SOIL CHEMISTRY

NUTRIENT AND WATER MANAGEMENT IN AGRICULTURAL SOILS

T. V. S. Prasad
Shakuli Saxena

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Ph. 0120-4270027, 4273334

e-mail: dominantbooks@gmail.com
info@dominantbooks.com

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CHAPTER 1

EXPLORATION OF SOIL AND WATER MANAGEMENT: A REVIEW STUDY

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

ABSTRACT:

Soil and water management are critical components of sustainable agriculture and environmental stewardship. This abstract provides a concise overview of key aspects related to soil and water management practices, emphasizing their significance in maintaining ecosystem health and food security. It explores the challenges and opportunities in these fields and highlights the importance of integrated approaches to address soil and water-related issues. The abstract concludes by underlining the need for continued research, policy development, and community engagement to ensure the responsible management of soil and water resources for current and future generations.soil and water management play pivotal roles in maintaining the ecological balance and ensuring food security on a global scale. This comprehensive review has underscored the multifaceted nature of these two interconnected domains, emphasizing the complex challenges they face, including soil degradation, water scarcity, and pollution. The adoption of sustainable practices such as conservation tillage, agroforestry, and precision irrigation has shown promise in mitigating these issues, promoting soil health, and conserving water resources.

KEYWORDS:

Agriculture, Conservation, Erosion, Management, Nutrient, Pollution.

INTRODUCTION

Students studying agricultural and environmental sciences will find the subjects covered in this course to be significant in terms of managing and conserving soil and water. Examining processes that harm Nigeria's soil and water resources and talking about how to assess, prevent, and manage them. With regard to the interception, storage, and flow of water in dryland and irrigated agro-ecosystems, there is a major emphasis on quantitative theory and practice of monitoring and regulating soil water using commercially accessible equipment. There are also broader topics in water and soil conservation highlighted. Exercises in the lab, on the computer, and in the field are used in practical courses to demonstrate the ideas learned in lectures.It is impossible to overstate the value of soil and water to crop productivity. All-year-round production of many arable crops is guaranteed by healthy soil and water from reliable sources. The goal of this course is to inform the students about both the positive and negative effects that using soil and water for agriculture and other reasons may have.

Additionally, it makes an effort to address the majority of issues brought on by the improper usage of soil and water. There are six modules with a total of 10 units in the course. These lessons will demonstrate how to use soil and water management research as a tool and a methodical procedure to make sure that soil and water factors are taken into account in all planned actions. This course guide outlines the course's objectives and the readings you must complete to make sure the course is straightforward and within your grasp. It gives some broad suggestions for how long you should expect to spend studying each course in order to effectively finish it. Additionally, it offers advice about your tutor. marked homework. The course will cover the fundamental ideas and specific applications of biotechnology for agricultural crops, with an emphasis on the need for a new kind of agriculture to meet the rising demand for food in the face of climate change and rising abiotic and biotic stress conditions. The fundamental components of the main biotechnology instruments and solutions will be assessed[1], [2].

There are established objectives in order to accomplish the goals. Additionally, this course's unique goals are listed at the start of each unit. These goals must be understood before you begin each unit's work. You are urged to consult them from time to time to assess how well you are understanding and remembering the material. You may review the goals after finishing a unit to make sure you've understood everything. You can be certain that you have fulfilled the unit's expectations by doing this. The goals of the course as a whole would have been accomplished by achieving these goals. These goals include:

1. Educate you on soil conservation techniques

2. Recognize the root causes of soil deterioration

3. Recognize the fundamental concepts of soil management

4. Identify reliable water sources

5. Establish the amount of water that crops need and manage how it is distributed to them.

Completing This Course

You must attentively read the study modules and other suggested resources in order to pass this course. To reinforce the main concepts, you will be asked to provide answers to certain questions based on what you have read in the Content. You must turn in some tutor-marked assignments for marking at the conclusion of each unit. You have a TMA as one of your ongoing tasks. The course's final test is held at the conclusion. You should be able to finish the course in 12–13 weeks. You are provided the component of the course so that you can understand what to accomplish and how to spend your time to each unit in order to effectively finish the course on time.

In each unit, there are both tutor-marked tasks and self-assignments. The TMA would need to be completed for each unit's revision. Additionally, you must complete and turn in four tutor-marked assignments as part of your course assignment. You would have a more comprehensive grasp of the issue as a result. You would get information from your tutorial facilitator on the specific TMA you need to turn in to him for recording and grading. Please ensure that your work is sent to your tutor by the due date specified in the assignment file and presentation schedule. If for whatever reason you are unable to finish your project by the deadline, get in touch with your tutor before it is due to explore the possibility of an extension. After the deadline, extensions won't be given unless there are special circumstances. You may complete your assignment questions using the course materials' Contents and References/Further Reading, but it is advisable to look up additional References/Further Reading to get a more comprehensive grasp of the topic.

DISCUSSION

Water and soil are two crucial natural resources that are also prerequisites for agricultural development. It has been noted that the strain of an expanding population has contributed to the deterioration of these natural resources during the last century. In other words, it is only viable to raise agricultural output to feed the growing population if there is enough fertile land and water for farming. Out of 328 million hectares of land in India, 68 million hectares are badly eroded, and 107 million hectares are gravely degraded. Soil and water should thus be given top importance from the perspective of conservation, and suitable techniques should be used to assure their sustainability and future availability. worldwide state of land degradation. The use and management of water for the benefit of all users is known as conservation. Although there is a lot of water on the planet, just 3% of it is fresh water, and only about 7/10 of that is potable. The majority of the water that is useable is used for agriculture. According to a thorough research, two-thirds of the world's population would experience some kind of water scarcity in around 15 years. Almost all facets of existence include the utilization of water. Numerous residential, commercial, and agricultural applications exist. Although soil conservation is crucial, many people are unaware of it since water conservation is quickly becoming a prominent subject[3], [4].

Controlling soil erosion is what is referred to as "soil conservation," and it is done so as to keep agricultural production high. Soil erosion often results from a variety of unavoidable factors, including water and wind. In addition, human activities including farming, building, and other activities accelerate soil erosion. Some would argue that soil erosion is not damaging since it is a natural process. The fact is that organic matter and nutrients are also eliminated when the top layer of soil is removed.The task of conservation is shared by landowners, forest or mine owners, hydrologists, soil and plant experts, and wildlife managers. Because natural resources are so crucial to our survival, all residents should be made aware of their significance and encouraged to take an active role in protecting and wisely exploiting them.To actively participate in maintaining soil water content at an ideal level for all specified goals, including environmental requirements, is to practice soil water management. An ideal condition often involves striking a balance between conflicting demands and the need to take the soil water system's long-term viability into consideration.

Advantages of Water and Soil Management

Soil erosion causes the soil to lose a lot of its organic matter and nutrients. Better soil and water conservation may be accomplished by enhancing the overall circumstances for plant development. When the land is actively being used for agricultural production, better land management is increasingly important.Some of the significant issues are water contamination, gully formation, land slip, sedimentation and silting in the reservoirs, and soil erosion. By lowering the runoff rate and the land slope, soil conservation techniques attempt to retain soil fertility, soil productivity, etc. Maintaining a plant cover is crucial to preventing erosion of bare soil, particularly in the most susceptible locations, such as those with steep slopes, during dry seasons or times of very high rain. Only a portion of the forest should be harvested for this purpose, and seasonal wet or dry parts should be used for grazing instead of arable land. Crop rotation should be practiced by farmers in areas of heavy farming to avoid the soil's organic matter and other soil-building components from getting depleted. Contour plowing should be performed whenever soils are plowed in sensitive regions.

To lessen the issue of soil salinity development, irrigation should be managed carefully to avoid applying too much or too little water. To avoid overgrazing, livestock grazing has to be properly controlled. Highway construction and urbanization should be limited to regions with less potential for agriculture. Before approval for quarries or mines is given in the extractive industries, a guarantee to return the land to its prior state must be obtained. Controlling soil erosion is what is referred to as "soil conservation," and it is done so as to keep agricultural production high. Soil erosion often results from a variety of unavoidable factors, including water and wind. In addition, human activities including farming, building, and other activities accelerate soil erosion. Some would argue that soil erosion is not damaging since it is a natural process. The fact is that organic matter and nutrients are also eliminated when the top layer of soil is removed. The task of conservation is shared by landowners, forest or mine owners, hydrologists, soil and plant experts, and wildlife managers. Because natural resources are so crucial to our survival, all residents should be made aware of their significance and encouraged to take an active role in protecting and wisely exploiting them.

