, water quality and soil type. It has been observed that many crops can be grown without irrigation if water table remains within a specified depth provided groundwater is of good quality.A proper understanding of soil-water-plant-climate relationship under different conditions is essential for deciding the most appropriate irrigation practices. Despite irrigation water is costly; water management has been neglected in India, thereby resulting in widespread problems of water logging and soil salinity. Urgent steps are needed to prevent all avoidable water losses and to achieve most efficient and economic use of water resources consistent with optimum cropping system. There is need to check further spread of water logging and soil salinity through efficient utilization of irrigation water[11], [12].

Soil Fertility Management

At a given level of salinity, growth and yields of crops are depressed more when crop nutrition is disturbed than when it is normal. The salt affected soils are often poor in most of the essential plant nutrients owing to lack of vegetation and low organic matter content. Nitrogen deficiency is widespread in saline soils and a large fraction of the applied nitrogen is lost in gaseous forms under high soil salinity. Availability of phosphorus increases up to a moderate level of salinity but thereafter it decreases. Saline soils are generally medium to high in available potassium but plants grown under high salinity may show K deficiency due to antagonistic effect of sodium and calcium on potassium absorption and or disturbed sodium/potassium ratio. Under such conditions application of potassium fertilizer might increase yield. A judicious application of bulky organic manures and chemical fertilizers would be inevitable to ensure stable crop yield[13].

The nitrogen requirement of crops is higher in saline soils than in normal soils. High concentration of salts inhibits nitrification and resultant NH4-N accumulation. The plants, which absorb N only as NH3-N, would show nitrogen deficiency even if nitrogen is present in the soil. Field experiments at CSSRI, Karnal on saline soils indicated significant response of wheat, barley, mustard, pearl millet and cotton up to 160, 120, 100, 120 and 80 kg N ha-1, respectively. Nitrogenous fertilizers should be applied in split doses to reduce nitrogen losses through volatilization and denitrification. The required quantity of phosphorus and potash along with first dose of nitrogen should be applied at or before sowing. The remaining quantity of nitrogen should be applied in two equal splits at first and second irrigation i.e., 25 and 45 days after sowing in pearl millet, wheat and barley and in one dose in cotton and mustard. Under limited water supply conditions, nitrogen in wheat and barley should be applied in two equal doses at sowing and during first irrigation[14].

Application of phosphorus helps in increasing the yields of crops in saline soils by directly providing phosphorus or by decreasing the absorption of toxic elements like fluoride and chloride. It was observed that yields of wheat and mustard increased significantly with the application of 13 kg P ha-1 as compared to control with saline water irrigation. On moderately saline soils, application of potassic fertilizers may increase the crop yields either by directly supplying K or by excluding the uptake of Na, Ca and Mg. However, under high salinity conditions it is difficult to effectively exclude Na from the plant by use of potassic fertilizers. In general, micronutrient deficiencies have not been widely reported in saline soils[15].

Management of Sodic Irrigated Soils for Crop Production

The selection of crops and cropping sequences to be followed in sodic soils is of paramount importance, since crops vary in their tolerance to sodality and are either too sensitive or semi-tolerant to tolerant to a given level of sodality.Therefore, the selection of the first crop should be based upon the expected level of soil sodicity after the initial reclamation measures and tolerance of crop. Rice enjoys a favorable place in any cropping sequence for adoption in sodic soils because it is suited to the environment that promotes reclamation. Results of several agronomic trials, having various rice-based cropping sequences have shown that rice-wheat- dhaincha and rice-berseem cropping sequences were more remunerative in sodic soils. Recent studies on cropping sequences with rice and sorghum based cropping sequences revealed that rice-based cropping sequences were better than sorghum based cropping sequences in terms of yield as well as reclamation of sodic soils. These studies further revealed that rice-berseem cropping sequence was best followed by rice-mustard and rice-wheat. Results of the experiment indicated that rice-wheat cropping sequence performed better than rice- mustard, sorghum –wheat, sorghum-mustard and dhaincha wheat cropping sequences in soils irrigated with sodic waters. Gypsum should be applied after 4 to 5 years for sustaining higher yield of crops under sodic water irrigation conditions[16], [17].

Some of the oilseed crops like sunflower, mustard, safflower; linseed, groundnut, soybean and sesamum were tested for their performance on sodic soils. It was observed that mustard, rapeseed and sunflower were moderately tolerant, linseed and groundnut semi-tolerant, while rest oilseed crops were sensitive to alkalinity. Recently it was observed that oilseed crops such as mustard, rapeseed and Indian rape can be grown during rabi season followed by sorghum and pearl millet for fodder in kharif in highly deteriorated sodic soils with the application of gypsum. It was observed that the dry forage yield of sorghum and pearl millet increased with the increasing levels of gypsum but the differences in sorghum forage were not significant beyond application of 50 GR. Sorghum is more tolerant than pearl millet in sodic soil. Pulse crops are most sensitive to sodicity. It was observed that urd bean, lentil, Bengal gram and pigeon pea failed to yield satisfactorily even at low ESP of10 in surface soil. It suggests that these crops require normal soil for satisfactory yields.

Field experiment conducted with sodic water irrigation indicated that rice-wheat cropping sequence performed better than rice-mustard, sorghum -wheat, sorghum -mustard and dhainchawheat cropping sequences. The pH of soil, after the continuous use of sodic water for 8 years without application of gypsum remains unchanged. However, the application of gypsum decreased the soil pH as compared to no gypsum. Gypsum application caused minimum structural deterioration of soil irrigated with sodic water. Gypsum should be applied after 4-5 years for sustaining higher yields of different cropping sequences under sodic water irrigation conditions[18].

Improved Agronomic Practices

In sodic soils, the germination of seed is a very serious problem, poor germination and plant stand can be counterbalanced by avoiding puddling, increased seed rate or plant population, proper age of seedling and date of transplanting, spacing and method of planting etc.

Seedbed Preparation:

In highly sodic soils, owing to dispersed conditions when soil is wet, puddling has not been found useful. Puddling is done to reduce deep percolation loss of water, control weeds and create mallow surface soil for ease in transplanting. Neither of these problems is encountered in early years of reclamation of sodic soils. However, with continuous cropping, the soil will improve and then puddling is required. On drying, the sodic soils become very compact and require more energy to prepare a fine seed bed for sowing of rabi crops. If these soils are not tilled at proper soil moisture, clods are formed. This problem is particularly severe in medium to heavy textured soils[19].

Seed rate and Plant Population:

Due to poor physical conditions of sodic soils, mortality of young seedlings occurs and tillering is reduced. The plants put fewer infrastructures than in normal soils. To counterbalance these effects, it is inevitable to adopt higher seed rate and closer spacing. In case of transplanted crops, seedlings should be raised in normal soils. For transplanting one-hectare rice in sodic soils, 50 kg seed is required to raise the seedlings. In rice, planting of 3-4 seedlings per hill at a spacing of 15cm x15cm or 20cm x15cm has been found optimum. In case of sorghum, pearl millet, cotton, wheat, barley, mustard and other crops about 25% higher seed rate over the recommended seed rate for normal soil is required to ensure good crop stand during the initial years of reclamation.

Time of Sowing and Planting:

Rice transplanting has to be completed by second week of July in case of medium duration cultivars and by the end of July in case of short duration cultivars. Young seedlings of rice are relatively sensitive to sodic conditions; therefore, older seedlings are recommended for transplanting in sodic soils as compared to 25-30 days in case of normal soil. For delayed planting more than 40 days old seedlings should be used for better yields.

Planting pattern and method of sowing:

For best yield, rice needs to be transplanted. In case of crops that grow closely i.e., sorghum, pearl millet, cotton, sugarcane, barley,wheat, and mustard etc., flat sowing by drilling is recommended. In case of forage crops like berseem, shaftal and Lucerne sowing may be accomplished by broadcasting in standing water. In sugarcane, trench method of sowing gave significantly higher yield than the flat sowing in sodic soils due to less concentration of salts in the trenches, which moves to the top of adjoining ridges[20].

Water Management

The water management for crop production in sodic soils / sodic irrigated soils is quite different from that practiced in normal soils because of differences in their physical and chemical properties. The water intake rate of these soils may be as low0.2 cm per day as compared to 12.0 cm per day of normal soils. It is a common observation that on sodic soils, water accumulates following a rainstorm or a heavy irrigation. It remains on the soil surface for long periods until it is evaporated and hardly penetrated few centimeters in the soil profile. During the drying process, particularly in the periods of high atmospheric evaporative demand as in summer months, the soil surface gets dried up very quickly but there is particularly no change in the water content below 15 cm depth. This indicates a very poor upward water flux to replenish the water loss taking place at the surface.

Rice is the principal crop to be grown in sodic soils during kharif season. Being a semi-aquatic plant, rice needs submerged moisture regime for optimum grain yield. High yielding, dwarf rice varieties require only shallow submergence; deeper submergence reduces crop yield. Poor moisture transmission characteristics of these soils help to maintain submerged moisture regime with ease as compared to normal soils. The total irrigation requirement is considerably reduced as compared to normal soils. Results of a field experiment revealed that during lean periods, application of 7 cm irrigation after one day of disappearance of ponded water produced as much grain yield as with continuous submergence and with a saving of 3 irrigations. Moisture stress during grain filling and heading stages is most critical and results in significant reduction in grain yield.During rabi season, wheat, barley, berseem, raya, sugar beet could be grown with success in these problem soils. Wheat, barley and raya cannot tolerate standing water and also relatively wet moisture regime, whereas berseem and sugar beet, will perform better with the later moisture regime. In view of poor moisture transmitting properties of sodic soils, light and frequent irrigations to the crops are desirable[21], [22]. The irrigation intervals for wheat may be of three weeks during November, December and January and two weeks during February and 10 days during March.

DISCUSSION

The use of manures and fertilizers is very important in sodic water irrigated soils. Application of the organic manures, besides adding plant nutrients, brings out improvement in the chemical, physical and biological properties of the soil. Increased crop growth resulting from the addition of manures tends to promote soil aggregation, reduces crust formation and causes rapid increase in the biological activity of the soil.Application of the FYM or compost or green manures also improved soil physical, chemical and biological properties. Amongst the several green manuring crops, dhaincha has been found to be the most efficacious in alkali soils. Field studies revealed that best results were obtained when rice was transplanted immediately after the burial of the dhaincha green manure crop. It was found that green manuring with dhaincha during summer produced rice yield as much as 80 kg N ha^{-1}. Subsequent studies showed that incorporation of 60 days old dhaincha turns about 60 kg N ha^{-1}.Sodic soils are low in organic matter content and hence poor in available nitrogen content. Moreover, transformation of inorganic and organic form is not only slow but also wasteful[23]. Due to these reasons nitrogen deficiency is widespread in sodic soils.

Also a large fraction of applied nitrogen is lost in gaseous form as ammonia under high soil pH conditions. Because of low fertility status of sodic soils, crops suffer from inadequate supply of soil-nitrogen and it needs to be supplemented through chemical fertilizers. Work at CSSRI, Karnal suggests that a given crop sequence on sodic soil generally needs 20-25 % more nitrogenous fertilizers than a normal soil. The optimum dose of rice and wheat in sodic soil have been found to be 150 kg N ha-1 . In case of short duration variety of rice, the optimum dose of nitrogen is about 120 kg N ha-1. The optimum dose for mustard, rapeseed, sorghum and pearl millet was found to be 120 kg N ha-1 in alkali soils.Nitrogenous fertilizers should be applied in split doses to reduce loss of nitrogen in volatilization and denitrification. Results of fertilizer experiments in alkali soil showed that in rice and wheat crops, the optimum nitrogen dose should be applied in 3 doses, half or one-third at transplanting/sowing and remaining in two equal splits at 3 and 6 weeks after transplanting and sowing[24]. In case of medium dose at 80 kg N ha-1, half should be applied at 3 weeks and remaining at 6 weeks of crop age. In other crops, the time and methods of fertilizer application are same, which are recommended for normal soils.

CONCLUSION

Under high soil pH conditions, availability of “P” is more and hence no response in crops to “P” application has been noticed in the early phase of reclamation, but with time, soil is improved and decline in soil pH occurs as a result of which “P” availability decreases. At Karnal, no response to phosphorus application has been reported in rice- wheat cropping system for initial 3-4 years. It was observed that application of 22 kg P ha^{-1} to either or both rice and wheat increased the grain yield of rice and wheat only after 5 and 11 years of cropping, respectively. Probably rice with a shallow root system fails to make use of higher P status of lower soil depths unlike wheat, which is able to tap P from lower depths. Thus, sub-soil fertility plays an important role in P nutrition of crops with deeper root system relative to rice. Application of K has no effect on yield of rice and wheat as well as pearl millet even after 20 years of continuous cropping.Zinc deficiency has been reported in alkali soil and the crop responds favorably to its application. In alkali soils, application of zinc significantly increases the yield of rice and berseem fodder as compared to no zinc application. Basal application of 20-25 kg zinc sulphate ha^{-1} only to rice crop was enough. After 3-4 years when the alkali status is reduced, its application may not be necessary.

Due to excess sodium, the sodic soils / sodic irrigated soils are highly dispersible and prone to spontaneous slaking and surface crust formation after each irrigation or rain. Upon drying, this surface layer becomes very hard. This hard layer puts its pressure on the young seedlings by wrapping their delicate stems. Young seedling cannot bear this pressure and show very poor growth. Apart from this, the hard layer on the soil surface restricts water entry into the soil and disrupts the normal exchange of gases between the soil atmosphere around the root zone and free atmosphere. This unfavorable environment would further restrict growth and development of roots and hence yield will be adversely affected. Therefore, it is recommended that hoeing in sodic soil to break the crust formed after first or second irrigation is essential to get higher yield.From the foregoing discussion, it is inferred that selection of crops and adoption of the package of management practices developed after scientific consideration, can only ensure successful crop production in saline and sodic water irrigated soils. It is only then that the reclamation of salt affected soils may be made more attractive to the farming community. Since the salt affected soils vary considerably in their nature and characteristics, it is imperative that only location specific management practices are developed and adopted.