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Managing the soil

The effectiveness of site-specific soil management depends on effective soil management. Beginning with the farmer's capacity to adjust the level of tillage in accordance with soil conditions, soil management for sustainable agriculture is crucial for seedbed preparation, weed control, and fuel efficiency, with the potential to reduce production costs within a single field. The majority of living things are supported by soil since it is their primary supply of mineral nutrients. Both directly and indirectly, soil management impacts agricultural yield, environmental sustainability, and human health.All activities, procedures, and treatments used to safeguard soil and improve its functionality are referred to as soil management.These are the soil management techniques that have an impact on soil quality.

Aeration and water infiltration may both be hampered by soil compaction, which can be reduced by limiting traffic on the soil's surface. In the off-seasons, cover crops keep the soil anchored and protected, preventing wind and rain from eroding it. For row crops, crop rotations alternate high- and low-residue crops to enhance the quantity of plant matter that is left on the soil's surface throughout the year and prevent soil erosion. The management of nutrients may assist increase the soil's fertility and organic matter content, which benefits soil structure and function. Tillage, particularly reduced-tillage or no-till operations, helps to keep plant leftovers on the soil's surface for erosion prevention and water retention while limiting the amount of soil disturbance while cultivating a new crop.

Gains from Soil Management

The benefits of soil management are emphasized below.

1.Keep the land fertile.

2.Replenish the soil's fertility.

3.Make agriculture a profitable endeavor.

4.Aid in boosting production.

The goal of integrated soil fertility management is to increase crop yield and the agronomic use of nutrients as efficiently as possible. This may be done by using grain legumes, which increase soil fertility by biologically fixing nitrogen, and by using chemical fertilizers. One of the main benefits of leguminous crops is their capacity to fix atmospheric nitrogen, which lowers the need for synthetic nitrogen fertilizer and improves soil fertility. Leguminous crops may be produced as pastures, green manure, pulses for grain, green manure, pastures, or the tree components of agro-forestry systems. Legumes that fix nitrogen are the foundation of integrated nutrient management-based sustainable agricultural systems. Understanding the dynamics and interactions between different pools in agricultural systems, such as nitrogen fixation by legumes and consumption of soil and fertilizer nitrogen by crops, both in solo cropping systems and mixed cropping systems, is made possible by the use of nitrogen-15. By using green manure or growing legumes to fix nitrogen from the air through the process of biological nitrogen fixation, applying micro-dose fertilizer applications to replace losses through plant uptake and other processes, and minimizing losses through leaching below the crop rooting zone, soil fertility can be further improved. These practices improve soil structure and foster a healthy, fertile soil[7], [8].

Bring Back Soil Fertility

Plant nutrients lost to erosion, crop harvesting, and leaching are replaced by fertilizers. Farmers have the option of using commercial inorganic fertilizers made from different minerals or organic fertilizer made from plant and animal matter. The three main categories of organic fertilizer are compost, green manure, and animal manure. The excrement and urine of agricultural animals including cattle, horses, chickens, and other creatures are included in animal manure. It strengthens soil structure, supplies organic nitrogen, and encourages healthy soil fungus and bacteria. To boost the organic matter and humus that is accessible to the next crop, green manure is fresh or still-growing green vegetation that has been plowed into the soil. Leguminous crops may be used as green manure, which is a significant way to increase the amount of nitrogen in the soil. Compost is a rich natural fertilizer and soil conditioner that increases soil aeration, water and nutrient retention, aids in preventing erosion, and keeps resources from being squandered in landfills. Farmers and households create compost by stacking alternating layers of topsoil, nitrogen-rich plant wastes, weeds, animal manure, and vegetable kitchen scraps.

High levels of microbial activity, increased quantities of organic matter, and sound soil structure are characteristics of healthy soils. "Healthy soil" may seem quite differently everywhere because soil qualities vary according to temperature, geology, geography, and the history of land use and management on a field or farm. Farmers may use a variety of management techniques that have costs and advantages for them to minimize erosion and maintain and enhance the quality of their soil. Farmers often consider whether a strategy would increase crop yields and/or lower the cost of agricultural inputs when making choices on soil health activities. Other personal advantages that may be important to the farmer include increased crop resistance to adverse weather and the chance to practice environmental stewardship. In addition to lowering greenhouse gas emissions from agriculture and increasing carbon sequestration, soil health techniques may also enhance water quality by reducing nutrient and sediment contamination. Farmers may not be taking these possible societal advantages into account when choosing to implement soil health techniques, despite the fact that they might have an impact on both current and future generations.

Aid in Increasing Yield

There are several causes of erosion. Crop rotation and slope both contribute significantly to erosion control. Uphill and downhill planting is thought to reduce erosion on intermediate slopes by about 50% less than on steep slopes, where the risk of rill erosion is enhanced. Along with conservation tillage techniques, row spacing is a technique that effectively reduces soil erosion on slopes. The amount of soil surface exposed to water impact may be reduced and thick surface cover can be provided by reduced row spacing. By splitting the slope into distinct sections, strip cropping, terracing, and grassed streams are further methods for preventing erosion. Despite some soil movement on the terrace, the vast bulk of the separated dirt remains there. These procedures aid in clearing the water before it leaves the field of silt and certain nutrients. Such procedures make a considerable contribution to raising production and water quality.

Management of Water

The world's population will expand by 50% from 2000 to 2050, reaching 9.1 billion people. In order to counteract the declining availability of and competition for land and water from other uses, including non-food crops, urbanization, and industrial expansion, agriculture must offer this increase. The majority of cropland is really rainfed, and this is the region with the biggest yield differential in agricultural output among all of the world's regions. The complete review on water management in agriculture found that upgrading rainfed farming might increase productivity by two to four times. The lack of appropriate financial incentives for farmers to use yield-enhancing crops or cropping practices is one of the primary causes of yield disparities. Lack of information access, access to extension services, and technical skills are further causes. Significant barriers to the adoption of new technology at the farm level may also be created by inadequate infrastructure, poor institutions, and discouraging agricultural policies. Other problems can include the failure to adapt technology to regional circumstances.

Improving water usage efficiency and sustainability is the key issue facing water management in agriculture. This can be accomplished by improving soil and water management practices at the farm and community levels, which will increase crop water productivity through irrigation, reduce water losses through soil evaporation that plants could otherwise use for their growth, and increase soil water storage within the plant rooting zone.

Because of the interactions between water sources from rainfall, irrigation, subsurface water, plant uptake, soil evaporation, plant transpiration, and runoff or drainage losses from crop-growing areas, tracking and quantifying water fluxes at various spatial and temporal scales within the plant rooting zone remains a difficult task. The development of water management plans that take into account the type of crops grown, growth stages, and overall agro-ecosystems will be greatly aided by the use of isotopic and nuclear techniques to investigate the relative importance of soil and irrigation management factors that influence these interactions. This will help to minimize not only water but also nutrient losses from the farmlands and improve water and nutrient use efficiencies in agro. Planning, producing, distributing, and monitoring the best use of water resources are all parts of the activity of water management. It is a part of managing the water cycle. Planning for water resource management should ideally take into account all competing demands for water and aim to distribute water equally to meet all needs. This is seldom feasible in reality, much as with other resource management[9], [10].

Recommendations for Water Management

Take action to reduce effects on the ecology. If the agricultural area is situated in or close to a place of ecological interest, this may also incorporate integrated pest control and low water fertilizers. Make sure the water supply infrastructure is properly maintained. Determine the maximum water extraction levels beyond which the underlying ecosystem would suffer from overexploitation. Make that the resource protection for aquatic resources is adequate. Unused wells are seen on many farms. The contaminants that enter these wells swiftly and unfetteredly reach the groundwater. Pumps, pipes, and other objects are taken out of abandoned wells to seal them, and the hole is then filled with a slurry of cement or bentonite chips.

Enhancing Water Management Techniques

Improving water usage efficiency and sustainability is the key issue facing water management in agriculture.

Through improved soil and water management practices at the farm and regional levels, there will be an increase in crop water productivity through irrigation, a decrease in water losses through soil evaporation that plants could otherwise use for their growth, and an increase in soil water storage within the plant rooting zone. Contrary to the declining availability of and competition from other uses for land and water, including non-food crops, urbanization, and industrial expansion, agriculture must supply this increase. The majority of the world's cropland is really rain-fed, and here is where there is still the biggest yield disparity in crop production across various regions. The full review on water management in agriculture found that upgrading rain fed farming might increase productivity by two to four times. The lack of appropriate financial incentives for farmers to use yield-enhancing crops or cropping practices is one of the primary causes of yield disparities. Lack of information access, access to extension services, and technical skills are further causes. Significant barriers to the adoption of new technology at the farm level may also be created by inadequate infrastructure, poor institutions, and discouraging agricultural policies.

Other problems can include the failure to adapt technology to regional circumstances.In semi-arid environments as well, there are usually significant connections between measures for conserving soil and approaches for conserving water. Although most strategies include elements of both, many are focused largely on one or the other. It will also assist to decrease erosion if buildings or modifications to land management reduce surface run-off. Similar to this, limiting splash erosion, crust development, or structural failure will typically result in less erosion since these factors all promote infiltration and aid in water conservation.The prevention or reduction of soil erosion, compaction, and salinity; the conservation or drainage of water are examples of local activities that maintain or improve the productive capacity of the land, including soil, water, and vegetation in areas prone to degradation.

Techniques for Soil and Water Conservation

Techniques for conserving soil and water are mostly used for the following goals:

1.Reduce soil compaction by managing flow to stop soil erosion and soil loss.

2.Preserving or enhancing soil fertility.

3.Either discharge or save water.

4.Gather Water.

Classification of Techniques for Water and Soil Conservation

Many techniques for conserving soil and water are widely recognized. These technologies may be distinguished either by kind or by primary function. Since many of them perform many tasks at once, they are categorized here by kind as physical techniques, biological techniques, and agronomic techniques.

CONCLUSION

Emphasizes the need of comprehensive, integrated methods that take soil and water management into account simultaneously while recognizing their complex interrelationship. Education, better water resource governance, and sustainable land use planning are essential for successfully resolving these issues. But the path to responsible soil and water management is still being traveled, and it calls for coordinated efforts by authorities, academic institutions, farmers, and the larger community. Sustainable soil and water management techniques will be made possible through technical advancements, information sharing, and the establishment and implementation of policies. As we go ahead, it is crucial to understand that ethical soil and water management is not just a need for the environment but also a crucial aspect of ensuring the world's food security and reducing climate change. Therefore, it is up to us all to protect these priceless resources in order to ensure a robust and sustainable future for both the present and future generations.

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CHAPTER 2

PHYSICAL SOIL AND WATER CONSERVATION TECHNIQUES

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

ABSTRACT:
Physical soil and water conservation techniques represent a crucial aspect of sustainable land management. This abstract provides an overview of these techniques, highlighting their significance in preventing soil erosion, improving water quality, and enhancing ecosystem resilience. It explores various methods such as terracing, contour farming, and check dams, emphasizing their practical applications and benefits. The abstract concludes by stressing the importance of integrating physical soil and water conservation techniques into land-use practices to ensure long-term environmental and agricultural sustainability.physical soil and water conservation techniques are indispensable tools for preserving our natural resources and promoting sustainable land management.

This review has elucidated the diverse array of methods available, each tailored to specific landscapes and environmental challenges.These techniques, including terracing, contour farming, check dams, and others, have demonstrated their efficacy in preventing soil erosion, conserving water resources, and mitigating the adverse impacts of climate change. They not only protect valuable topsoil but also improve water quality by reducing sediment runoff and the transport of pollutants into water bodies.

KEYWORDS:

Conservation, Erosion, Techniques, Physical, Soil, Water.

INTRODUCTION

Physical approaches are constructions created to save soil and water. Some principles need to be taken into account. They should try to divide a long slope into several short ones, reducing the amount and velocity of surface runoff, increasing the time of concentration of runoff to allow more of it to infiltrate into the soil, and protecting against damage brought on by excessive runoff.Any physical measure, such check dams or contour ditches, may be constructed in the majority of systems. Techniques for conserving water and soil in the watershed of the A River. Walls and terraces are used in the basin of the A River. Both act as controls to stop soil erosion processes, which are a big issue in this drainage basin[1], [2].

In order to collect surface runoff, earthen terraces are erected at a right angle to the sharpest slope. An embankment typically consists of two components: a dug channel and a bank or ridge on the channel's downhill side that are built using the channel's excavated material. Based on the layout and contours of the canal and ridge, several terrace kinds exist. They should be chosen based on the issues and situations present locally. In the watershed of the A River, there are bench terraces.

Terracing of this kind is done on slopes that are rather steep. Here, constructing merely walls that shorten the slope is insufficient to limit runoff power. The degree of slope must also be changed by half-excavating a channel and half-filling a bank. Fields that resemble steps will be created from the original ground.Bench terraces serve four basic purposes: 1. control erosion by lowering the slope's steepness and length; 2. increase rainwater penetration; 3. maintain soil fertility; and 4. provide enhanced irrigation when required.The following list of biological techniques may be used in conjunction with the built terraces.

Biotechnological Methods

Through their protective effect on the plant cover, biological strategies for soil and water conservation function. A dense vegetated area prevents splash erosion, slows down surface runoff, promotes soil particle accumulation, increases surface roughness, which decreases runoff and increases infiltration, and stabilizes soil aggregates while also promoting infiltration.In contrast to exposed soil, which often has a high soil erosion rate, these factors result in a low soil erosion rate. Even in agricultural settings, grown crops provide superior protection against soil erosion than bare soil. The condition of the soil's hydration has improved, among other favorable effects. Therefore, biological techniques are a successful way to save soil and water, particularly given their cheap cost. These may also be utilized in conjunction with agronomic and structural techniques.There are several biological techniques for conserving soil and water[3], [4].

Reforestation

Reforestation is a crucial step in the recovery of the soil and water balances in severely damaged regions. Numerous tasks are accomplished by trees, such as preventing soil erosion or preserving soil moisture. When reforestation is planned, two choices must first be made: Should the land be fully off-limits to farming and grazing for a certain amount of time? If so, a distinct boundary must be indicated. Which is more effective, direct sowing or planting seedlings from a nursery?The answer is dependent on a number of variables, including soil, biotic factors, and climate.

Nursery techniques

If a nursery is chosen, the ideal location must be carefully considered. At least four requirements must be met. The proposed nursery location should be close to the planting site, big enough, with year-round access to water, and with suitable soil.The nursery may be run for profit or for the neighborhood. It is necessary to have some knowledge of irrigation, species selection, and soil-mixing ratios, among other things. As prior experience with invasive plants like eucalyptus has shown, native species are generally to be chosen. The seedlings are placed outside once they reached a suitable size. The forest may also be utilized by humans in the future, after the trees have matured, for example, for beekeeping.The third category of soil and water conservation techniques described in this Watershed Management-Module is agronomic techniques.

Techniques for Conserving Soil and Water in Agriculture

Agronomic conservation approaches work by 1. decreasing surface runoff and soil erosion via increased infiltration rates and 2. decreasing the effect of rainfall through interception.On the right are a few potential agronomic methods. These methods may be used in conjunction with biological or physical soil and water conservation methods. They could perform better than structural approaches in certain systems. Additionally, it is the most affordable method of conserving soil and water. In a comparison done in 1996 by Tidemann, it is shown how important land use practices are when it is said that "the differences in erosion rates caused by different land use practices on the same soil are much greater than the corresponding values from different soils under the same land use". However, since they call for a shift in routine behaviors, agronomic techniques are sometimes more challenging to put into effect than structural ones. Contoured plowing is a common agronomic technique that is explained in greater detail in the next step. It is a well-known agronomic practice called contour plowing that helps save soil and water. Instead of up-and-down, the dirt is plowed following the contour. By concentrating water in the downhill furrows, this reduces runoff velocity and subsequently soil erosion. Contrarily, contour ploughing creates a barrier against runoff from rain that collects in the furrows on purpose. More water is retained in situ and infiltration rates rise. At the start of the wet season, when biological conservation benefits are weak, contour plowing is particularly crucial. With an increase in slope gradient and length, rainfall intensity, and soil erodibility, contour plowing becomes less effective[5], [6].

Contour Plowing

Contour plowing is also used in the A River watershed to lessen soil erosion. Due to the length of the field inquiry, it could only be observed once, and as a result, it was not taken into account when determining the risk of soil erosion in the drainage basin.

Utilization of Techniques for Soil and Water Conservation

Particularly the many conventional methods for soil and water conservation, these strategies are often employed in conjunction. This is becoming seen as more and more rational. Purely technical techniques often fail, particularly when local farmers, forest managers, etc. aren't involved. Additionally, it has been acknowledged that in order to accomplish sustainable resource management, conventional techniques alone may often not be enough to protect the essential soil and water resources.