REFERENCES:

[1] P. Rengasamy and K. A. Olsson, “Irrigation and sodicity,” Aust. J. Soil Res., 1993, doi: 10.1071/SR9930821.

[2] R. A. B. Gonçalves, T. V. Gloaguen, M. V. Folegatti, P. L. Libardi, Y. Lucas, and C. R. Montes, “Pore size distribution in soils irrigated with sodic water and wastewater,” Rev. Bras. Ciência do Solo, 2010, doi: 10.1590/s0100-06832010000300011.

[3] G. Cucci, G. Lacolla, M. Pagliai, and N. Vignozzi, “Effect of reclamation on the structure of silty-clay soils irrigated with saline-sodic waters,” Int. Agrophysics, 2015, doi: 10.1515/intag-2015-0005.

[4] L. Barbiéro, V. Valles, A. Régeard, and C. Cheverry, “Residual alkalinity as tracer to estimate the changes induced by forage cultivation in a non-saline irrigated sodic soil,” Agric. Water Manag., 2001, doi: 10.1016/S0378-3774(00)00124-4.

[5] O. P. Choudhary, J. K. Gill, and Bijay-Singh, “Water-extractable carbon pools and microbial biomass carbon in sodic water-irrigated soils amended with gypsum and organic manures,” Pedosphere, 2013, doi: 10.1016/S1002-0160(12)60083-6.

[6] H. Frenkel, J. O. Goertzen, and J. D. Rhoades, “Effects of Clay Type and Content, Exchangeable Sodium Percentage, and Electrolyte Concentration on Clay Dispersion and Soil Hydraulic Conductivity,” Soil Sci. Soc. Am. J., 1978, doi: 10.2136/sssaj1978.03615995004200010008x.

[7] A. Bannari, A. M. Guedon, A. El-Harti, F. Z. Cherkaoui, and A. El-Ghmari, “Characterization of slightly and moderately saline and sodic soils in irrigated

agricultural land using simulated data of advanced land imaging (EO-1) sensor," Commun. Soil Sci. Plant Anal., 2008, doi: 10.1080/00103620802432717.

[8] P. Sundha, N. Basak, A. K. Rai, R. K. Yadav, and D. K. Sharma, "Utilization of municipal solid waste compost in reclamation of saline-sodic soil irrigated with poor quality water," J. Indian Soc. Soil Sci., 2018, doi: 10.5958/0974-0228.2018.00004.X.

[9] A. Bannari, A. El-Harti, A. M. Guedon, F. Z. Cherkaoui, A. El-Ghmari, and A. Saquaque, "Slight and moderate saline and sodic soils characterization in irrigated agricultural land using multispectral remote Sensing," Int. Arch. Photogramm. Remote Sens. Spat. Inf. Sci., 2013.

[10] A. K. Mandal, "Mapping and characterization of salt-affected and waterlogged soils in the Gangetic plain of central Haryana (India) for reclamation and management," Cogent Geosci., 2016, doi: 10.1080/23312041.2016.1213689.

[11] N. Hussain, A. Ali, M. Salim, and A. R. Nasim, "Management of saline sodic soil irrigated with brackish ground water employing gypsum and soil ripping," Int. J. Agric. Biol., 2000.

[12] D. C. Joshi, T. Toth, and D. Sari, "Spectral reflectance characteristics of na-carbonate irrigated arid secondary sodic soils," Arid L. Res. Manag., 2002, doi: 10.1080/153249802317304459.

[13] O. P. Choudhary, B. S. Ghuman, Bijay-Singh, N. Thuy, and R. J. Buresh, "Effects of long-term use of sodic water irrigation, amendments and crop residues on soil properties and crop yields in rice-wheat cropping system in a calcareous soil," F. Crop. Res., 2011, doi: 10.1016/j.fcr.2011.01.004.

[14] M. Gal, R. Stern, J. Levin, and M. Ben-Hur, "Polymer effect on infiltration and erosion of sodic soils," South African J. Plant Soil, 1992, doi: 10.1080/02571862.1992.10634612.

[15] N. de S. Cavalcanti, M. M. Rolim, J. A. Santos Júnior, M. de F. C. Barros, and E. M. R. Pedrosa, "Gypsum waste to recover saline-sodic soil from irrigated perimeter of the brazilian semiarid," IRRIGA, 2018, doi: 10.15809/irriga.2018v23n3p505-517.

[16] Z. Hussain, R. A. Khattak, M. Irshad, and A. E. Eneji, "Ameliorative effect of potassium sulphate on the growth and chemical composition of wheat (Triticum aestivum L.) in saltaffected soils," J. Soil Sci. Plant Nutr., 2013, doi: 10.4067/S0718-95162013005000032.

[17] E. M. Hafez, W. H. A. El Hassan, I. A. Gaafar, and M. F. Seleiman, "Effect of Gypsum Application and Irrigation Intervals on Clay Saline-Sodic Soil Characterization, Rice Water Use Efficiency, Growth, and Yield," J. Agric. Sci., 2015, doi: 10.5539/jas.v7n12p208.

[18] A. Kumar et al., "Genotypic correlation and path coefficient analysis for yield and yield contributing traits in released varieties of barley (Hordeum vulgare L.) under partially reclaimed saline sodic soil," J. Appl. Nat. Sci., 2017, doi: 10.31018/jans.v9i1.1170.

[19] G. Cucci and G. Lacolla, "Irrigation with saline-sodic water: Effects on two clay soils," Ital. J. Agron., 2013, doi: 10.4081/ija.2013.e13.

[20] S. Hillier and A. L. Pharande, “Contemporary pedogenic formation of palygorskite in irrigation-induced, saline-sodic, shrink-swell soils of Maharashtra, India,” Clays Clay Miner., 2008, doi: 10.1346/CCMN.2008.0560507.

[21] C. Alexandre, T. Borralho, and A. Durão, “Evaluation of salinization and sodification in irrigated areas with limited soil data: Case study in southern Portugal,” Spanish J. Soil Sci., 2018, doi: 10.3232/sjss.2018.v8.n1.07.

[22] P. J. A. Van Asten, J. A. Van ’t Zelfde, S. E. A. T. M. Van Der Zee, and C. Hammecker, “The effect of irrigated rice cropping on the alkalinity of two alkaline rice soils in the Sahel,” Geoderma, 2004, doi: 10.1016/j.geoderma.2003.08.002.

[23] M. Ashraf, S. M. Shahzad, N. Akhtar, M. Imtiaz, and A. Ali, “Salinization/sodification of soil and physiological dynamics of sunflower irrigated with saline–sodic water amending by potassium and farm yard manure,” J. Water Reuse Desalin., 2017, doi: 10.2166/wrd.2016.053.

[24] T. Bhattacharyya, S. K. Ray, P. Chandran, K. Karthikeyan, and D. K. Pal, “Soil quality and fibrous mineral in black soils of Maharashtra,” Curr. Sci., 2018, doi: 10.18520/cs/v115/i3/482-492.

CHAPTER 10

SOLUTIONS FOR SOIL MANAGEMENT IN ALKALI AND SODIC SOILS: AN OVERVIEW

Heejeebu Shanmukha Viswanath, Assistant Professor
College of Agriculture Sciences, TeerthankerMahaveer University, Moradabad, Uttar Pradesh, India
Email Id- shanmukhaviswanath92@gmail.com

ABSTRACT:

India has a 6.74-million-hectare area that is desert because of an excessive salt accumulation. Large areas also produce very low and unprofitable yields as a consequence of varying degrees of salt accumulation. These areas are expected to develop as salinity and water logging worsen due to greater irrigation of canals and significant use of poor groundwater for agriculture in canal and non-canal sectors. Based on the pH, exchangeable sodium percentage, concentration, and composition of soluble salts in the soil, as well as the intended mode of reclamation, these salt-affected soils have been categorized into two primary groups, namely acidic and alkaline soils. soils that are acidic and basic. The 2.4 million ha of alkali/sodic soils in the Indo-Gangetic plains often have low fertility due to their high pH, plenty of soluble and exchangeable Na, higher amounts of $CaCO_3$, negligible to low organic matter concentrations, and unfavorable soil physical properties.

KEYWORDS:

Alkali Soils, Management Solutions, Soil Fertility, Sodic Soils, Soil Reclamation, Soil Salinity.

INTRODUCTION

The goals of maximizing yields and fertilizer use efficiency, maintaining soil productivity, proper environment, and ecological balance can be achieved by balancing the use of inorganic fertilizers and organic sources of nutrients like organic manures like FYM and compost, green manures, and bio-fertilizers. Crop yields are higher when both chemical and organic sources are used than when either chemical or organic sources are used. This is related to enhanced physical, biological, and nutrient supply conditions in the soil. Fertilizers provide the plants quickly available types of nutrients, in contrast to organic manures, which only make a tiny fraction of their total nutrients accessible to plants during the first few weeks after application [1].

Making optimal use of fertilizers:

Fertilizers must be prescribed in the right quantities, at the right times and places, from the right sources, and in the right combinations in order to increase fertilizer use efficiency. Numerous components of good fertilizer management are included in the following list:

Nitrogen:

Alkali soils feature very little organic matter and readily available nitrogen over the whole soil profile. As a consequence, most crops struggle with N supplies. Sodality and high pH are harmful to the conversion of nitrogen [2].

Nitrogen fertilizer effectiveness:

Numerous nitrogen utilization studies have shown that the recovery of fertilizer nitrogen for rice in alkali soils normally ranges from 20 to 40%. Fertilizer N has to be controlled effectively for higher N consumption efficiency. The volatilization losses of applied nitrogen in alkali soil are increased by high amounts of calcium carbonate and high pH/alkalinity. The author discovered that 32 to 52% of applied N evaporated away in alkali soils. The results of an experiment showed that application of ammonium fertilizers directly onto the soil without incorporation resulted in the production of NH_3[3].

Volatilization losses ranged from 10% to 60% of the applied nitrogen fertilizer. In unclaimed alkali soils and in the field moisture range, ammonia losses were higher. Another field investigation showed that ammonia volatilization losses were significantly decreased when FYM or green manuring was employed in combination with urea-N treatment as compared to urea-N application alone. Because the old nitrifying population could effectively oxidize the ammoniacal-N slowly, the usage of green manuring may save around 6% of fertilizer-N. When urea-N was applied with green manuring, the losses of NH3 volatilization were less than when urea-N was applied alone. Rao and Batra also observed lower losses from green manuring compared to urea-N during laboratory incubation studies. Significant decreases in ammonia losses were seen when the second and third half of urea-N were added to the first dose of urea-N given as a baseline therapy. Lower N levels improved plant absorption of NH3-N during second and third split treatments, which explains the benefits [4].

Amount of nitrogen in the fertilizer:

Less than 0.2 percent of the organic carbon in the majority of the salt-affected soils in the Indo-Gangetic alluvial plains is a sign of their low organic matter content. Because these soils often lack nitrogen, crops greatly benefit from the use of nitrogenous fertilizers. The addition of N impacts both rice and wheat in reclaimed sodic soils. The findings obviously suggest that rice and wheat crops respond to nitrogen dosages (150 kg N/ha) that are much higher under sodic soil conditions than is often recommended under normal soil conditions. The crop responses to greater levels of N may be explained by the low intrinsic organic matter quality of these soils, N losses owing to volatilization, and the beneficial influence of N in boosting plant tolerance to increased salt or sodality [5].

Application and timing:

Nitrogen distribution should be timed to coincide with the stage of growth when plants are most in need of this nutrient. The maximum tillering stage is when plants use nitrogen most efficiently, and this is true for both rice and wheat. During the commencement and joining of panicles, rice plants also require N. The most effective application of N was shared between wheat and rice at 42 days following planting. The highest yields of rice and wheat were obtained when N was applied in three equal splits, as a basal fertilizer and at 3 and 6 weeks following transplanting or sowing. On the basis of the aforementioned, it is suggested that in order to increase crop production and fertilizer-N efficiency, one should: i) apply 25% more nitrogen (N) than the doses advised for non-sodic soils, typically adding 120-150 kg N/ha; ii) split N application into three doses, applying 50% as a basal dose, 25% as a top dressing after 21 days, and another 25% after 25 days of transplanting/sowing [6].

Phosphorus:

In normal soils, P is the second-most crucial nutrient required for efficient crop growth after nitrogen. Arid alkali soils, on the other hand, are categorized as having a medium to high available phosphorus status because they have a high degree of accessible phosphorus. Due to their high pH and the presence of soluble carbonates and bicarbonates, these soils produce sodium phosphates that are water-soluble. Research at CSSRI has shown that adding phosphorus to sodic soils has minimal impact in the early years after restoration. Other studies reveal that adding P fertilizer greatly boosts the yields of certain crops even when sodic soils are not always rich in easily available phosphorus. Due to its transport to lower sub-soil layers, absorption by the crop, and enhanced immobilization, Olsen's extractable P of surface soil diminishes when additives are applied to these soils and rice is grown under submerged conditions [7].