DISCUSSION

Preventing soil loss through erosion or diminished fertility due to excessive use, acidification, salinization, or other chemical soil pollution is known as soil conservation. Some less developed regions still use slash-and-burn farming and other unsustainable techniques. Large-scale erosion, loss of soil nutrients, and even complete desertification are common effects of deforestation. Crop rotation, cover crops, conservation tillage, and installed windbreaks are methods for better soil conservation that have an impact on both erosion and fertility. When plants, particularly trees, pass away, they decompose and mix with the soil. The U.S. Natural Resources Conservation Service's suggested standard practices are outlined in Code 330. For centuries, farmers have conserved their soil. In order to better address soil conservation, programs like the Common Agricultural Policy are focusing on the adoption of best management practices including decreased tillage, winter cover crops, plant residues, and grass margins. Additional political and economic effort is needed to address the erosion issue. A straightforward governance barrier has to do with how we value and identify the land, and this may be overcome via cultural adaptation[7], [8].Preventing soil loss through erosion or diminished fertility due to excessive use, acidification, salinization, or other chemical soil pollution is known as a soil conservation approach. Some less developed regions still use slash-and-burn farming and other unsustainable techniques.

Creating and preserving ground cover vegetation

Reduce soil erosion caused by wind and water, enhance soil quality by choosing plants that assist increase organic matter, utilize perennial plants, such as trees, shrubs, grasses, and perennial forbs, to improve the air quality. Planting native grasses, forbs, and shrubs will improve the habitat for animals. Boost water quality by adding more vegetation[9], [10].

Cropland

minimizing soil surface disturbance and controlling the quantity and distribution of plant debris on the soil surface. These are the advantages:

1. Reduce erosive surface water

2. Reduce erosive wind

3. Boost organic matter in the soil

4. Boost the plant's accessible moisture

5. Give wildlife shelter and nourishment.

Mulching

1. Adding to the soil plant residues or other suitable ingredients.

2. Reduce erosion;

3. Lessen weed establishment and development.

4. Preserves the moisture in the soil;

5. Improves vegetative cover

6. Boosts the soil's quality

Technique for Water Conservation

Techniques for conserving water include policies, strategies, and actions designed to manage fresh water as a sustainable resource, safeguard the aquatic ecosystem, and satisfy present and future human demand. Affluence, growth, family size, and population all have an impact on water use. Water conservation techniques include the policies, strategies, and activities made to manage fresh water as a sustainable resource, to protect the water environment, and to meet present and future human demand.

Factors like climate change have increased pressure on natural water resources, especially in manufacturing and agricultural irrigation.

Affluence, growth, family size, and population all have an impact on water use. Pressure on natural water supplies, particularly in industries and agricultural irrigation, has grown due to factors including climate change.

Techniques for Water Conservation Have a Purpose

Among the objectives of water conservation measures arepreserving freshwater for future generations by ensuring that freshwater loss from an ecosystem does not exceed the pace of natural replenishment.

Energy conservation is important since facilities for waste water treatment, distribution, and pumping water use a lot of energy. In certain parts of the globe, water management accounts for more than 15% of all power use. Reduced human water consumption contributes to habitat conservation by protecting local wildlife's access to freshwater habitats and the quality of the water.

Techniques for Water Conservation Strategies

The following are the main strategic actions that promote water conservation

1. Any efficient reduction in resource use, water loss, and waste.

2. Preventing any deterioration of water quality.

3. Improving water management techniques that reduce consumption or maximize water's beneficial uses.

Farmer Water Conservation Techniques

1. Improved irrigation machinery

Upgrades to irrigation equipment may be expensive, but they will undoubtedly be worthwhile in the long term. As the water supply continues to diminish in the face of increasing demand, the full cost of water will ultimately become apparent. The kind of crop, the type of soil, the local climate, and other variables will affect which irrigation technique is most effective. Irrigation systems and gravity-flow systems are only a few of examples of potential approaches to more effective water utilization. The quantity of water used for irrigation may be measured and managed with the use of water flow meters.

2. Weather equipment that works well

Some farmers may want to program an automatic watering plan and leave it in place all year round. It requires more effort, but modifying irrigation systems to perform better in unison with precipitation from natural sources is unquestionably a method to conserve a lot of water.There are several different weather applications that provide real-time data on precipitation. These may be used in conjunction with irrigation systems to assist save water, which will save farmers money and lessen system wear and tear.

3. Effective soil management

Water conservation is mostly dependent on good soil management. There are many things a farmer may do to modify the nature of soil, which is particularly useful if the soil quality is disturbed. Soil is what absorbs, transports, and keeps water for crops to utilise. Farmers may use a variety of methods, such as conservation tillage, composting, and crop cover. Once again, the kind of soil being managed will determine what methods of water conservation are most effective.

4. Recycle your water.

Over the course of a growing season, avoiding or reducing runoff may result in water savings of millions of gallons. Runoff is a natural outcome of irrigation to some extent and may be caused by overwatering, poor soil, and other issues. Recycling runoff helps preserve whole ecosystems in addition to saving water. Large levels of chemicals found in agricultural runoff often contaminate groundwater, rivers, streams, and other water bodies. Both the expenses and the rewards are considerable.

5. Using organic agricultural practices

When a farmer does not need to purify the water before reusing it, water recycling is much less costly. Farmers may save water by using organic farming techniques that lessen or completely eliminate the use of chemicals, which eliminates an expensive stage in the recycling process. By conserving the quality of water that would otherwise be harmed by dirty runoff, using organic agricultural techniques may also be able to reduce the water footprint. However, not all organic farming techniques do so, therefore farmers who care about conservation should carefully weigh their alternatives.

6. Cut down on alkaline salts

management of land, water, and vegetation to prevent and reduce salt and/or sodium buildups at the surface and in the root zone. The Soil Restoration page will go into further depth on this subject. Techniques for conserving water include policies, strategies, and actions taken to manage fresh water as a sustainable resource, to safeguard the aquatic ecosystem, and to satisfy present-day and future human demand. Affluence, growth, family size, and population all have an impact on water use. Pressure on natural water supplies, particularly in industries and agricultural irrigation, has grown due to factors including climate change.

1) Ensuring water availability for future generations by ensuring that freshwater loss from an ecosystem does not exceed its natural replacement rate is one of the objectives of water conservation activities.

2) Energy conservation, since facilities for waste water treatment, distribution, and pumping water use a lot of energy. Over 15% of the total power used in various parts of the globe is used for water management and

3) Habitat preservation, when reducing human water consumption helps to maintain the water's quality and freshwater habitats for nearby species. However, the following are some water conservation strategies that are beneficial.

4) Any efficient reduction in water consumption, loss, and resource waste.

5) Preventing any deterioration in water quality. And

6) Enhancing water management techniques that reduce consumption or increase the useful use of water. Farmers may save water by using more effective irrigation equipment, weather equipment, good soil management, water recycling, organic agricultural practices, minimizing the use of alkaline salts, ecological restoration, and management of wildlife habitats.

CONCLUSION

These physical conservation techniques have larger effects, favorably affecting food security and agricultural output. They help farmers to preserve or grow their crop yields over time and eventually contribute to the world food supply by lowering soil erosion and boosting soil fertility. It is crucial to include physical soil and water conservation practices into land-use planning, agricultural policy, and educational initiatives in order to assure their broad acceptance and effectiveness. Additionally, efforts in research and development should go on to improve these procedures and modify them to fit changing environmental circumstances. A proactive step toward sustainable land management is the prudent use of physical soil and water conservation strategies in the face of escalating environmental concerns, such as soil deterioration and water shortages. Governments, farmers, and environmentalists must adopt these strategies as essential parts of our team effort to protect the planet's priceless soil and water resources for coming generations.

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CHAPTER 3

AN OVERVIEW OF SOIL TILLAGE SYSTEM

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

ABSTRACT:

Soil tillage systems represent a pivotal component of modern agriculture, profoundly influencing soil health, crop production, and environmental sustainability. This abstract offers an overview of various soil tillage systems, including conventional, reduced, and no-tillage practices, highlighting their impacts on soil structure, nutrient management, and erosion control. It explores the trade-offs associated with different tillage approaches and emphasizes the need for context-specific decision-making. The abstract concludes by underlining the importance of adopting conservation-minded tillage systems to balance agricultural productivity with long-term soil and environmental preservationsoil tillage systems are integral to agricultural practices worldwide, and their influence extends far beyond crop cultivation. This review has illuminated the multifaceted implications of different tillage approaches, underscoring the importance of informed decision-making.Conventional tillage, while effective in weed control and seedbed preparation, often comes at a cost to soil health, leading to erosion, compaction, and nutrient loss. On the other hand, reduced and no-tillage systems have emerged as promising alternatives, offering improved soil structure, reduced erosion risk, and enhanced water retention. They also contribute to mitigating climate change by sequestering carbon in the soil.

KEYWORDS:

Agricultural Machinery, Conservation Tillage, Crop Cultivation, Farm Equipment, Farming Practices, Plowing.

INTRODUCTION

All crops are produced with a tillage method of some kind. To plant seeds, seedlings, tubers, or other plant propagation materials, it may be as easy as punching or digging holes in the soil. Competing plants may then be eliminated by hoeing or slashing. On the other hand, it might be a very intricate system that includes initial tillage, several successive tillage’s, the use of fertilizers and pesticides, and the planting process. Additional operations may be employed after plant establishment to manage weeds, prevent erosion, or crack surface crusts to improve soil aeration or water penetration. There are an endless number of methods that have been or are being utilized to create the world's food supply in between the two extremes mentioned above.

Even within the same geographical area, it is uncommon for two manufacturers to follow precisely the same procedures in terms of things like kind, timing, depth, and speed of operation. Practically speaking, each farmer has his or her own tillage method. It is beyond the purview of this paper to describe a range of systems that seems to be infinite. The development of several generalized tillage techniques will be addressed in relation to how they affect crop productivity and the conservation of soil and water resources.Here are some condensed explanations of the tillage system's significance drawn from various literary sources[1], [2].

1. All seedbed preparation procedures that optimize soil and environmental conditions for seed germination, seedling establishment, and crop development are referred to as tillage.

2. The soil-related activities required for crop production are referred to as tillage. Tillage, according to Antapa and Angen, is any procedure used to get the soil surface ready for planting crops.

3. According to Ahn and Hintze's definition, tillage is any physical loosening of the soil that takes place throughout a variety of cultivation procedures, whether done manually or mechanically.

Goals and Advantages of the Tillage System

Tillage's overarching objective is to boost agricultural yield while preserving resources and the environment. While the advantages of tillage systems are: 1. preparation of the seedbed; 2. weed control; 3. reduction of evaporation; 4. improvement of water infiltration; and 5. erosion management. Crop yields are raised and maintained as a consequence of these advantages. The aforementioned definitions of tillage include the ideas and traits of both conventional and conservation tillage systems.

Different Tillage Systems

The two main categories of tillage systems are conventional and conservation tillage methods.

Systems for minimizing tillage

According to the Conservation Tillage Information Center, traditional tillage techniques that invert the soil and bury crop leftovers are not included in conservation tillage. The CTIC classified conservation tillage systems into five categories:

No-tillage

The no-till system is a specific kind of conservation tillage that entails a one-pass planting and fertilization operation with little disturbance to the soil or surface leftovers. For the protection of soil and water, the surface residues of such a system are crucial. Herbicides are often used to manage weeds, while crop rotation may also be used in certain circumstances. According to Lal, no-tillage techniques do away with all mechanical pre-planting seedbed preparation except for the opening of a tiny hole or narrow strip for the laying of seeds to guarantee optimal seed/soil contact.

Crop residue mulch or destroyed sod covers the whole soil surface. No-tillage with residual mulch is optimal for Luvisols in the humid tropics, according to a study of tillage research in Nigeria.

Northern Tanzanian mechanized wheat farming and certain permanent crops, such coffee plantations, employ no-tillage techniques. No-tillage systems have been successful in several US regions, according to many research. No-till farming is becoming more common, but acceptance has been gradual[3], [4].

The USA's dryland regions utilize a sort of no-tillage technique called no-till fallow. Areas with summer rains have had the most results with no-till fallow. Recharging the soil profile with water in order to significantly lower the probability of failure for the next crop is one of the main objectives of fallowing.

When compared to alternative tillage techniques, no-till fallow has the ability to reduce soil erosion more effectively, store more water, use less energy per unit of output, and provide greater grain yields. Herbicide usage is a significant drawback of no-till fallow since it helps manage weeds.

Mulch cultivation

Mulch tillage methods are founded on the idea of minimizing soil disturbance and retaining as much crop residue as possible on the soil surface while yet achieving a rapid germination, a sufficient stand, and a satisfying yield. Lal also said that any hard crust or hard pan in the soil may be broken up by using a chisel plough in the previously shredded crop leftover. It is important to take care not to integrate any crop residues into the soil, however. Special mulch tillage methods or procedures are required when using living mulch and crop leftovers in situ. The residue of a dead or chemically killed cover crop left in place, known as in situ mulch, is increasingly being used in mulch tillage methods. A farmer in Georgia, USA, employed stubble mulch tillage or stubble mulch farming for the first time to reduce water erosion in the early 1930s. This crop production method uses surface residues. It was created mainly to reduce wind erosion, but it quickly became clear that it was also valuable for lowering runoff and stopping water erosion. Small- and large-scale farmers in Tanzania use this technique for both annual crops like wheat and barley and perennial crops like coffee and bananas.

Zo-neal or strip tillage

the idea of zonal or strip tillage. A soil management zone and a seedling zone are separate areas of the seedbed. To optimize the soil and microclimate conditions for germination and seedling establishment, the seedling zone is mechanically tilled. The interrow zone is mulch-protected and not disturbed. Strip tillage may also be accomplished by chiseling in the row zone to promote root growth and aid in water penetration.

Hill till

In this approach, the soil is not disturbed before planting but a third of the soil surface is tilled during planting using sweeps or row cleaners; row crops are planted on prepared cultivated ridges, and weeds are managed with herbicides. For the cultivation of corn and soybeans in the USA, ridge till is becoming more and more popular as a conservation technique.

Little Or Reduced Tillage

This methodology satisfies the 30% residue criterion while also covering alternative tillage and cultivation methods not mentioned above. The phrase "minimal tillage" is not necessarily used in Africa with the same connotation as it is in temperate regions. It may also be used differently depending on whether shifting cultivation is being utilized or automated agriculture is being used.

Customary tillage techniques

Mechanized and conventional systems make up the conventional system;

I automated systems

These include mechanically moving the dirt throughout the whole field via plowing, followed by one or more harrowing operations. The kind of tool used, the number of passes made, the soil, and the type of crop being planted all affect how much soil disturbance occurs.

II Conventional farming

The most significant native tools are the cutlass and hoe, which come in a variety of forms depending on their role, and are used mostly by manual labor in the humid and subhumid areas of West Africa as well as in certain parts of South America. With a cutlass, forest undergrowth or grass is removed to make room for seedbed preparation and planting. Trees and shrubs are left but are clipped. Burning in place is used to dispose of the chopped biomass and leftovers. This form of clearing is non-exhaustive since it leaves behind the root system that offers the topsoil structural integrity for a year or two, as well as a sizable amount of soil cover.

DISCUSSION

Tillage is a capital- and energy-intensive activity in large-scale mechanized farming and a labor-intensive activity in low-resource agriculture done by small landowners. The decision of a tillage method will rely on one or more of the following elements for every specific location:

Choosing a Tillage System

The tillage strategy used for a certain circumstance relies on aspects including the climate zone, the crop to be cultivated, the soil characteristics, the producer's economic status, his or her preferences, societal pressures, and governmental regulations. The apparently unlimited diversity of systems noted earlier is due to the fact that no variable is completely independent of the others. The impact of each variable, however, on the choice of tillage strategy and, therefore, on soil and water conservation, will be explored. To prepare the seedbed, control weeds, manage crop residues, mix fertilizer into the soil, improve soil aeration, reduce compaction, and achieve the best soil temperature and moisture regimes, tillage activities are necessary. The selection of tillage techniques is influenced by soil, meteorological, crop, and socioeconomic variables. Conservation tillage, a crop production method that manages surface residues, stops degradative processes, enhances soil productivity, and restores soil quality. While the specific site-specific conservation tillage practices are required.

It is crucial to fit the technique to the soil type, crop cultivar, meteorological variables, and other environmental elements in order for them to be applied and used successfully under a variety of soil circumstances. Suitable advice for farmers should be based on data from scientifically sound, suitably resourced, long-term trials. The development of effective and specific herbicides to control weeds for countries where the farmers can afford them, development of suitable crop rotations including cover crops, and improved cropping sequences that result in more effective storage of rainfall and efficient utilization of available resources are among the priorities for the development of conservation tillage systems.

These priorities are especially important for farmers in tropical Africa who have limited resources. The following are some definitions and explanations of the tillage system that have been condensed from many sources of literature: 1) Tillage covers all seedbed preparation procedures that optimize the soil and surrounding environment for seed germination, seedling establishment, and crop development. 2) The soil-related activities required for crop production are referred to as tillage. Tillage, according to Antapa and Angen, is any procedure used to get the soil surface ready for planting crops. And last, according to Ahn and Hintze's definition, tillage is any physical loosening of the soil that is done throughout a variety of cultivation processes, whether they are done manually or mechanically. Tillage's overarching objective is to boost agricultural yield while preserving resources and the environment. While the advantages of tillage systems include the preparation of the seedbed, weed control, reduction of evaporation, improvement of water infiltration, and erosion control. Crop yields are raised and maintained as a consequence of these advantages.