Rice, wheat, and pearl millet were grown in a 25-year sequence on an alkali, gypsum-amended soil using NPK fertilizer. The sources of N, P, and K were urea, single super phosphate, and muriate of potash, respectively. Phosphorus applied at a rate of 22 kg P ha^{-1} to either or both rice and wheat crops in rotation resulted in a significant increase in the grain yield of rice once Olsen's extractable P in the first 15 cm of soil had decreased from the initial level of 33.6 kg ha^{-1} to 12.7 kg ha^{-1}, which is very close to the widely used critical soil test value of 11.2 kg P ha-1. Wheat responded to the application of P when the quantity of available P in the soil between 0 and 15 cm fell to around 8.7 kg/ha and was nearly at the critical threshold at the deeper depths. However, the output was unaffected by the addition of phosphorus to either or both crops, even though the quantity of available P reduced to below the critical soil test value in the 0-15 and 15-30 cm soil levels. Pearl millet's grain yield was significantly boosted by the addition of nitrogen alone. Further investigation showed that only rice crops in a rice-wheat cropping cycle responded to sprayed P in the early cropping years, at only 11 kg. The continual application of fertilizer P, green manuring, and FYM to crops has been proven to greatly raise rice and wheat yields and improve the available P status of the alkali soils, according to recent study on integrated nutrient management [8].

Potassium:

The use of K fertilizer on either one or both of the crops had no impact on the yields of wheat or rice. The absence of crop responses to applied K is attributed to the high available K status brought on by the presence of K-bearing minerals and the large contribution of non-exchangeable K to total K absorption by plants in these soils. According to recent studies, rice-wheat systems may stop using K fertilizer without having a detrimental impact on crop productivity or K fertility status. The non-exchangeable K's share of total potassium elimination was around 94.9% in the absence of applied K, but it was reduced to 69.9% when applied K was employed. When K was combined with organic manures, the decrease was around 50.6% [8].

Zinc:

In addition to amendment and nitrogen use, Zn treatment is essential for the optimum crop yields in alkali soils. Despite the high total Zn concentrations found in the majority of alkali soils, accessible Zn is often less than 0.6 ppm. This is due to the high pH, low quantities of organic matter, high levels of soluble P, and high levels of calcium carbonate that limit the solubility of Zn in the calcareous alkali soils. Rice crops usually suffer from soils that are deficient in Zn. The earliest signs of a deficiency brown rusty patches appear 15 to 21 days after transplanting on the third complete leaf. Low grain production, delayed maturity, poor tillering, and stunted growth are all characteristics of the affected plants. Use 10 to 20 kg of zinc sulphate for the highest crop yields [9].

Use fertilizers both organic and inorganic:

The heavy use of chemical fertilizers in cropping systems has caused problems in the economy, environment, and ecology and is detrimental to the sustainability of agriculture. Utilizing organic manures may help manage a cropping system more sustainably. Continuous application of organic and green manures as a crucial source of plant nutrients may undermine the sustainability concept. Therefore, integrating the use of organic manures with chemical fertilizers is essential for the long-term sustainability of cropping systems for rice, wheat, and other crops. 25 years of study on long-term fertilizer trials and other long-term soil fertility tests in the Indo-Gangetic Plains revealed that wheat yields were mostly steady whereas rice yields in rice-wheat systems dropped in the majority of experiments. It is uncertain whether or not this stability in wheat yields would continue in the future since the results of two significant studies conducted by the IRRI's Irrigated Rice Research Program showed declining tendencies in rice-wheat yields. In addition, researchers showed that 8 out of 11 long-term rice-wheat studies that lasted longer than 8 years showed a downward trend in rice yields with time. In contrast, only 3 of 11 wheat samples exhibited a falling trend. The primary cause of unsustainable yields in a rice-wheat cropping system on alkaline soils is nutritional imbalance caused by persistent application of plant nutrients, particularly N alone or in combination with inadequate rates of other nutrients [10], [11].

Green manuring has a troubled past in India. In low intensity agricultural systems, green manuring is straightforward to adopt, but it would be challenging to include green manure crops that are 50 days long in intensive cropping systems. Making green manuring an effective practice requires meticulous planning. In the summer, that is, after the wheat harvest and before transplanting the paddy, the green manure crops in the rice-wheat system may be easily cultivated. In 50 days, Dhaincha green manure could produce 4.2 t ha-1 of dry matter, accumulate 90 kg of nitrogen, 11 kg of phosphorus, and 90 kg of potassium, conserving 60 kg of nitrogen and 11 kg of phosphorus per hectare. The introduction of Sesbania cannabin that was 50 days old created 3.85 Mg ha-1year-1 of biomass, which in turn contributed 110 kg N and 11 kg P/ha/year and significantly boosted the grain yield of rice and wheat, according to another study by Swarup on an alkali soil with gypsum amendment. Sesbania species degraded in a reclaimed sodic soil in less than five days as compared to the typical 10-15 days for non-alkali soils, according to researchers. However, the advantages in alkali soils were bigger when green manure was digested for a week under submerged conditions before rice was transplanted.

The yields of rice and wheat were much greater when chemical fertilizers were used in combination with green manuring, or FYM, than when inorganic fertilizers were applied alone at the necessary dose of 100%, according to recent study on integrated nutrient management. The yield of rice and wheat may be maintained even with lower doses of inorganic fertilizer treatment when used in combination with FYM or Sesbania green manuring. In response to the application of the 100% suggested treatment and its combination use with green manuring or 10 t ha^{-1} FYM and 150% advised treatment, rice yielded 2.98, 4.27, 4.10, and 3.54 t ha^{-1}, respectively. When combined with 10 t FYM/ha of green manuring, the proposed treatment of 100% NPK increased rice production by 60 kg N, 13 kg P, and 21 kg K ha^{-1}. According to these findings, it is more important to utilize a combination of chemical fertilizers, organic manures, including green manures, and crop residue recycling in alkali soils, particularly during the post-reclamation phase, to increase the effectiveness of chemical fertilizers [12].

Integrated Nutrient Management to Maintain Crop Production

Sodic groundwater poses a threat to agricultural output in many arid and semi-arid regions of the world where it serves as the major or only source of irrigation due to its high levels of residual sodium carbonate and high sodium absorption ratio. Lower agricultural yields, major nutrient imbalances/disorders in the irrigated soils and crops, and sodicity and salinity concerns are all consequences of prolonged use of these fluids. In-depth research in diverse agroclimatic zones of the country has led to the development of practical concepts and sustainable irrigation techniques using low-quality water. Solutions for integrated nutrient management that are currently being developed to increase crop yield in salt-affected soils may be useful in regions with high-quality underground irrigation water. However, there is a big problem with growing and sustaining agricultural production, particularly in areas with poor groundwater quality. According to field research, the rice-wheat cropping system will continue to be successful and sustainable in sodic waters provided it is maintained properly [13].

Working of sodic water

Sodic water has a high sodium content as well as a higher carbonate and biocarbonate concentration than calcium and magnesium. Calcium precipitates as calcium carbonate when these fluids are used for irrigation, immobilizing it and raising the pH and exchangeable sodium percentage while oversaturating the soil with sodium. The soil's physical properties are negatively impacted by high sodicity and pH; these effects are most apparent after a rainfall or irrigation event, which causes water to pool and hinder aeration. The notion of cation exchange equilibrium is often used to describe changes in the soil's exchangeable cation composition after irrigation with sodic fluids.

The yields over the years were much higher when NPK fertilizer was mixed with either 10 t ha^{-1} FYM, 5 t ha^{-1} gypsum, or 10 t ha^{-1}pressmud, according to recent study on integrated nutrient management. The residual impacts of FYM, gypsum, and pressmud considerably reduced wheat yields. Adding gypsum together with FYM or pressmud raised both crops' yields even more, although the differences between these treatments 10 t ha^{-1} FYM, 5 t ha^{-1} gypsum, or 10 t ha-1 pressmud alone were not noticeably different. The key factors affecting the fluctuations in rice and wheat yields over time are inconsistent rainfall and its impact on the SAR of the soil. After 10 years of continuous farming with sodic water and the application of inorganic fertilizer, the soil pH and SAR, which were originally 8.6 and 29.0, respectively, were now 8.50 and 18.7. However, compared to treatments using inorganic fertilizers and the control, treatments using the application of gypsum, FYM, and pressmud significantly decreased the soil pH and SAR and increased soil organic carbon as well as available N, P, K, and Zn [14].

According to different research, utilizing N and P fertilizer either alone or in conjunction with organic sources significantly increased rice and wheat yields. The progression for the wheat and rice crops was WRP + SPM > WRP + GM > WRP > WRB. For example, wheat residue burning increased yield by 1.0 to 6.2%, wheat residue plowing increased output by 9.5 to 24.6%, wheat residue with green manure increased production by 16.9 to 25.6%, and wheat residue plus sulphuration press mud increased yield by 16.2 to 27.4%. The findings suggest that in order to increase and maintain the productivity of rice-wheat systems in locations with sodic water, it is required to include wheat residue before 50 days after rice transplanting using green manuring or with sulphuration press mud together with the appropriate quantity of fertilizer. Burning WR, a common practice, was later proved to be ineffective [15].

DISCUSSION

Soils that are sodic or alkaline need fertilizer management that is efficient, balanced, and integrated. For production to continue both during and after reclamation, the following strategies must be used. Farmyard manure, organic waste, and green manuring all help to increase productivity and hasten the restoration process because of the nutrients they contain. As a result, combining the application of chemical and organic amendments is essential. The high soil pH levels associated with sodic conditions have a negative influence on the availability of essential plant nutrients, especially N and Zn [16]. Since these soils are severely lacking in organic matter and nitrogen, it is advised that crops be treated with 25%

additional nitrogen during the first few years after reclamation. It is ideal to use urea to provide nitrogen in two different applications. A baseline dose of urea should be given prior to puddling under pre-submerged conditions to reduce ammonia volatilization losses and increase nitrogen consumption efficiency in rice. It is essential to apply 20 kg of zinc sulphate per hectare of rice during the first few years; afterwards, treatments should be based on soil testing. It is recommended to maintain rice submerged to enhance the ionic environment of the soil and the availability of nutrients, and to keep crops that are not used to wetland conditions well-drained to minimize water stagnation and crop damage. Irrigating often and sparingly may ensure this. If there is temporary waterlogging, adding more nitrogen at the time of the first and second irrigations helps to reduce the N shortage and improve crop growth. Ongoing monitoring of the nutritional state of the soil and the quality of the groundwater is essential in order to provide suitable fertilizer recommendations other than those for N, P, and Zn and to repeat the application of gypsum if necessary [17].

CONCLUSION

Nitrogen continues to be the plant nutrient that restricts growth the most in soils that get irrigation from sodic water. Continuous fertilizer N application significantly boosted the yields of wheat and rice grains when compared to controls. The average yields increased by 72.9% and 53.9%, respectively, for wheat and rice. Phosphorus, second only to nitrogen, limits crop yield from the beginning. The soils' Olsen's P levels vary from low to medium. A 26 kg P ha^{-1} phosphorus application to rice and wheat significantly boosted yields, with mean increases of 0.72 and 0.65 t ha^{-1}, respectively. Soils with sodic water irrigation often have high levels of available K. Both crops received 42 kg ha^{-1} of potassium, but there was no noticeable difference in yields. Integrated use of gypsum or FYM with the recommended NPK dose may improve long-term rice-wheat productivity and soil fertility in areas with sodic ground water. Farmers in the Indo-Gangetic plains have access to press mud, a byproduct of the sugar industry that is also more reasonably priced than gypsum, as an alternate option for efficiently using poor quality groundwater and boosting soil fertility and rice-wheat output. Adding wheat residues 50 days before rice was transplanted either by themselves or in conjunction with GM or SPM improved soil fertility and boosted and sustained rice-wheat yields in the context of sodic water irrigation. There aren't many advantages to burning the remaining wheat.

REFERENCES:

[1] T. Batey, “Soil compaction and soil management - A review,” Soil Use and Management. 2009. doi: 10.1111/j.1475-2743.2009.00236.x.

[2] A. K. Techen and K. Helming, “Pressures on soil functions from soil management in Germany. A foresight review,” Agronomy for Sustainable Development. 2017. doi: 10.1007/s13593-017-0473-3.

[3] T. Vanwalleghem et al., “Impact of historical land use and soil management change on soil erosion and agricultural sustainability during the Anthropocene,” Anthropocene. 2017. doi: 10.1016/j.ancene.2017.01.002.

[4] B. Mátyás et al., “Comparing organic versus conventional soil management on soil respiration,” F1000Research, 2018, doi: 10.12688/f1000research.13852.1.

[5] N. Wang, Y. Gao, Y. Wang, and X. Li, “Adoption of eco-friendly soil-management practices by smallholder farmers in Shandong Province of China,” Soil Sci. Plant Nutr., 2016, doi: 10.1080/00380768.2016.1149779.

[6] L. T. Bennett, P. M. Mele, S. Annett, and S. Kasel, “Examining links between soil management, soil health, and public benefits in agricultural landscapes: An Australian perspective,” Agriculture, Ecosystems and Environment. 2010. doi: 10.1016/j.agee.2010.06.017.

[7] H. Yan, M. Cao, J. Liu, and B. Tao, “Potential and sustainability for carbon sequestration with improved soil management in agricultural soils of China,” Agric. Ecosyst. Environ., 2007, doi: 10.1016/j.agee.2006.11.008.

[8] S. S. Andrews, D. L. Karlen, and C. A. Cambardella, “The Soil Management Assessment Framework,” Soil Sci. Soc. Am. J., 2004, doi: 10.2136/sssaj2004.1945.

[9] F. Kosmowski, “Soil water management practices (terraces) helped to mitigate the 2015 drought in Ethiopia,” Agric. Water Manag., 2018, doi: 10.1016/j.agwat.2018.02.025.

[10] M. Biddoccu, S. Ferraris, A. Pitacco, and E. Cavallo, “Temporal variability of soil management effects on soil hydrological properties, runoff and erosion at the field scale in a hillslope vineyard, North-West Italy,” Soil Tillage Res., 2017, doi: 10.1016/j.still.2016.07.017.

[11] B. Vanlauwe et al., “Looking back and moving forward: 50 years of soil and soil fertility management research in sub-Saharan Africa,” Int. J. Agric. Sustain., 2017, doi: 10.1080/14735903.2017.1393038.

[12] R. Retzlaff et al., “UAS-based multi-angular remote sensing of the effects of soil management strategies on grapevine,” J. Int. des Sci. la Vigne du Vin, 2015, doi: 10.20870/oeno-one.2015.49.2.91.

[13] B. J. Wienhold, D. L. Karlen, S. S. Andrews, and D. E. Stott, “Protocol for indicator scoring in the soil management assessment framework (SMAF),” Renew. Agric. Food Syst., 2009, doi: 10.1017/S1742170509990093.

[14] V. O. Chude and A. C. Odunze, “Priorities for sustainable soil management in Nigeria.,” Nat. & Faune, 2016.

[15] K. Helming et al., “Managing soil functions for a sustainable bioeconomy—Assessment framework and state of the art,” L. Degrad. Dev., 2018, doi: 10.1002/ldr.3066.

[16] G. B. Tesfahunegn, “Soil Quality Indicators Response to Land Use and Soil Management Systems in Northern Ethiopia’s Catchment,” L. Degrad. Dev., 2016, doi: 10.1002/ldr.2245.

[17] S. J. Wheeler and G. J. Pickering, “Optimizing grape quality through soil management practices,” Food, Agric. Environ., 2003.

CHAPTER 11

MANAGING SALINE DRAINAGE WATER FOR SUSTAINABLE AGRICULTURE AND WATER RESOURCE CONSERVATION

Devendra Pal Singh, Assistant Professor
College of Agriculture Sciences, TeerthankerMahaveer University, Moradabad, Uttar Pradesh, India
Email Id- dpsinghevs@gmail.com

ABSTRACT:

Managing saline drainage water for sustainable agriculture and water resource conservation highlights the importance of drainage and irrigation in the production of sustainable food as well as the challenges associated with managing drainage water, preserving water quality, and supplying the increasing demand for water resources. It examines how to handle salinized waterlogged soils, how much water drains, issues with water quality, and the potential for irrigation using drainage water. The abstract emphasizes adequate subsurface drainage, careful planning, crop selection, and insights on best methods for salt management in agricultural systems. In the conclusion, it underlines the need of efficient water resource management in achieving agricultural sustainability over the long term while addressing the problem of scarce water resources globally.

KEYWORDS:

Resource Management, Saline Water, Sustainable Farming, Water Conservation, Water Resources.

INTRODUCTION

For the world's population to get food in a sustainable way, drainage and irrigation are crucial. More than one third of the world's total food crop is produced on an estimated 260 million hectares of irrigated farmland, or around one sixth of all cultivated land. There are concerns with water quality when drainage water is discharged, and there are worries about the long-term sustainability of irrigation and drainage systems. Another problem is land degradation brought on by irrigation-induced salinity and waterlogging [1]. The mechanism for producing food in agriculture still depends heavily on drainage. In humid environments, agricultural drainage is required to remove surplus soil water from the plant root zone. For irrigated crops to effectively manage salt and waterlogging, drainage is essential. If the total benefits of the drainage system are to be increased, drainage water management has to be given more thought. Saline irrigated agriculture offers a plethora of information that may be utilized to make decisions, even though the reuse and disposal of drainage water are relatively new management challenges [2].

However, it's crucial to realize that every drainage site is and always will be unique. Numerous ideas have been put up about the use of drainage water for irrigation. Which method to use depends on the kind of soil, the crops to be watered, the drainage water quality, and agro-climatic factors. Reusing saline drainage water may be more practical in areas where non-salty water is available during the early growing season but is not enough to fulfill agricultural water demands for the complete irrigation season. Dry and semi-arid regions have poor quality groundwater, and there isn't enough fresh canal water to meet the whole region's irrigation demands. In these conditions, reusing salty drainage water may increase crop production [3]. In India's arid and semiarid regions, this presentation illustrates the feasibility of recycling drainage water for irrigation as well as management strategies to support such utilization.

Water Resources Are Limited

Despite being an essential element for the social and economic growth of a community, there simply isn't enough fresh water available to meet the demands of all economic sectors. The bulk of the country's high-quality water resources are now utilized by agriculture, but projections show that these resources will need to be increased in order to satisfy the expanding demands of cities, companies, and energy production, which are predicted to absorb approximately 22% of all available water by 2025 AD. In India, consumptive usage predominates over non-consumptive use, however non-consumptive use is also increasing. Demand for water will increase since the population won't stabilize by 2025. To fulfill the water demand in the future under these circumstances, careful planning that emphasizes water conservation, water recycling, and the reuse of low-quality waters is required. In order to ensure long-term sustainability in agricultural production, water resources in the region must be managed with the least negative influence on the economy and ecology [4].

Saline Waterlogged Soil Management

Two key management strategies for waterlogged saline soils are salt leaching and lowering water levels below the root zone. Leaching generally entails substituting high-quality water or water with less salt for the salty soil solution. The salts displaced during leaching must be eliminated using a subsurface horizontal drainage system if the soil's natural drainage system is impaired. Subsurface drainage has helped restore and conserve irrigated fields in dry and semiarid locations. However, it is challenging to dispose of the drainage fluids created by such systems since there are no natural outlets for them. This problem has limited attempts to use subsurface drainage systems to restore potentially lucrative waterlogged saline areas. To maximize the total benefits of the drainage system, more thought should be given to the management and disposal of drainage water [5].

Amount of Water Drainage

Subsurface return flow is the term used to describe water from irrigation and rainfall that has passed through the crop root zone. Some of this return flow percolates into the groundwater storage zone as it moves laterally along the hydraulic gradient. The subsurface return flow is intercepted and collected by the local subsurface drainage at a certain depth in a shallow groundwater system. The limited quantity of water in the subsurface drainage is only available when the water level is above the drains. However, the depth and spacing of the drains, the depth and methods of irrigation, leaching requirements, the hydrological characteristics of the soil, the volume and duration of rain, the kind of crops, and seepage from neighboring sites all affect the quantity of return flow. The average discharge rates from drains constructed in a 10-ha area of sandy loam saline soil at 1.75 m depth with spacing of 25, 50, and 75 m, for example, were 3.7, 1.1, and 0.9 mm/day, respectively, during the irrigation season, but flow was 8.1, 2.2, and 1.7 mm/day during the monsoon season. In monsoon-type climates in arid and semiarid locations where reclamation rather than aeration is more crucial, there is emerging consensus that drainage rates between 1 and 5 mm could be beneficial. Based on the area drained and the actual drainage discharge rate, the drainage water may be calculated. The drainage water quality in the project area may influence the management decisions that are made [5], [6].

Drainage Water Quality Issues

The kind and concentration of salts in the soil profile, together with the salinity of the groundwater, define the drainage discharge's quality. The salt content of the drainage water fluctuates and progressively rises over time depending on the original salinity levels of the soil and groundwater. Iron, manganese, zinc, boron, and other elements are scarce in these drainage streams. Sampla had a minimal danger of groundwater pollution as a result of nitrate and phosphorus leaching since it lacked phosphate, NH^+, and NO^{--}, N. Drainage system construction, however, could change the local ecosystem. These changes might be beneficial or detrimental. However, in other countries, drainage may have a detrimental effect on the water's quality. The amounts of salt, fertilizer, and other chemicals connected to crops in drainage flow vary with time and with discharge rate. In certain instances, the intensive agricultural production's use of pesticides and fertilizers has caused damage to downstream ecosystems. Drainage designers must thus check the wastewater for nutrients and pesticides. The nutrients that matter the most are N and P. Furthermore, naturally occurring trace elements from the soil itself may sometimes be harmful to the ecosystem. Along with agricultural chemicals and trace elements, drainage water from irrigated areas often contains salts. The potential impact of salts on customers farther downstream must be considered. Large levels of trace elements may be present in certain soils and infiltrate into the drainage system. Trace metals including Cd, Hg, Pb, B, Cr, and Se may be harmful to aquatic creatures in minute amounts due to biological amplification. It is well acknowledged that draining water into the 470 ha Kesterson Reservoir from California's irrigated San Joaquin Valley has adverse environmental impacts [7], [8].

Reusing Drainage Water for Irrigation

Growing disposal problems with saline drainage water and rising demands for high-quality water for other applications have made the practice of reusing salty drainage water for crop cultivation more widespread. Research results have shown the potential for utilising salty drainage water for agricultural growth. It is possible to utilize this water for irrigation in many ways. The sections that follow examine a number of technologically feasible options. Irrigation with mixed drainage water is not viable with higher salinity drainage water. Two different fluids must be combined to produce water suitable for irrigation. The salinity created by mixing should remain within the allowable limits depending on the kind of soil, the crop that will be grown, and the local environment. In order to use the blending process, the water sources must be blended in a controlled way [9].

Sampla was utilized to research mixed drainage water reuse, with a subsurface drainage system installed there at a depth of 1.75 meters. Wheat was irrigated after planting only and only with mixed drainage water of different salinities. With the usage of blended drainage water of 6, 9, 12, and 18.8 dS m-1, the mean relative yields of wheat were 95.8, 90.3, 83.7, and 77.8%, respectively. These yields were determined using the potential yield obtained by utilizing canal water. The experiment's pooled data were used to do piecewise linear regression to see how wheat reacted to the salt drainage water's quality. The study shown that on soils with subsurface drainage systems, 90% of the wheat could be produced using irrigation fluids with substantially higher salinities. The mean relative yield of the following crops of pearl millet and sorghum fodder only decreased significantly in plots where the previous wheat crop had received water with a higher saline level. The mean relative green forage production of sorghum was 80.3 and 70.4%, respectively, under treatments with 12 and 18.8 dS m^{-1}, indicating that it is somewhat less salt tolerant than pearl millet. Our results in a monsoon setting support the notion that both salt-sensitive and salt-tolerant crops may be grown in cycle provided non-saline water is used to irrigate subsequent crops [10].

Utilizing drainage water in a circular or revolving pattern: This technique, also known as sequential application or rotational mode, enables the use of both freshwater and saltwater drainage effluent. In this mode, canal water is switched out for salty drainage water in a predefined cycle or order. The advantage of the cyclic technique is that it prevents the soil profile's salt levels from reaching steady state. Researchers have also supported the seasonal cyclic usage, or "Dual Rotation" technique, where non-saline water is used for salt sensitive crops/the beginning stage of tolerance crops, in order to remove accumulated salts from the irrigation of previously established tolerant crops with salty waters. Although it is often used in monsoon zones, this strategy could be more successful in desert areas with little or no rainfall. In the pearl millet/sorghum/wheat cycle, researchers' tests combined the use of salty drainage water and canal waters, which indicates the practicality of a cyclic use method where canal water was used for pre-plant irrigation. Sorghum and pearl millet crops received no extra watering beyond the monsoon rains that fell during the growing season [11].

A method for reducing drainage volumes may be to encourage the use of water to partly meet agricultural water demands. Subsurface drainage leads to a gradual improvement in the subsoil water quality in drained areas. The first few centimeters of subsoil water had very little salt, which the plants could use by regulating the drainage system's operation. Thus, the water in the soil would provide a fraction of the evapotranspiration needs of plants. Shallow water at 1.0 m with salinity in the range of 3.0 to 5.5 dS m-1 made it simpler to attain potential yield, even when surface water application was reduced to 50%. In certain places, subsurface drainage has been built. There wasn't much salinity that did accumulate, and what little salt there was leached during the next monsoon season. These results imply that maintaining the highest level of water and land productivity may benefit from a drainage system operation strategy that involves intensive operation during the soil reclamation phases and less intensive operation during the later stages simply to satisfy the annual leaching needs.

Best Practices for Managing Saline Drainage Waters

When using salty drainage water for irrigation, a system with rigid criteria will not work since there are numerous conceivable combinations and most management decisions are subjective. Focus must be placed on managing salt balances in the soil-water system, preventing the buildup of salinity, sodicity, and toxic ions in the root zone to the point where they limit soil productivity, and minimizing the adverse effects of salinity on crop growth. The following recommendations are offered:

a) Drainage water analysis:

To determine the drainage water's potential for reuse, standard water sample techniques and analyses should be carried out. The boron concentration, EC, SAR, RSC, and SAR are the most important indicators of water quality. It is also important to look into if the water contains any dangerous contaminants.

b) Replacement crops:

The majority of agricultural crops have varying levels of tolerance for soluble salt concentrations in the root zone. Picking plants or cultivars that will provide respectable yields when irrigated with saline solution is recommended. The levels of tolerance between the least and most susceptible crops vary by 8–10 times. The wide range of tolerance may allow for more frequent exploitation of marginal waters. Crops that need less water and those that are tolerable to semi-tolerable should be grown. For example, following seeding, mustard, a crop that tolerates salt, requires one or two irrigations. High salinity drainage water may be used for mustard post-plant watering, according to Sampla research, without adversely affecting production. The grain yield was greater when it was irrigated with 8 dS/m salinity water as opposed to canal water. Crop yield was considerably influenced positively by the amount of salt input [12].

c) Pre-sowing irrigation:

The period between seed germination and seedling emergence is the most important stage of crop development. Failure at this stage has the effect of weakening the stand and significantly lowering the yield. Pre-sowing irrigation with so high salinity will have very poor germination results. By utilizing canal water for pre-sowing irrigation, it is possible to reduce the risk of irrigation with high salt during later stages of growth.

d) Adequate underground drainage:

Using salty drainage water for irrigation adds salts to the soil with each irrigation. If there is no leaching, salts may gradually accumulate in the root zone over time. Adequate subsurface drainage is essential to permit the draining of accumulated salts from the root zone during the rainy season. The results demonstrated that the critical limits of salty irrigation water would be higher than those reported by the literature for different levels of agricultural output decline under subsurface drainage systems.

e) Moving to a different area:

To enable the sustainable use of salty drainage water for irrigation, the project area may be divided into a number of pieces. Depending on the availability of drainage water, different locations may be selected for irrigation with canal water or drainage water. Irrigate the selected area with salty drainage water for three to four years before moving on to the next one. Through this process, salt accumulation in the lowest layers will be prevented. Utilizing it in the surrounding area may be a possibility if there is a surplus of drainage water in the project zone.