The aforementioned definitions of tillage include the ideas and traits of both conventional and conservation tillage systems. The two main categories of tillage systems are conventional and conservation tillage methods. No-tillage, mulch tillage, strip or zonal tillage, ridge till, and reduced or minimal tillage are the several types of conservation tillage methods. While the typical system included both traditional and mechanized methods. The decision about tillage will be influenced by one or more of the following criteria for any specific location: 1) Soil parameters, including erodibility, erosivity, rooting depth, texture and structure, organic-matter concentration, and mineralogy. 2) Climate and the length of the dry spell). Crop-related variables; 3. Socioeconomic aspects are number four. 5) Economical considerations, including the potential for more intense cropping, the ability to avoid lengthy fallow times due to improved water conservation, and in many cases, better agricultural yields. And 6) Other elements. The tillage strategy used for a certain circumstance relies on aspects including the climate zone, the crop to be cultivated, the soil characteristics, the producer's economic status, his or her preferences, societal pressures, and governmental regulations. The apparently unlimited diversity of systems noted earlier is due to the fact that no variable is completely independent of the others[5], [6].

Soil tillage's effects on crop production

Tillage has played a significant role in agricultural technical advancement, particularly in the production of food. Preparing the seedbed, preserving the soil and water, and controlling weeds are some of the goals of tilling the soil. Depending on how suitable or inappropriate the techniques are, tillage has different physical, chemical, and biological consequences on the soil that may be both useful and damaging. Physical factors that directly affect soil productivity and sustainability include aggregate stability, infiltration rate, soil conservation, and water conservation, in particular. Tillage technology first appeared in the form of stick or metal jabs used for seeding, and as agriculture gradually advanced, it went through phases of animal-drawn ploughs, tractor-drawn equipment, and more recently, more potent machines. The use of energy sources and their availability are at the heart of all this progress. Fossil fuels are now the primary energy source in rich nations and in certain emerging nations, however in the majority of developing tropical nations, human labor still dominates. However, many developing nations, especially those in the semi-arid tropics, have a heritage of using animal draught power. The lack of sufficient fodder is and has always been a key barrier to the usage of animals.

Tractors and other tools have recently been deployed in several developing nations in an effort to boost food production. The common lesson discovered in the majority of these nations is that the equipment often wasn't selected in accordance with the numerous agro-ecological zones and soil kinds. Additionally, the personnel working on the tillage operations lack sufficient training. Widespread soil deterioration and decreased soil production are the results of this. The modernisation of African agriculture is now confronting significant difficulties. Inevitably, food supply must keep up with population increase. There won't be much additional land available for agricultural expansion in many nations until then, leaving little choice except to increase production per unit area. In order to sustainably increase agricultural yields and soil productivity, soil management and conservation must play a significant role[7], [8].

Two crucial aspects of soil management in Africa, particularly in the semi-arid tropics, are tillage and residue management, which have a direct impact on soil and water conservation. Due to the different soil and climatic restrictions, as well as the ease with which substantial soil degradation occurs if farm activities are not properly managed, this agro-ecological zone offers a huge potential for greater agricultural output but also presents a significant challenge. This module discusses and emphasizes the tillage components of soil management, in particular, research, development, and technology transfer to users to boost agricultural productivity in Africa.

Soil tillage is one of the fundamental and crucial elements of agricultural production technology. Around the globe, several types of tillage are used, from the simple stick or jab to the complex para-plough. No tillage, minimal tillage, conservation tillage, and conventional tillage are the main categories into which the techniques adopted, regardless of the equipment employed, may be divided. With regard to the different tillage techniques, energy is crucial. Why till? is a key question at the heart of all these procedures. There has been a lot written on this subject, which may be summed up as follows:

1.Preparing the seedbed

2.Water and soil conservation

3.Prevention of erosion

4.Releasing tightly packed soil

5.Weed removal

The least amount of tillage required to cultivate the desired crop is often included in the best management practices. This not only results in significant energy cost savings, but also guarantees that a resource base, namely the soil, is preserved to produce in a sustainable manner[9], [10].

Tillage's Impact on Soil Qualities

Physical, chemical, and biological aspects of the soil are impacted by tillage. The key physical characteristics altered by tillage are soil aggregation, temperature, water penetration, and retention, according to research findings that have been extensively publicized. Both the kind of soil and the makeup of the soil affect how drastic the changes are. Chemical property changes are mostly influenced by the amount of organic matter in the soil. The rate of organic matter decomposition is impacted by tillage, which also impacts aeration. Through the actions of earthworms, termites, and the many other living things in the soil, biological activities in the soil are essential to soil production. These penetrate the soil, affecting the rate of water penetration, and their mucilage encourages soil aggregation. The management of crop residues in and on the soil's, surface has a direct impact on how tillage affects the soil. Crop residue management and tillage are the two methods having the most influence on soil conservation, according to study. In the semi-arid tropics, surface soil residue management, which is more concerned with soil and water conservation, is replacing the customary plowing-in of crop leftovers.

Effect of Tillage on Crop Yield

Numerous experimental studies on the impact of tillage on crop yields under diverse climatic, agro-ecological, soil, crop, and residue management systems have been published. Some of these circumstances either directly or indirectly connect the tillage impact to soil aggregation, which affects water penetration rate and water storage capacity. In semi-arid settings, moisture conservation is very crucial. The different responses that different soil types have to tillage are very important in choosing which approach is best. However, while choosing between two practices to follow, socio-economic factors should always be taken into account.

When comparing different tillage treatments in the past, problems have occurred since there was little information provided on the varieties of soil. Transferring technology from one soil type or agro-ecological zone to another requires considerable prudence. Additionally, there has been considerable misunderstanding about the no-tillage technique. There have been several occasions when residues were removed, as opposed to certain examples where surface soil was mulched or pesticides were employed to kill weeds in situ. In these situations, comparison is not only challenging but conclusions may also be reached that are not applicable to soils and agro-ecological circumstances that are comparable. Depending on the agro-ecological zone, tillage may have different consequences. One of the most important things to take into account in semi-arid areas is moisture conservation. the significance of managing residues and tillage on soil water content. 20–30 centimeters of the soil were mechanically tilled. Similar to how different soils may respond differently to the same tillage method, not all crop species are affected by tillage systems in the same way, affecting crop output in different ways. the impact of tillage on the yields of different crops in the semi-arid tropical regions of West Africa. Out of all the crops evaluated, cotton had the poorest yield gain with tillage.

The management of agricultural residues and moisture conservation are thus intimately related in semi-arid regions, where tillage has an impact. The relationship between agricultural residue management and tillage is emphasized by researchers, who identify these two practices as having a significant influence on soil conservation in semi-arid regions. The production of cowpeas was dramatically boosted in a cropping system in Burkina Faso through residue retention. Porosity, water infiltration, and water storage are all increased when sufficient amounts of residues are preserved. Further impacts of various tillage techniques on sorghum yield.

Deep plowing enhanced grain sorghum production on the Luvisol in comparison to other treatments. Numerous findings in the literature demonstrate that conventional tillage produces higher crop yields than conservation tillage. There are, however, a lot of other findings that demonstrate the opposite. In both situations, the economics of the tillage input, including labor and energy expenses as well as capital equipment investments, are not taken into account. When determining a system's economics, the impact of tillage on soils must be taken into account in both the short- and long-term.

The abundant published data on tillage makes clear that the impact on crop output and soil varies depending on soil conditions. Therefore, generalization and the transfer of technology should be handled with more care than in the past. The choice of tillage techniques is influenced by a number of variables, but soil characteristics are crucial in determining the amount, frequency, and kind of tillage needed. Therefore, many emerging nations would profit by fully using their soil data to purchase tillage technology packages created abroad. Climate variables, such as soil temperature regimes, rainfall patterns, and the duration of the growing season, should also be considered in addition to soil parameters. Given the connection between tillage and climate, it is crucial to consider the unique characteristics of the soil and the crop when deciding the precise kind of tillage operations.

Conventional tillage outperforms no tillage, reduced tillage, or mulching in semi-arid settings with a variety of crops, including sun hemp, barley, mustard, and chickpea produced during the dry season. Soil inversion and deep plowing outperformed no tillage in boosting plant-available water and crop production in semi-arid parts of West Africa. Similar findings indicate that tillage produces higher reactions than either no tillage or very little tillage. On particular soils and in some climates, some workers in the United States and worldwide have discovered that conservation tillage is better and a more economical agricultural technique than conventional tillage. Despite the widespread use of conservation tillage, for instance in the United States, generalization should be avoided. There is compelling evidence that conventional tillage performed once every two to three years would be beneficial for soils prone to surface crusting and sealing.