Salt Buildup in the Profile

When using saline drainage effluent for irrigation, the salts in the water would accumulate in the soil. However, if the salt accumulation in the root zone is below the threshold amount for crop salt tolerance, crops will grow normally. Studies that looked at soil salinity revealed that when irrigation water salinity increased, so did the soil profile salinity. The bulk of the salts injected during irrigation were washed out of the soil profile by the monsoon rains, according to observations. There was minimal salt build-up over time. The salinity levels were brought within acceptable limits for the succeeding wheat crop's proper germination as a result of the salt flowing downhill. Under the current conditions, soluble salts were leached by rainwater and a pre-plant irrigation; extra irrigation water was not employed to speed up the leaching of salts. If the monsoon rainfall is insufficient to remove the salts from the profile, a strong pre-plant irrigation with canal water should be applied [13].Salinity profiles that were taken before and after the monsoon rains were used to establish a link between salt removal and downpour depth. The correlations predict that, following irrigation with water with salinities of 6, 9, and 12 dS m-1, respectively, 0.51, 0.76, and 0.92 meters of rainfall will be required for every meter of soil depth to remove 80% of the salts that have accumulated. In order to prevent salt building at the lower depths if, after 5–6 years, certain salts start to accumulate in the subsoil as a consequence of inadequate rainfall, canal water should be used for irrigation for 1–2 years.

Effects on Soil Properties over Time

Numerous studies done in India have shown that many crops may be successfully cultivated for at least 6-7 years using irrigation water that has salt concentrations beyond what is typically suitable without experiencing yield losses. The long-term effects of these treatments are still somewhat unclear. Examples of long-term effects on soil include the accumulation of dangerous substances, soil dispersion, crusting, and decreased water penetration. The quality of the drainage water will have an impact on how well these effects work. In the Sampla drainage project area, six years were spent monitoring the impact of irrigation with high salinity drainage effluent on several soil properties. Using saline drainage water enhanced soil SARe since it had a higher SAR than canal water [14]. Due to salt leaching, monsoon rains reduced SARe, and the remaining SARe levels did not provide an alkali hazard to the following crops. Saturated hydraulic conductivity and water-dispersible clay did not significantly suffer after the monsoon rains. After monsoon leaching, a little decrease in hydraulic conductivity won't pose any problems during the irrigation season since the drainage water's high salinity counteracts the detrimental effects of its high SAR. Water dispersible clay showed little change in soils irrigated with high salinity drainage water after six years of irrigation, suggesting minor structural damage. The author cautions those considering the reuse of drainage water to carefully analyze their particular circumstances first even though there were no potential negative effects found in these testing at Sampla Farm. Utilizing salt-tolerant plants to irrigate low-quality drainage water is an efficient approach to manage it and lessen the need for disposal. Studies show that without causing much soil damage, winter crops may be efficiently watered with saline drainage water of various salinity levels, either alone or in conjunction with canal water by blending or by cyclic utilization [15].

DISCUSSION

In terms of managing agricultural resources, the use of saline drainage water for sustainable agriculture is a problem that is becoming more and more important. Although it is frequently considered trash, saline drainage water offers a chance to solve the escalating issues of water shortage and soil salinity. The main objections to and issues with using saline drainage water for sustainable agriculture are covered in this debate.First, in arid and semi-arid locations where freshwater supplies are few and agricultural water use is on the rise, the technique of recycling salty drainage water has promise[16]. If you adopt the proper management measures, including picking your crops correctly and irrigating your fields, you may use salty drainage water to improve agricultural productivity without diminishing crop yields.Additionally, using saline drainage water might help reduce soil salinity, an issue that is prevalent in many agricultural regions. When used properly, saline drainage water may assist in removing excess salt from the soil, increasing its long-term fertility and lowering the possibility of yield losses brought on by plant stress from salinity.It must be underlined, nonetheless, that the use of saline drainage water for agriculture requires meticulous planning, exact control over water quality, and in-depth knowledge of crop salt tolerance restrictions. Since certain crops can't thrive in salinity, poor management may make the problem of soil salinity worse rather than better.Using saline drainage water for sustainable agriculture may successfully address the problems caused by water shortage and salt in the soil[17], [18]. It can use this resource to promote crop development while also enhancing the long-term health of our agricultural soils if the right management practices are used. To ensure that the advantages of saline drainage water are achieved without having a negative impact on agricultural output and the environment, meticulous planning and ongoing monitoring are necessary.

CONCLUSION

In conclusion, using saline drainage water for sustainable agriculture has a lot of potential for resolving some of the most urgent issues facing the industry today. The effective management of salty drainage water appears as a useful resource-saving method as global water resources grow more limited and soil salinity continues to harm agricultural output.It is feasible to use saline drainage water to boost agricultural output while at the same time reducing problems with soil salinity by carefully applying strategies including crop selection, regulated irrigation techniques, and subsurface drainage systems. This strategy promotes the long-term fertility and health of agricultural soils in addition to aiding in the conservation of freshwater supplies.But it's crucial to approach the usage of saline drainage water with a thorough grasp of its makeup and its effects on certain crops. Poor management may have unforeseen effects since not all crops are equally adapted to saline environments. Therefore, for the effective integration of saline drainage water into sustainable agriculture, thorough planning, continual monitoring, and the implementation of best practices are essential.The appropriate use of saline drainage water is a significant step toward guaranteeing food security and environmental protection in the years to come, especially in light of the developing water shortage and the need for sustainable agricultural methods. We can improve this strategy even further and build a more resilient and sustainable agricultural future through ongoing research and innovation.

REFERENCES:

[1] W. Liu et al., “Water resources conservation and nitrogen pollution reduction under global food trade and agricultural intensification,” Sci. Total Environ., 2018, doi: 10.1016/j.scitotenv.2018.03.306.

[2] G. Halkos and S. Matsiori, “Exploring social attitude and willingness to pay for water resources conservation,” J. Behav. Exp. Econ. , 2014, doi: 10.1016/j.socec.2014.02.006.

[3] Y. Liu, Q. Tao, C. Liang, and Y. Wu, “Research on water resources conservation of mountain river based on the concept of region partition,” J. Mt. Sci., 2011, doi: 10.1007/s11629-011-0241-9.

[4] C. Dalin, H. Qiu, N. Hanasaki, D. L. Mauzerall, and I. Rodriguez-Iturbe, “Balancing water resource conservation and food security in China,” Proc. Natl. Acad. Sci. U. S. A., 2015, doi: 10.1073/pnas.1504345112.

[5] C. Asdak and M. Munawir, “Integrated Water Resources Conservation Management for a Sustainable Food Security,” KnE Life Sci., 2017, doi: 10.18502/kls.v2i6.1045.

[6] A. Ahmed, H. Iftikhar, and G. M. Chaudhry, “Water resources and conservation strategy of Pakistan,” in Pakistan Development Review, 2007. doi: 10.30541/v46i4iipp.997-1009.

[7] C. X. Hong and G. W. Moorman, “Plant pathogens in irrigation water: Challenges and opportunities,” Critical Reviews in Plant Sciences. 2005. doi: 10.1080/07352680591005838.

[8] M. L. Calijuri, J. de S. Castro, L. S. Costa, P. P. Assemany, and J. E. M. Alves, “Impact of land use/land cover changes on water quality and hydrological behavior of an agricultural subwatershed,” Environ. Earth Sci., 2015, doi: 10.1007/s12665-015-4550-0.

[9] M. Fan and H. Shibata, “Spatial and temporal analysis of hydrological provision ecosystem services for watershed conservation planning of water resources,” Water Resour. Manag., 2014, doi: 10.1007/s11269-014-0691-2.

[10] D. Maryanto, D. P. Tejo, And B. Barus, "Perencanaan Penggunaan Lahan Berbasis Konservasi Sumber Daya Air Di Sub Das Cisadane Hulu (Landuse Planning Based On Water Resources Conservation In Cisadane Hulu Sub Watershed)," Globe, 2013.

[11] A. Musa, M. Ahmed, and K. Roy, "Utilization and Conservation of Water Resources in Bangladesh," J. Dev. Sustain. Agric., 2007, doi: 10.11178/jdsa.2.35.

[12] J. Li et al., "A space optimization model of water resource conservation forest in Dongting Lake based on improved PSO," Shengtai Xuebao/ Acta Ecol. Sin., 2013, doi: 10.5846/stxb201207281072.

[13] A. Singh, "Decision support for on-farm water management and long-term agricultural sustainability in a semi-arid region of India," J. Hydrol., 2010, doi: 10.1016/j.jhydrol.2010.07.006.

[14] C. A. Vettorazzi and R. A. Valente, "Priority areas for forest restoration aiming at the conservation of water resources," Ecol. Eng., 2016, doi: 10.1016/j.ecoleng.2016.05.069.

[15] F. Bin Alam and A. Hossain, "Conservation of Water Resource in Textile and Apparel Industries," IOSR J. Polym. Text. Eng., 2018.

[16] H. F. Cook, The Protection and Conservation of Water Resources. 2017. doi: 10.1002/9781119334316.

[17] A. K. Pradhananga, M. A. Davenport, and V. Perry, "The influence of beliefs and norms on landowners' civic engagement in water resource protection," J. Soil Water Conserv., 2017, doi: 10.2489/jswc.72.6.639.

[18] W. Hamumpuni and J. A. Rini, "A study on the implementation of water resources conservation technology and domestic wastewater management in the building design of dr. Heinz frick house in semarang and turi house in solo," J. Archit. Res. Des. Stud., 2017, doi: 10.20885/jars.vol1.iss1.art5.

CHAPTER 12

REVITALIZING ARID AND SALINE LANDS FOR AGRICULTURE AND REFORESTATION

Ashutosh Awasthi, Associate Professor
College of Agriculture Sciences, TeerthankerMahaveer University, Moradabad, Uttar Pradesh, India
Email Id- ashuaw@yahoo.in

ABSTRACT:

Revitalizing arid and saline lands for agriculture and reforestation explores the pressing challenges posed by waterlogged, saline, and arid regions encompassing vast areas of land in certain countries. This article delves into the myriad issues that plague these regions, exacerbated by both natural processes and human activities. With approximately 175 million hectares of land affected by various water and land-related problems, the need to optimize existing land resources becomes paramount.The text underscores the critical importance of developing sustainable strategies to utilize these otherwise unproductive wastelands to meet the growing demands for food, fodder, and fuel. Highlighting the dire consequences of soil salinity and alkalinity, the article presents evidence of their devastating effects on agriculture, particularly in regions like India. Moreover, it emphasizes the need for prudent water management in regions where water scarcity is a persistent challenge.To address these complex issues, the article advocates for alternative land use systems, including the cultivation of salt-tolerant plants and the introduction of non-traditional medicinal and aromatic species. Furthermore, it explores the potential of agroforestry as a means to harness the productivity of arid and saline lands, offering insights into tree species that thrive in these challenging conditions.

KEYWORDS:

Reforestation, Saline Soils, Sustainable Farming, Water Management, Wasteland Utilization, Soil Rehabilitation.

INTRODUCTION

Around 175 million ha of the country's 329 million ha of land are impacted by different water and land-related problems, and the problem areas are exacerbated by either natural or anthropogenic processes. These areas are categorized as wastelands because the bulk of the affected lands have low productivity as a consequence of soil-based issues such waterlogging, salinity, sodicity, shallowness, and sand, stony, or gravelly soil. Since there are no new land resources available for horizontal growth of agriculture, must discover workable strategies for utilizing existing land resources, particularly wastelands, in order to meet future needs for food, fodder, and fuel[1]. Significant tracts of land in the country's semiarid and desert regions are affected by waterlogging and salinity, and as a consequence, agricultural productivity is declining at an alarming rate. The author claims that soil salinity and alkalinity have devastated 8.6 million acres of land in India. These areas are devoid of all vegetation, except for a few hardy tree and grass species as Salvadorapersica, Capparis decidua, ProsopisJuli flora, Acacia nilotica, Desmostachyabipinnata, Sporobolus spp., Kochia indica, and Suaeda maritime.

Furthermore, the desertification of saline places is facilitated by the poor quality of the groundwater. Around 10% of the state of Haryana, which is mostly an agricultural state, has already suffered waterlogging, which has reduced crop production and forced farmers to quit their fields. Nearly 50% of the state is impacted by rising water levels and salt concerns[2].

In semiarid regions, only two-thirds of the overall water need is fulfilled, but only one-third of the total water need is supplied in arid zones. One may imagine a water scarcity in arid areas. The dry zone covers a relatively small area, including portions of Rajasthan, Gujarat, Andhra Pradesh, Punjab, Haryana, Karnataka, and Maharashtra. It accounts for 37.6% of the overall geographic area, which is dispersed throughout 10 states. The amount of rain that falls in desert regions varies greatly, from less than 100 mm in westernmost India to 150 mm. High evaporation in contrast to little rainfall causes severe aridity.The arid and semiarid regions are characterized by a number of restrictions, such as soils' susceptibility to wind erosion, weather anomalies, salinity/sodicity in soil and groundwater, low water retention capacity, high infiltration rate, poor soil structure and crusting, low organic matter, soils' inability to buffer nutrient levels, and frequent droughts. Water is scarce in desert regions, and only around 4% of the land can be irrigated. Therefore, in order to optimize productivity per available drop of water, we must acknowledge this and alter the agricultural pattern[3].

Since utilizing salty or poor-quality water is unavoidable, care must be taken while using it to preserve the soil's health. The optimum option for such places in this circumstance is an alternative land use system that includes forages, non-traditional medicinal and aromatic plants that need less water, as well as forest and fruit trees. This approach will help preserve biodiversity, improve the general environment, and prevent the rural poor's nomad way of life from relocating in addition to sustaining production.

Developing strategies for agriculture based on fruit and forests

For agricultural output, the majority of dry regions depend on the erratic monsoon rains, and drought is a common occurrence. Agroforestry methods may be used to efficiently cover these lands. Khejri, Ber, and Kikar have long been produced in the fields by farmers in dry regions. It has been shown that Khejri trees provide life to dry surroundings, supporting the generally held belief that they increase agricultural productivity. It takes a long time for this tree to provide adequate feed and fuel, despite the fact that it is often used in modern agroforestry systems in arid regions. There are several more multipurpose trees that are compatible with agriculture.Arid regions often have sodic and saline fields. They may be placed under the right fruit and forest trees with minimum irrigation. In order to identify suitable forest and fruit tree species for the rehabilitation of extremely alkali soils in semiarid regions, long-term studies were conducted on 30 forest tree species, 15 Prosopis strains, and 10 fruit tree species. Seven years of seeding resulted in just 13 species remaining.

It was discovered that the Prosopisjuliflora species that flourish in these circumstances include Tamarixarticulata and Acacia nilotica[4]. Eucalyptus tereticornis showed great survival and plant height but did not yield any significant quantities of biomass. Despite having survival rates of more than 70%, Cordiarothii, Kigeliainnata, Parkinsoniaaculeata, Pithecellobiumdulce, Terminalia arjuna, and Dalbergiasissoo failed to generate enough biomass to be economically viable. Changes in soil parameters under three successful species showed that Tamarixarticulata improved the soil with the largest drop in ESP and pH values in seven years. Next followed Prosopisjuliflora and Acacia nilotica. The growth was rather small at deeper levels, but under T. articulata, P. juliflora, and A. nilotica plantations, it rose by 0.23%, 0.26%, and 0.10%, respectively, in the top 15 cm layer. ESP was decreased by 50 in T. articulata, 33 in P. juliflora, and 20 in A. nilotica in the top 15 cm of depth. When this site was walled in, a natural grass community dominated by Sporobolusmarginatus emerged, and it helped to ameliorate the soil, which was substantially the same in all plantings during the first three years of the study. Later, the grass underneath the tree canopies started to vanish. One of the 15 Prosopis strains, P. juliflora, was the most effective species in terms of growth and biomass production after six years of culture. Fruit tree species that did well on these soils were Ziziphusmauritiana, Syzygiumcuminii, Psidiumguajava, Emblicaofficinalis, and Carissa carandus[5]. Neutral soluble salts, especially sodium, magnesium, and calcium chlorides and sulphates, are present in excess in saline soils, which is detrimental to plant growth. The water-saturated paste extract of these soils has an electrical conductivity of at least 4 dS m-1 and a pH below 8.2. Subsurface drainage is the sole practical strategy for recovering these soils, however it is exceedingly costly and impractical without government funding. Therefore, cultivating salt-tolerant plants and commodities remains the greatest option for rehabilitating these regions. Reforestation efforts for salty, wet soils must employ the appropriate tree species and planting technique. Since the main problems with these soils are: high water table, high salt content of soil and subsurface water, hampered drainage, and restricted soil aeration for tree growth, tree species should be ones that can tolerate these many stresses[6].

In order to properly afforest heavily salinized, moist soils, it is equally important to use the proper planting method. It has been shown that the furrow planting technique enables the maintenance of relatively low salinity levels in the rooting zone of tree seedlings, enabling them to escape the harmful effects of excessive salinity. The most promising tree species are Acacia farnesiana, Parkinsoniaaculeata, Prosopisjuliflora, Salvadorapersica, S. oleoides, and Tamarixarticulata. All of these species have the potential to thrive when planted in saline, moist soils with an ECe value greater than 25 dS m-1 in their active root zone. Tree species including Acacia nilotica, Acacia tortilis, Casuarina glauca, and Casuarina obesa were discovered to be moderately tolerant. The experimental findings demonstrated that furrow planting considerably boosted the survival and growth of tree species when compared to subsurface and ridge-trench planting methods. Prosopisjuliflora and C. glauca had the highest biomass when planted using subsurface or furrow techniques, followed by Acacia nilotica and A. tortilis, showing that these species are suitable for salty, wet soils.

Plantations for forestry and horticulture may be grown using salted water

Arable crops are being grown in the majority of productive locations that have access to high-quality irrigation water. In dry and semi-arid areas, when there is only salty groundwater available for irrigation, farming agricultural crops is economically unviable. 31 tree species from the very calcareous soil of Hisar were evaluated for saline irrigation in one experiment. A number of interesting tree species were discovered, according to the research, including Acacia nilotica, Acacia tortilis, Acacia farnesiana, Azadirachtaindica, Eucalyptus tereticornis, Pithellobiumdulce, Prosopisjuliflora, P. cineraria, Tamarixarticulata, and Feronia limonia.

In another field experiment conducted at the same site, seven understudied species of economic significance were developed in furrows utilizing saline water. The results showed that all seven species performed well up to water with an EC of 12 dS m^{-1}. The salt content of the soil grew very little in the furrows compared to the spaces between the two[7].

a) Everywhere there is some water, fruit trees like Carissa carandus, Emplicaofficinalis, and Ziziphusmaurtiana may be found.

b) Feronia limonia and Aegle mamelos may grow in wider rows, and other low-water-use crops including barley, mustard, taramira, dill, cluster beans, and pearl millet can be intercropped well.

Plantations in Specific Situations

Balanitesroxburghii, Calligonumpolygonoides, Colophospermum mopane, Dichrostachyacinerea, Acacia tortilis, Acacia senegal, Acacia farnesiana, Acacia jacquemontii, Acacia radiana, Anogeissuslatifolia, Acacia pendula, Prosopis cineraria, P. juliflora, and These plants and grasses might help with forage production and sand dune stability. Along with the aforementioned grasses, semi-established sand dunes benefit from the presence of trees including Acacia salicina, Acacia nilotica, Azadirachtaindica, Eucalyptus camaldulensis, E. tereticornis, Cassia siamea, Albizialebbeck, Cordiarothii, Tamarixarticulata, and Parkinsoniaaculeata.

In an unstable and unpredictable climate with recurrent droughts, the notion of "Fodder Banks" is suitable. To satisfy requirements during the lean season, it comprises the development of blocks of fodder trees coupled with grasses and legumes, storage of dry fodder, hay production, bailing/densification, and transportation of fodder[8].Mehta reported that in a field study on gypsiferous and impeded soils of arid regions where underground waters were highly saline and could not be used for growing crops, kinnow, ber, and guava &aonla fruit plantations were successful with the dilution of rain water stored in a concrete tank and the adoption of drip irrigation system.The results show that low water-requirement saline conditions are capable of supporting the growth of salt-tolerant fruit and forest plantings. For this project to be successful, it is essential to develop appropriate management systems for their economic research and to form a network with other organizations interested in bio saline agriculture[9].

The limited water and land resources in developing countries could not keep up with the rising population due to the fast population expansion. Irrigation is being increased to bring more land in dry and semiarid regions into production, although this often leads to waterlogging and soil salinization. In many parts of the world, salinization is reducing the quantity of land that can be utilized for conventional agriculture. As a consequence of the world's population growth and efforts to feed itself from poor quality water and land, there is a rising need for crops that can survive salt.In dry and semiarid regions with limited rainfall, salty soils, a lack of quality surface water, and brackish groundwater, growing conventional crops may be difficult. For instance, a groundwater quality evaluation conducted in India found that 32 to 84% of the country's total groundwater irrigation potential, mainly in the states of Rajasthan, Haryana, and Punjab, is made up of water of poor quality. Low water quality may be best used by growing plant species with aromatic and medicinal properties. One option for increasing agricultural production, even for crop diversity, is the cultivation of non-traditional crops[10].Due to the opening of the global market, it is anticipated that the trade in aromatic and herbal medicines would be valued Rs. 600 crores yearly in India. It is necessary to increase the supply of these products in order to meet local demand and create international revenue. The main problem is conserving rich areas for the development of these goods given the need to generate more food, fiber, fodder, and other agricultural commodities. It could be possible to use these crops on soils impacted by salt and other cultivable wastelands.

Important Medicinal Plants for the Economy

In Ayurvedic medicine, Cassia angustifoliacommonly referred to as Indian sennais known as sanai. The plant is successfully cultivated on more than 25,000 acres of irrigated and rainfed land in Tamil Nadu, Andhra Pradesh, Maharashtra, Rajasthan, Gujarat, Karnataka, West Bengal, and Tripura. India is the country that produces and exports the most senna leaves, pods, and sennoside concentrate to the global market. At the moment, its export brings in around Rs 300 million per year. It is an erect, perennial shrub that is between 0.6 and 1.0 meters tall. Flowers have a vibrant yellow color. Senna leaves and pods contain anthraquinone glycosides, often known as sennosides, which have laxative effects. At 0.33%, B-sitosterol is also detected[11]. Traditional medicine uses an infusion of the leaves as a laxative in the form of tea, but modern medicine uses it as calcium sennoside. Senna is a deeply rooted, hardy plant that is often produced as a rainfed crop and does well in warm, dry regions. A single or two irrigations are required to preserve life during drought years. The crop's low water need and salt tolerance were investigated over the course of three years of pot culture, microplot, and field experiments on sandy loam calcareous soils. The results demonstrated that when plants were irrigated with saline waters with ECiw up to 10.0 dS/m rather than fresh water, plant productivity and the amount of active medicinal component increased. Sennoside concentration was 37% greater under salt stress than under control conditions at moderate salinity levels[12]. Salinity in irrigation water up to 8.0 dS/m exhibited no detrimental impact on plant quality or development. Sennoside levels were also found to be greater in young leaves than in mature leaves, in leaves than in pods, and in green pods than in ripe pods, according to the research. Rainfed crops were shown to have a greater sennoside proportion than irrigated crops. provide quality satisfies both Indian and British Pharmacopia criteria, which indicates it might provide good foreign currency. Currently, senna leaves cost Rs. 35/kg on the wholesale market in India. Senna's cathartic properties may persist for up to five years when kept in tightly closed containers[13], [14].

DISCUSSION

In this section the author discussed about the revitalizing arid and saline lands for agriculture and reforestation touches on a number of significant problems and potential solutions. In these challenging circumstances, it is essential to use sustainable techniques to utilize the land efficiently.Due to the little rainfall and high evaporation rates in desert locations, traditional agriculture is greatly affected. Because of the erratic monsoon rains in these areas, dry conditions often occur, drastically limiting agricultural productivity. The employment of agroforestry methods turns out to be a workable fix for this issue.

Agroforestry, which combines tree growth with traditional agriculture, has the potential to strengthen the resilience of these places by providing shade, retaining soil moisture, and enhancing soil fertility. The choice of suitable tree species becomes crucial since they must not only endure in arid situations but also provide valuable items like feed, timber, and unusual medicinal plants.However, saline locations provide particular challenges. Excessive salts, particularly sodium, magnesium, and calcium chlorides and sulfates, obstruct plant growth and reduce soil productivity.

To solve this issue, creative replanting methods and the use of appropriate tree species that can last in saline soils are needed. Furthermore, using certain planting techniques like furrow planting aids in lowering the salt levels around tree roots, boosting the growth and development of those roots. Regarding the production of biomass and the survival of trees, this technique has shown potential.Water management in these locations is necessary because of the paucity of this vital resource. In areas where water scarcity is a recurring problem, it is vital to investigate alternative sources of water for irrigation, including the use of saline groundwater. Selecting tree and agricultural species that can withstand various water sources without reducing production is necessary for this approach. Scientific research has shown the effectiveness of saline irrigation of several tree species, opening up new prospects for sustainable agriculture. The rebuilding of dry and saline lands for agriculture and forestry is a complicated problem that calls for creative and long-lasting solutions. These dry areas have a great deal of potential to be transformed into usable and sustainable resources via the use of agroforestry, careful species selection, improved planting techniques, and saline water resources. Such programs help environmental preservation and climate change resistance in addition to improving food security and economic opportunities.

CONCLUSION

Consequently, efforts to resurrect dry and salty areas for agriculture and forestry are not only vital, but they also hold the key to solve some of the most pressing issues of our day. These challenging conditions, which are often characterized by water scarcity, soil salinity, and aridity, have long been thought to be unsuited for traditional farming. However, there is cause for hope when we take a closer look at original concepts and environmentally friendly techniques. Agroforestry offers a practical solution to transform arid places into productive landscapes because of its ability to improve soil fertility, save water, and create high-value items. Carefully selecting tree species that can thrive in these conditions and sustain local economies and ecosystems is crucial. Additionally, we can reduce the detrimental effects of soil salinity and promote tree growth by using effective planting techniques like furrow planting. Although it was formerly believed that using saline water sources would be challenging, this is now seen as an opportunity. Thanks to the ability of certain tree species and crops to thrive when irrigated with saline water, there are now greater prospects for sustainable agriculture in locations with limited access to freshwater. This program to rehabilitate dry and salty areas seeks to enhance environmental resilience and climate adaptation in addition to attending to immediate agricultural needs. It attempts to save biodiversity, improve soil health, and prevent the eviction of rural inhabitants. Adopting these cutting-edge techniques helps us promote the more general goals of sustainable development and environmental preservation in addition to improving food security and economic opportunities. In essence, the regeneration of salty and arid landscapes is a testimony to our ingenuity and our ability to solve problems in the most difficult situations. It highlights the value of resource management that is informed, sustainable land management, and our shared responsibility to build a more resilient and flourishing future. As we continue to investigate and use these solutions, we are coming closer to a day when dry and saline places don't represent challenges but rather opportunities for growth, prosperity, and sustainability.