Factors influencing the selection of tillage techniques

Tillage Development Strategy

In affluent nations, tillage research has advanced with equipment improvement. Since small-scale farmers in Africa generate the majority of the continent's food, the restricted scope of tillage research and the neglect of small-scale tool development have had a negative impact on food production. Complex variables including rising population and food demand, young flight from rural regions, and an aging agricultural population make the situation more difficult. These farmers are finding it harder and harder to put up with the grind of utilizing crude tools. In order to develop and enhance tillage equipment and teach specialists and farmers in its effective usage, it is important to construct additional centers. Such centers may at first be situated in semi-arid and savannah regions where the usage of draught animals is customary. To supply feed for animals and release agricultural leftovers for soil management, crop rotation and cropping systems will need to be enhanced. Considering the lack of research institutes, a significant amount of study on tillage has been done in Africa during the last 20 years. The various farming systems, climatic circumstances, and soil types, however, need further detailed study. There must be careful thought given to the utilization of agricultural waste for soil management. But only if other fuel and feed sources can be created for draught animals as well as for the provision of home energy supplies would this be possible. Options with great potential include developing suitable agricultural systems and including legumes into the rotation. In designing tillage trials, more emphasis has to be placed on the utilization of soil and meteorological data. To offer accurate recommendations for the kind of conservation tillage system appropriate to the various soil types, the impacts of tillage on different soil types must be evaluated. These rules should also be simple enough for farmers to follow. The strengthening of information distribution methods among tillage research workers is one of the key strategies for the development and transmission of suitable tillage technology in Africa. In addition to ensuring efficient use of the scarce human and financial resources, this will also prevent needless duplication of research work already done under comparable ecological and climatic conditions elsewhere.

As a result, countries may think about cooperating and connecting research programs through networking systems. Such agreements can only have the intended effect if individual nations invest enough time and money into creating cooperation programs. In Africa, tillage work has mostly been done in agro-ecological zones that are semi-arid and sub-humid. There isn't a lot of information accessible on the wet tropics. Due to the availability of animal draught power, the crops and cropping systems used, and the urgent need for the development of soil and water conservation and management practices to increase crop production, the semi-arid zone has the best prospects for rapid tillage technological package development. One cannot overstate the importance of using soil, climate, and cropping system data more effectively when constructing tillage strategies in the area. The naming and categorization of the different soil types are essential prerequisites. Any common tillage network program created in Africa should include information distribution as well as standardization of research methodology. A significant obstacle to raising output on the majority of small farms in Africa is the absence of institutions for the creation and upgrading of instruments specifically for small farmers. Planning must take into account the preservation of the resource base, especially any projected soil, in order to achieve sustainable productivity. Tillage procedures must also be evaluated before being used on a larger scale. Soil tillage is one of the fundamental and crucial elements of agricultural production technology. Around the globe, several types of tillage are used, from the simple stick or jab to the complex para-plough. No tillage, minimal tillage, conservation tillage, and conventional tillage are the main categories into which the techniques adopted, regardless of the equipment employed, may be divided. With regard to the different tillage techniques, energy is crucial. Why till? is a key question at the heart of all these procedures. There has been a lot written on this subject, which may be summed up as follows:

1.Preparing the seedbed

2.Water and soil conservation

3.Prevention of erosion

4.Releasing tightly packed soil

5.Weed removal

The least amount of tillage required to cultivate the desired crop is often included in the best management practices. This not only results in significant energy cost savings, but also guarantees that a resource base, namely the soil, is preserved to produce in a sustainable manner. However, the definition and significance of the term "tillage effects on soil and crop production," "tillage effect on soil properties," "tillage effect on crop yield," and "approach to tillage development in Africa" were also extensively covered.

CONCLUSION

Context-specific considerations should be made when selecting a tillage method, taking into account elements including soil type, climate, crop choice, and farm resources. Farmers may need help and instruction when they make the transition to reduced or no-tillage techniques since it may need changes to their management and equipment procedures.

The development of conservation-minded tillage techniques is crucial as global agriculture deals with expanding difficulties, such as the need to feed a growing population while protecting natural resources. It provides a way to achieve sustainable agriculture, in which crop yield coexists peacefully with soil health and environmental protection. Making choices about soil tillage are essential if we are to be able to sustainably satisfy the world's food demands in this period of climate change and resource shortage. Promoting and putting into practice soil tillage techniques that are in line with the larger objectives of agricultural sustainability and environmental stewardship requires close cooperation amongst stakeholders, including farmers, researchers, legislators, and environmental activists. Agriculture's future rests on our ability to strike a balance between production and appropriate soil and ecosystem management.

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CHAPTER 4

AN OVERVIEW OF THE PRINCIPLES OF SOIL EROSION

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

ABSTRACT:

Soil erosion is a natural geomorphological process, but human activities have accelerated it to alarming rates, leading to significant environmental and agricultural consequences. This abstract provides an overview of the principles of soil erosion, including its causes, mechanisms, and effects. It explores key factors such as land use, topography, and climate that influence erosion rates. The abstract also highlights various erosion control strategies and emphasizes the importance of sustainable land management practices. Ultimately, it calls for a collective commitment to mitigate soil erosion to preserve soil resources and protect ecosystems.the principles of soil erosion underscore the complex interactions between natural processes and human activities, which can result in the degradation of our most vital natural resource—soil. This review has illuminated the multifaceted nature of soil erosion, from its causes, mechanisms, and environmental consequences to the factors that exacerbate erosion rates.Human activities, including deforestation, agriculture, urbanization, and improper land management, have accelerated soil erosion to unsustainable levels. The loss of fertile topsoil, sedimentation in water bodies, and damage to ecosystems are just a few of the adverse effects of unchecked erosion.

KEYWORDS:

Conservation Practices, Erosion Control, Land Degradation, Sedimentation, Soil Erosion.

INTRODUCTION

Soil is the name for the topmost, most worn and broken-down layer of the earth's crust. The soil layer contains both mineral and organic material and may support plant growth. The depth of the soil varies from almost none to several meters, being less in some locations and higher in others. The atmosphere's effects are continually exposed to the soil layer. The two major forces that work on the soil layer to move and dislodge soil particles are wind and moving water. Soil erosion is the loosening of soil from its location and its movement from one area to another. The Latin word reordered, which meaning to eat away or dig, is the source of the English term erosion. In geology, the term "erosive hollow" was initially used to describe this phenomenon. Erosion is essentially a two-phase process that entails the separation of each soil particle from the soil mass, transportation, and depositing. A third phase known as deposition happens when there is not enough energy available to convey a particle.

Generally speaking, finer soil particles dissolve more quickly than coarse ones. Therefore, soil erosion is described as a process of soil particle separation, transit, and deposition. Sediment is undoubtedly the last result of soil erosion. Therefore, any substance that is broken up and carried or deposited by water, ice, air, or any natural force is considered to be sediment. This implies that the process of detaching, transporting, and depositing degraded soil particles is also referred to as sedimentation. Consequently, the sediment cycle's natural progression is as follows: By using erosive chemicals, soil particles may be detached from the soil bulk. Raindrops and runoff water contacting the soil surface are the main erosive agents in cases of water erosion. The entrainment and movement of loose soil particles away from their initial position is referred to as transportation. Through the stream system, sediments travel from highland sources and may ultimately arrive to the ocean. Not all of the sediment makes it to the ocean; some is left behind along the route at the foot of slopes, in reservoirs, and in flood plains. Nearly everyone agrees that erosion poses a severe danger to human health. Erosion affects agriculture field production by eroding and washing away organic debris and plant nutrients. global loads of sediment. Asia has the most suspended sediment output due to heavy monsoon rains[1], [2].

Issues Caused by Soil Erosion

For the existence and wellbeing of humanity, balanced ecosystems comprised of soil, water, and plant habitats are crucial. However, overexploitation has harmed ecosystems in the past in many regions of the globe, including certain regions of India. The ecosystem's ensuing imbalance is shown by a number of negative side effects, including the deterioration of soil surfaces and the regular occurrence of strong floods, among others[3], [4].

Severity of Continental-scale land degradation

Due to rapid soil erosion brought on by the aforementioned and other reasons, large areas of land have been permanently transformed into infertile surfaces. These damaged land areas are now a source of water contamination in the open ocean. In the downstream portions of rivers, dirt that has been eroded from highland regions has deposited, aggravating the situation. This has increased the size of the rivers' flood plains, decreased the clearance under bridges and culverts, and sedimented reservoirs. The main issues with soil degradation brought on by sedimentation include erosion from water and wind Gullies, ravines, tidal lands, and torrents.