REFERENCES:

[1] W. Fialkiewicz et al., “Simplified direct water footprint model to support urban water management,” Water (Switzerland), 2018, doi: 10.3390/w10050630.

[2] A. K. Pradhananga and M. A. Davenport, “Community attachment, beliefs and residents’ civic engagement in stormwater management,” Landsc. Urban Plan., 2017, doi: 10.1016/j.landurbplan.2017.10.001.

[3] S. N. Poudel, “Tinau River Conservation and Integrated Water Resource Management,” Hydro Nepal J. Water, Energy Environ., 2012, doi: 10.3126/hn.v10i0.7099.

[4] X. Tang, Y. Jin, C. Feng, and B. C. McLellan, “Optimizing the energy and water conservation synergy in China: 2007–2012,” J. Clean. Prod., 2018, doi: 10.1016/j.jclepro.2017.11.100.

[5] Y. Li and M. A. Urban, “Water resource variability and climate change,” Water (Switzerland). 2016. doi: 10.3390/w8080348.

[6] M. Dou, J. X. Ma, G. Q. Li, and Q. T. Zuo, “Measurement and assessment of water resources carrying capacity in Henan Province, China,” Water Sci. Eng., 2015, doi: 10.1016/j.wse.2015.04.007.

[7] A. Goonetilleke and M. Vithanage, “Water resources management: Innovation and challenges in a changing world,” Water (Switzerland). 2017. doi: 10.3390/w9040281.

[8] L. Lebel, P. Garden, and M. Imamura, "The politics of scale, position, and place in the governance of water resources in the Mekong region," Ecol. Soc., 2005, doi: 10.5751/ES-01543-100218.

[9] A. Montanari et al., "Fifty years of Water Resources Research: Legacy and perspectives for the science of hydrology," Water Resour. Res., 2015, doi: 10.1002/2015WR017998.

[10] I. Monney and K. Ocloo, "Towards sustainable utilisation of water resources: A comprehensive analysis of Ghana's National Water Policy," Water Policy, 2017, doi: 10.2166/wp.2017.114.

[11] I. a. Shiklomanov, "World Water Resources. A new appraisal and assessment for the 21st century.," United Nations Educ. Sci. Cult. Organ., 1998.

[12] B. G. Rahm and S. J. Riha, "Toward strategic management of shale gas development: Regional, collective impacts on water resources," Environ. Sci. Policy, 2012, doi: 10.1016/j.envsci.2011.12.004.

[13] Y. Sun, N. Liu, J. Shang, and J. Zhang, "Sustainable utilization of water resources in China: A system dynamics model," J. Clean. Prod., 2017, doi: 10.1016/j.jclepro.2016.07.110.

[14] J. K. Domen, W. T. Stringfellow, M. K. Camarillo, and S. Gulati, "Fog water as an alternative and sustainable water resource," Clean Technologies and Environmental Policy. 2014. doi: 10.1007/s10098-013-0645-z.

CHAPTER 13

OPTIMIZING WATER MANAGEMENT STRATEGIES FOR SUSTAINABLE CROP PRODUCTION IN WATER-SCARCE ENVIRONMENTS

Kusum Farswan, Assistant Professor
College of Agriculture Sciences, TeerthankerMahaveer University, Moradabad, Uttar Pradesh, India
Email Id- kusumfarswan.14feb@gmail.com

ABSTRACT:

The most fundamental and necessary element for human existence is water. The existence of society and the advancement of civilizations have depended heavily on the effective management of water resources. There is now only 47196 km3 of water available annually on Earth. This little supply is inadequate to meet both the quickly expanding urban and industrial sectors as well as the continually increasing need for food production. The shortage is more obvious in densely populated emerging countries. However, shortage and excessive use are the two uneven aspects of water resources over the world. Water is one of the most important ecological factors that affects crop growth and development. Water scarcity has a significant negative impact on agriculture production, and agricultural yields are significantly impacted. Decisions regarding whether to irrigate are determined by soil, crop, water, and weather variables. Water use is particularly site-specific.

KEYWORDS:

Crop Production, Sustainable Agriculture, Water Management, Water Scarcity, Irrigation Optimization.

INRODUCTION

Crop yields and water consumption efficiency may be maximized by planning irrigations at the appropriate depth when drainage losses and unproductive evapotranspiration are kept to a minimum. Planning irrigation involves making decisions on how to divide the water among the many crops grown in a field. Reduce the quantity of water purposefully utilized without materially lowering crop output is the aim of irrigation optimization utilizing deficit irrigation. The method is sometimes referred to as controlled deficit irrigation, limited irrigation, and partial irrigation. Decreased irrigation depth, irrigating only a portion of the root zone, such as in alternating or widely separated furrows, or eliminating the least effective irrigations in each crop are some of the ways deficit irrigation can increase water consumption efficiency[1]. At different phases of crop development, soil water deficits are required to improve drought tolerance and the distribution of photosynthates in tissues and organs. For instance, researchers discovered that when irrigation was lowered by 30-60 mm during the jointing stage, wheat grain output improved by around 20-45% under identical climatic circumstances.In order to fully utilize these strategies, it is important to focus on water-efficient irrigation strategies such as creating crop genotypes that require less water, employing effective irrigation methods like drip and sprinkler, creating crop patterns that require less water, scheduling irrigation that includes deficit irrigation, and using low-quality water and water harvesting[2].

Crop Production Methods in a Water-Scarce Environment

Yield per acre is a traditional measure of agricultural production. The resource that is most scarce, though, is water. The concept of productivity per unit of water has grown significant due to the challenge of producing more with less water. A farmer with a restricted supply of water may benefit from strategies to increase water productivity in terms of increased income and better nutrition. For example, irrigation of crops during crucial growth stages, irrigation of a specific area of the crop root zone, and allowing more depletion of the available soil moisture are all potential strategies that can be useful for raising the productivity of water and landirrigation methods that are effective and watering crops that can resist it[3].

When there is a water scarcity, the best solutions for water conservation should be the adoption of drought-resistant crops and the use of efficient irrigation methods like drip and sprinkler systems. During the kharif season, crops including safflower, sorghum, pearl millet, cotton, and cluster beans are planted in addition to gram, lentil, barley, mustard, and Eruca sp. and wheat during rabi. The proper crops/cultivars and crop plans, as well as other engineering and agronomic tasks like sufficient water conveyance, adequate land leveling and grading, weed control, optimal fertilizer, and plant protection measures, must be carried out in order to achieve high productivity and reduce water losses. Crop plans that optimize net profit per unit of water and land are developed taking into account a farmer's ability to use other inputs to their fullest potential and the agro-climatic conditions. In semi-arid regions of north-west India, crop patterns such as pearl millet-Eruca-sunflower, pearl millet-mustard, pearl millet-mustard/toria-sunflower, cluster bean-wheat, cowpea-pearl millet-wheat, moog bean-pearl millet-wheat, and cotton-wheat are much more tolerant and productive. Although interplanting cowpea or moong bean with pearl millet, a crucial kharif crop, might boost the yields of grain or fodder, respectively. During the rabi season, eruca sp., mustard, and chickpeas may be good meals. The risk of a single crop failing due to a disease, bug, or other hardship is decreased by growing many crops in a particular area. In addition to arable crops, growing less water-intensive horticultural crops like ber, guava, and aonla might be a lucrative option[4].

The critical growth stage is approaching

Another way to save water is to just use irrigation at a certain stage of a crop's growth. Moisture stress affects crops differently depending on where they are in their growth. For determinate crops, the seedling and flowering stages are critical. At critical periods, crops must be watered because without it, yields might be drastically reduced. The depth of irrigation is based on the soil's capacity to hold water and is done in line with the crop's critical stages. Here, irrigations are scheduled to limit nonproductive evapotranspiration and drainage losses and coincide with the least sensitive growth stage in order to optimize crop yields and water consumption efficiency. This strategy is suggested when the soil's capacity to hold water is more than 200 mm per metre of soil depth and the soil depth is greater than 1 meter. Important growth stages are the most practical times to schedule irrigation since farmers, irrigation authorities, and agricultural officials are aware of these times and can arrange irrigation in accordance with them without the use of any tools or databases. The crucial stages of many crops' growth, when they occur, and how water stress impacts them. Regarding the use of this method, it boosts overall yield while using less irrigation water by providing deficit irrigation across a bigger region[5].

The two periods of the five critical stages of growth for wheat and barley that need watering most urgently are crown root initiation and blossoming. Insufficient water intake throughout the pre-flowering, blooming, and early pod formation periods in gram has a similar impact on growth and yield. In the case of mustard, at the three crucial times for water stress, flowering and pod filling are essential. The three most crucial stages in cotton irrigation are square formation, flowering, and boll growth. Sunflowers go through four important periods of growth, but the highest yield may be obtained by irrigating the plant during the seedling, flowering, and grain-filling phases. Groundnuts go through four critical stages of growth, and irrigation is necessary during the blossoming and pegging processes. In terms of water stress, the seedling and blooming periods are the most important, followed by the reproductive primordial, flowering, and grain filling phases. The heading phase of pearl millet is shown to be the most crucial for coping with water stress out of the three sensitive periods[6].

Inadequate irrigation of the crop's root zone or irrigation to a single location

The rate at which any crop is evaporating soil water determines the interval between two irrigations. The root zone is often started on irrigation after losing 50% of its water supply. Intervals are kept shorter in sandy soils during the summer compared to winter and clay soils. Planning irrigation may assist establish the best irrigation depth and schedule to maximize agricultural results. It comprises improving irrigation efficiency while decreasing runoff and deep percolation. A soil-crop-climate strategy, soil water monitoring, or climatic techniques may all be used as bases for scheduling irrigation[7].

Wheat was treated to two-degree regulated water deficits, soil moisture depletion, and no water deficit throughout different periods. up to jointing, which comes after booting, heading, heading, grain filling, and maturity. Wheat yield, biomass, yield characteristics, and water use efficiency under treatment SNNM, MNNS, and MNNM were better than no stress. Roots that are substantially deeper may help plants utilise the water stored in deeper soil layers more effectively under controlled water shortages, leading to higher wheat yields and more efficient water use. Pearl millet can be viewed as a suitable forage crop for water stress because scheduling irrigation at 75% of the soil's available moisture had no negative effects on the quantity and the majority of the quality traits of dry forage, and water-use efficiency increased with higher levels of water stress.The timing of irrigations based on the leaf water potential at which photosynthesis starts to fall is a key component of deficit irrigation. Critical leaf water potentials for the relative photosynthetic activities of many crops, as estimated by different studies. It has also been shown that the majority of drought-tolerant crops can maintain 75% of their photosynthetic efficiency with only 50% of the irrigation water that is advised for them[7], [8].

Partial Drying of the Root Zone

Here, the biochemical responses of plants to water stress are used to create a balance between vegetative and reproductive development. There was no noticeable yield reduction brought on by PRD even when the vines were only given half of the necessary watering. When soil water availability declines when irrigation stops, abscisic acid is created in the drying roots and transported to the leaves in the transpiration stream. As a consequence, stomata respond by shutting their aperture, therefore reducing water loss. Because the drop-in photosynthetic activity was proportionately less than the water loss, partial stomatal closure boosts WUE. Early attempts to let a piece of the vine root system dry while keeping the remainder well-watered were confounded by the transitory nature of the response to drying that part of the root system[9]. But by frequently alternating the dry and wet parts of the root zone, this temporary response was reduced.

They included two traditional 2 or 4 liters/h discharge drip emitters per vine in the inter-vine region situated at 450 mm from the vine stem, as well as underground drip lines, one on each side of the vine row at a depth of 200-250 mm and 350-400 mm from the center of the row. Each vine was to be split into two moist zones that could alternately receive watering on a cycle of around two weeks. Soil moisture sensors were placed in each zone to track the amount of water that permeated from one into the other. These investigations effectively differentiated wet and dry zones in a range of soil types while operating in the field. Studies with pears, citrus, New South Wales, Australia, commercial vineyards, and other perennial row-crop fruits have shown that partial root zone drying with furrow/flood irrigation is also efficient[10]. Groundwater in parts of Haryana and Punjab is salty, mostly as a result of rivers with high residual sodium carbonate contents. Both Haryana and Punjab feature saline groundwater regions with relatively poor transmission characteristics in their aquifers, as well as fresh water aquifers with significant yields where crops like rice and wheat are cultivated. In nearly every fresh water area of these two states, the water level is declining while it is consistently increasing in the saline parts. Many other Indian states, including western Uttar Pradesh, may experience comparable conditions. The future of agriculture in rice-wheat systems, which are very productive in locations with fresh groundwater, is under risk due to unsustainable groundwater use. Currently, Haryana, Punjab, and Uttar Pradesh account for around20 percent of the 1098 overused groundwater blocks throughout the country. Deep submersible pumps must be used by farmers in place of centrifugal pumps, which incurs large extra expenditures and increases energy consumption. There is a lot of uncertainty about the future supply of good quality water at higher depths because excessive pumping from deeper aquifers is causing a random expansion of the salt water front from salty to fresh groundwater zones[11].

In Punjab and Haryana, respectively, 1.2 million and 0.7 million private shallow tube wells have been built during the last forty years. Most of Haryana's slightly saline groundwater basins use low discharge shallow cavity wells for irrigation. Many shallow tubewells must be abandoned because salts from deeper layers come to the surface when groundwater depth diminishes. Under these conditions, it is imperative to prevent disturbing the salty water and instead, to carefully construct tubewells and to encourage groundwater recharge in order to selectively skim fresh water that has accumulated over the naturally salty groundwater as a result of recharge from rainfall, irrigation, and/or canal seepage. Cavity tubewells are easy-to-build, inexpensive structures that don't need a gravel pack or a strainer. They are created by drilling a hole through a dense clay layer until a sandy layer is reached. After pulling the casing pipe back into the clay layer, sand is forced out using a centrifugal pump until a stable cavity develops below the clay layer and clean water is recovered. The lifespan of a hollow tubewell may vary from a few months to over a decade or more, depending on the quality and thickness of the clay layer and the size of the sand grains. In order to skim the water with the least amount of salt, the farmers operate the well for a number of hours each day, halting when the salinity of the pumped water increases. Despite these aquifers' low transmissivity, there is a considerable need and potential to use injection via cavity wells to boost groundwater recharge and enhance groundwater quality[12].

A number of surface spreading and well injection techniques may be employed to promote groundwater recharge utilizing rain and surplus canal water. The Central Ground Water Board, research institutions, universities, and non-governmental organizations (NGOs) have all carried out several artificial recharge trials around the country. Chadha provided a thorough categorization of these systems based on the hydro-geological conditions and the source of the water to be replenished. The Ghaggar river basin in Haryana and Mehsana District are the subject of CGWB research on well injection and induced recharge. are the most important for states in the northwest. Pilot studies on vertical and lateral recharge shafts combined with injection wells in Punjab and Haryana, including a significant study in the Punjabi Dhuri Link drain, watershed management studies in the Shivalik foothills of Punjab, Haryana, and Uttar Pradesh, and a regional IWMI study on use of diverted excess Ganga water in western Uttar Pradesh are just a few examples. In Gujarat and Rajasthan, groundwater depletion in hard rock regions has sparked substantial community- and NGO-based rainwater collecting and recharging activities via check dam construction. A recent CSSRI-coordinated project on groundwater skimming and recharging for saline groundwater regions in Haryana, Gujarat, Andhra Pradesh, and Tamil Nadu came to the conclusion that farmer-based recharging programs are more viable and that farmers' and NGOs' involvement, as well as socioeconomic issues, are crucial to the success of these initiatives. Marginal groundwater regions may be able to improve the quality of their groundwater in addition to increasing their resource via the application of the appropriate technology and management techniques[13].

This paper presents the features and field evaluation of a combined groundwater skimming and recharging system composed of two cavities placed in distinct quality depth zones. For simultaneous freshwater and saltwater abstraction through two wells to reduce interface rise, the technique incorporates features with scavenger type skimming structures demonstrated in Pakistan's lower Indus basin. A groundwater recharge component was further incorporated to the skimming structure to boost the continuous flow of pumped water of typically respectable quality. The present system stands apart from comparable systems because to these two distinctions. A brief explanation of two inexpensive groundwater recharge structures based on specific farms for these regions is also supplied in addition to this structure.

Groundwater Recharging and Skimming System

Following thorough geo-hydro-chemical investigation of the area, discussions with local farmers, and field tests, Village Jagsi- Sarfabad in Haryana's Jind district was selected as the test site. The field investigation also included test borings up to 30 meters deep and the collection of soil and water samples from diverse zones. The resistivity profiles, electrical conductivity, pH, ionic content, and particle size distribution of water and soil samples were examined to evaluate the lithology and depth-wise groundwater quality. Three test bore sites at Jagsi-Sarfabad received soil texture, groundwater chemical characteristics, and resistivity profiles from researchers. Based on the horizon-wise texture, thickness of clay layers, and chemical characteristics of soil and water samples, a scavenger well type skimming structure with two cavities at different depths was first proposed. The groundwater at the site chosen for the skimming cum recharge construction, however, had marginal salinity in June 2001 up to a depth of 17 m, and between that depth and 30 m, the quality of the water drastically decreased due to residual sodium carbonate. A groundwater recharge component was added to the original skimming design as a result of these adverse conditions[14], [15].

With a skimming cum recharging system, a downstream region vulnerable to runoff floods during the rainy season was constructed. The system is composed of two hollow tubewells that were constructed 7 meters and 40 meters apart in the relevant freshwater and saltwater groundwater zones. To create water with different qualities, the two compartments may be utilized alone or together. A recharge chamber was constructed nearby with a 30 m3 capacity and a graded filter comprising fine, coarse, gravel, and boulders to make it simpler to fill one or both cavities with filtered surface runoff or additional canal water during the rainy season. The intention was to increase the quantity of high-quality water accessible in the upper cavity or, via dilution, to improve the quality of the lower cavity for prospective use before or after gypsum treatment. At 40 meters, where there was water and there were few RSC issues, the deep hollow installation finally functioned.

Hydraulics of the System Evaluation

A number of pumping cum recovery and recharge tests on the groundwater skimming cum recharging system were conducted in order to analyze the hydraulics of water and solute movement in cavity wells and estimate aquifer properties throughout different phases. For a shallow depression, the clay layer is present at a depth of around 6.5 m and has a thickness of about 30 cm. According to researchers 32 observation wells are arranged in a network with radial spacings varying from 5 to 120 meters, in pairs at 5 and 8 meters deep. The information on the fluctuations in groundwater salinity and water table level during recharge studies in November 2004 on the shallow cavity and pumping cum recovery experiments conducted in July 2003 is taken from researchers. The recharging studies consisted of filling the recharge chamber with water pumped from a remote cavity tubewell, maintaining a steady water flow through it, and then opening a shallow or deep cavity to determine the rate of recharge. Estimated recharge rates from several studies have been gathered. It can be seen that shallow cavity recharge rates of 2 to 3 liters per sec were low, at around one fifth of the pumping rates, while deep cavity recharge rates were very low, at less than one liter per second. It seems that in order to boost well injection rates under high groundwater circumstances, some kind of pressurized injection may be necessary. The efficiency and clogging of different recharge filters must be thoroughly investigated, particularly in relation to the role played by fine sand[16].

DISCUSSION

The improvement in groundwater quality was measured using the area covered by different apparent resistivity zones and recurrent resistivity surveys. The aquifer zone representing good to marginal groundwater increased from 31 to 54 percent over the period of two and a half years as a result of the combined impacts of forced recharge interventions and natural recharge, according to studies. Although filtration is crucial, farmers in the study area have started to use reflex valves whenever practical to transmit excess runoff to cavity tubewells. The overall cost of the system is Rs. 50,000, of which Rs. 30,000 is spent on the pumping unit and Rs. 20,000 is spent on the components used for recharging[17].The trial revealed that farmer-specific recharge initiatives outperformed community- or government-wide programs in terms of success rates. mechanisms to support charging. A recharge shaft and a pumping cum recharging system based on individual farmers were built in the fields of the farmers in the hamlet of Bindrala in the Assandh block of the Karnal district. A socioeconomic assessment highlighted the area's main challenges as being insufficient canal water supply, declining water tables, failure of tubewells due to cavities collapsing, irregular electricity supply, and salt water upconing from deeper salty layers.Both structures were built utilizing resistivity profiling, soil textural analysis, groundwater chemical studies at different depths, and test drilling down to a depth of 50 meters. At the project site, a medium sand aquifer with good water quality was discovered between 30 and 39 meters below the surface. It had no substantial salinity or problems with residual sodium carbonate. Due to the top limiting clay layer's weakness, there were no instances of functional strainer tube wells. Due to the general water table in the region, which is at a depth of approximately 10 m, farmers are being compelled to deepen the pumping units in masonry chambers to around 6 m[18].

CONCLUSION

The groundwater pumping cum recharging system, which is used to replenish excess rainfall and canal water, comprises of a pumping tubewell positioned at 39 m depth in a gravel-packed borehole of 25 cm. The tube well was constructed in the sandy zone from 30 to 33 and 33 to 39 meters, respectively, using 10 cm and 15 cm perforated pvc pipes covered with synthetic filters. The perforations were provided as collections of tiny holes, and they covered around 10% of the pipe's surface. There was 5 mm of gravel in the area around the strainer and 15 mm of gravel in the annular space between the bore and the well pipe.Two chambers, each measuring 1.25 m x 1.25 m x 2.0 m, made up the filtering apparatus. The excess surface runoff from rain or canal water enters the adjoining sedimentation chamber to settle any lingering sediment after passing through a graded filter comprised of layers of coarse sand, gravel, and boulders in the first chamber. The filtered water is then sent through a plastic pipe into the annular region filled with gravel packs to rehydrate sandy zones at varied depths. By recharging water through an annular gap with a gravel pack filled rather of a well pipe, the risk of the pumping unit clogging is reduced. During the 2004 rainy season, this mechanism may be used to replenish large volumes of rainwater and additional canal water. The recharge filter typically costs Rs. 15000, but with other filter designs, the cost might be much lower. CGWB and other organizations have successfully shown the efficacy of large-scale vertical and lateral recharge shafts alone or in conjunction with injection wells in numerous parts of Haryana, Punjab, and other states. The effectiveness of a smaller recharge shaft based on individual farmers was studied in the hamlet of Bindrala. The recharge shaft contained a 45 m deep, 45 cm diameter bore hole that was used to carry filtered recharge water to favourable sandy zones. The bore hole was filled with a 1.5–2.0 cm gravel pack. In order to avoid clogging, the surface runoff from rainfall or additional canal water is first passed through a graded filter consisting of coarse sand and smaller pebbles in a chamber that is 1.65 m x 1.65 m x 1.8 m in size. The filtering unit's borehole was positioned in the middle of the recharging shaft. The placement of the recharging shaft adjacent to an irrigation canal in a farmer's field produced encouraging performance evaluation results. Without the complexity of mixed systems, such as recharging and pumping, it just serves to refill groundwater and is far simpler in design, easier to install, and easier to manage.

REFERENCES:

[1] L. Liu and M. B. Jensen, “Green infrastructure for sustainable urban water management: Practices of five forerunner cities,” Cities, 2018, doi: 10.1016/j.cities.2017.11.013.

[2] K. L. Christ and R. L. Burritt, “Water management accounting: A framework for corporate practice,” J. Clean. Prod., 2017, doi: 10.1016/j.jclepro.2017.03.147.

[3] A. Azhoni, S. Jude, and I. Holman, “Adapting to climate change by water management organisations: Enablers and barriers,” Journal of Hydrology. 2018. doi: 10.1016/j.jhydrol.2018.02.047.

[4] S. Zhang, Y. Li, M. Ma, T. Song, and R. Song, “Storm water management and flood control in sponge city construction of Beijing,” Water (Switzerland), 2018, doi: 10.3390/w10081040.

[5] A. Hurlimann and E. Wilson, “Sustainable urban water management under a changing climate: The role of spatial planning,” Water (Switzerland), 2018, doi: 10.3390/w10050546.

[6] X. Zhou, Y. Li, and F. Lai, “Effects of different water management on absorption and accumulation of selenium in rice,” Saudi J. Biol. Sci., 2018, doi: 10.1016/j.sjbs.2017.10.017.

[7] V. Geissen et al., “Emerging pollutants in the environment: A challenge for water resource management,” Int. Soil Water Conserv. Res., 2015, doi: 10.1016/j.iswcr.2015.03.002.

[8] S. Gössling, “New performance indicators for water management in tourism,” Tour. Manag., 2015, doi: 10.1016/j.tourman.2014.06.018.

[9] D. Feingold, S. Koop, and K. van Leeuwen, “The City Blueprint Approach: Urban Water Management and Governance in Cities in the U.S.,” Environ. Manage., 2018, doi: 10.1007/s00267-017-0952-y.

[10] X. Yu, Y. Geng, P. Heck, and B. Xue, “A review of china’s rural water management,” Sustain., 2015, doi: 10.3390/su7055773.

[11] M. A. Fulazzaky, “Challenges of integrated water resources management in Indonesia,” Water (Switzerland). 2014. doi: 10.3390/w6072000.

[12] C. Pahl-Wostl, J. Sendzimir, P. Jeffrey, J. Aerts, G. Berkamp, and K. Cross, “Managing change toward adaptive water management through social learning,” Ecol. Soc., 2007, doi: 10.5751/ES-02147-120230.

[13] C. H. Lai, N. W. Chan, and R. Roy, “Understanding public perception of and participation in non-revenue water management in Malaysia to support urban water policy,” Water (Switzerland), 2017, doi: 10.3390/w9010026.

[14] S. J. Van de Meene, R. R. Brown, and M. A. Farrelly, “Towards understanding governance for sustainable urban water management,” Glob. Environ. Chang., 2011, doi: 10.1016/j.gloenvcha.2011.04.003.

[15] I. Kisekka, K. C. DeJonge, L. Ma, J. Paz, and K. Douglas-Mankin, “Crop modeling applications in agricultural water management,” Trans. ASABE, 2017, doi: 10.13031/trans.12693.

[16] J. Niemczynowicz, “Urban hydrology and water management - present and future challenges,” Urban Water, 1999, doi: 10.1016/s1462-0758(99)00009-6.

[17] S. W. Lee, S. Sarp, D. J. Jeon, and J. H. Kim, “Smart water grid: the future water management platform,” Desalin. Water Treat., 2015, doi: 10.1080/19443994.2014.917887.

[18] H. P. Ritzema and J. M. Van Loon-Steensma, “Coping with Climate Change in a densely Populated Delta: A Paradigm Shift in Flood and Water Management in The Netherlands,” Irrigation and Drainage. 2018. doi: 10.1002/ird.2128.