You will be able to comprehend the concept and significance of soil erosion at the conclusion of this lesson. understand what causes soil erosion list the several forms of soil erosion. description of the causes of soil erosion what are the causes of soil erosion? Describe the mechanisms causing soil erosion. talk about preventing and reducing soil erosion.

Meaning and Definition of Soil Erosion

All landforms are impacted by the naturally occurring process of soil erosion. In agriculture, soil erosion is the process of a field's topsoil being worn away by the physical forces of water, wind, or pressures brought on by agricultural practices like tillage.

Causes Soil Erosion

No one particular factor can be blamed for soil erosion or considered to be the root of the issue. There are several underlying causes for this process, some brought on by human activity and others by natural causes. Following is a list of the main contributors to soil erosion:destruction of natural protective cover caused by forest fires, overgrazing, and excessive tree cutting, among other things, Inappropriate Land Use, maintaining the land bare while exposing it to the effects of rain and wind;growing crops that hasten soil erosion; removing organic matter and plant nutrients via careless crop patterns; cultivating along the land slope; andusing subpar irrigation techniques[5], [6].

Soil erosion types

Erosion due to Geology

A balance between a location's climate and the vegetation that shields the soil layer develops under unaltered natural circumstances. Trees and other vegetative coverings, such as forests, slow the movement of soil particles and restrain excessive erosion. But even with the natural cover, there is a certain degree of erosion. Geologic erosion is a gradual process that is countered by soil development as a result of the weathering process. In terms of agricultural fields, its impact is of little relevance.

Speeded Up Erosion

The natural equilibrium between the soil, its plant coverings, and climate is altered when land is placed under cultivation. In such a situation, surface soil is removed by natural forces more quickly than it can be produced via the process of soil formation. Accelerated erosion is the term used to describe erosion that takes place in this circumstance. It occurs at a faster pace than geological erosion. In agricultural terrain, accelerated erosion reduces soil fertility.

As stated by Erosion Agents

According to the agent that initiates the erosion activity, there are many forms of soil erosion. The four primary forms of soil erosion are listed below. Stream erosion Many locations across the globe experience water erosion. Actually, the most frequent cause of soil erosion is flowing water.

This includes rivers that erode river basins, rain that erodes different landforms, and waves from the sea that erode coastal regions. Higher altitude soil particles are eroded and transported by water, where they are then dumped in low lying places. Based on the many ways that water causes erosion, it is possible to further categorize erosion as raindrop erosion, sheet erosion, rill erosion, gully erosion, stream bank erosion, and slide erosion.

Sheet erosion

The movement of soil caused by raindrop splash and runoff is known as sheet erosion. It usually takes place uniformly along a slope and remains undetected until the majority of the useful topsoil has been gone. At the bottom of the slope or in low places, the eroded soil is deposited. Other signs include lower crop yields on shoulder slopes and knolls, lighter-colored soils, changes in soil horizon thickness, and lighter-colored soils.

Drill erosive Ness

When surface water runoff concentrates and forms narrow but well-defined channels, rill erosion occurs. When these distinct channels where the dirt has been washed away are small enough to not obstruct field mechanical activities, they are referred to as rills. Rills are often filled in each year as part of tillage activities.

Gully erosion

Surface channels deteriorate to the point that they interfere with routine tillage activities in a gully, which is an advanced stage of rill erosion. Due to gully erosion, some farms are losing significant amounts of topsoil and subsoil every year. Inadequate outlet design for local surface and subsurface drainage systems often leads to surface water runoff, which results in the creation of gullies or the enlargement of existing gullies. Sloughing and slumping of the bank slopes are caused by the soil instability of gully banks, which is often brought on by groundwater seepage. These failures often take place in the spring, when the soil and water conditions are most favorable for the issue. If corrective techniques are not planned and built appropriately, gully developments may be challenging to manage. Control techniques must take into account the reason for the increased water flow over the landscape and be able to channel the runoff to the correct exit. Significant quantities of land are taken out of production as a consequence of gully erosion, which also puts farm equipment operators in danger.

Bank Erosion

Surface water runoff and subsurface drainage systems have outlets in the form of created drainage channels and natural streams.

The gradual undercutting, scouring, and slumping of these drainage routes is known as bank erosion. Bank erosion issues may result from poor building techniques, insufficient maintenance, unrestricted animal access, and too-close cropping. Additionally contributing to bank erosion are improperly built tile outlets. Some do not work well because they lack a rigid outlet pipe, have a poor or nonexistent splash pad, or have outlet pipes that have been harmed by bank collapses, erosion, or equipment. The loss of arable farmland, the collapse of buildings like bridges, the increased maintenance requirements for drainage systems, and the washing out of lanes, roads, and fence rows are only a few of the direct effects of bank erosion.

Water Erosion's Aftereffects On-Site

1. The effects of soil erosion by water go beyond just losing priceless topsoil.

2. The loss of natural nutrients and applied fertilizers directly affects crop emergence, growth, and output.

3. Erosion has the potential to entirely eliminate or damage seeds and plants.

4. Especially during spring thaw conditions, organic matter from the soil, residues, and any applied manure is rather lightweight and may be easily carried off the field.

5. Along with the eroding soil, pesticides could also be moved away from the location.

6. The loss of soil may have an impact on the texture, quality, stability, and structure of the soil. The structure may be weakened and even the texture altered by the breakdown of aggregates and the removal of smaller particles, complete layers of soil, or organic substances. As a result, the soil may become less able to retain water, leaving it more vulnerable to harsh weather conditions like drought.

Off-site

The consequences of soil erosion by water off-site are not necessarily as obvious as the effects on-site. Eroded soil that has been dumped downward on a slope prevents or delays the germination of seeds, engulfs young seedlings, and makes replanting necessary in the affected regions. Additionally, downslope homes may collect silt, which may harm roads. Reaching streams or watercourses with sediment may hasten bank erosion, clog drainage channels, fill reservoirs, harm fish habitat, and impair downstream water quality. Pesticides and fertilizers, which are typically carried by the eroding soil, contaminate or pollute lakes, marshes, and other downstream water sources.

The management of "non-point" pollution from agricultural land is a crucial factor because of the potential gravity of some of the off-site effects.

Erosion by Wind

Most typically, wind erosion occurs in arid locations where powerful winds brush against different landforms, cutting through them and loosening the soil particles, which are then lifted and carried in the wind's direction. Sand dunes and mushroom rock formations, which are generally seen in deserts, are the greatest examples of wind erosion.

DISCUSSION

Wind erosion harms crops by burying plants or seed, sandblasting young seedlings or transplants, and exposing seed. Crops are destroyed, causing expensive delays and necessitating reseeding.Sandblasting leaves plants open to disease entrance, which lowers output, degrades quality, and lowers market value. Additionally, wind erosion may provide unfavorable operating conditions that delay field operations.In fields where wind erosion is a persistent issue, soil drifting is a fertility-depleting process that may cause poor crop development and yield losses. The soil's texture progressively changes as a result of ongoing drifting. Sandier soils lose fine sand, silt, clay, and organic particles, which reduces the soil's ability to retain moisture. This exacerbates the issue by making the soil more erodible.It is expensive to remove wind-blown soils from built drainage systems, roadways, fence rows, and the area surrounding structures. Additionally, soil particles may carry surface-applied chemicals and soil nutrients, which may have an effect off-site. Blowing dust may also endanger public safety and negatively impact human health[7], [8].

Erosion from tillage

The redistribution of soil caused by tillage and gravity is known as tillage erosion. It causes the soil to slide down the hill gradually, losing a lot of soil on the top slopes and building up on the lower slopes. This kind of erosion is a significant means of delivering water erosion. A field's convergent zones, where surface water runoff accumulates, are where soil is moved by tillage activity. Additionally, uncovered subsoil is quite vulnerable to erosion from wind and water. The greatest potential for soil movement "on-site" is due to tillage erosion, which is often more erosive than water or wind.

Tillage erosion's effects

The growth and yield of crops are impacted by tillage erosion. Due to weak soil structure and loss of organic matter, crop development on shoulder slopes and knolls is sluggish and stunted. It is also more vulnerable to stress under challenging environmental circumstances. Changes to the soil's composition and texture may make it more erodible and subject it to more erosion from wind and water.

Tillage erosion sometimes involves the movement of subterranean soil. The fertile topsoil in the lower slope locations may be buried by subsoil that has been transferred from higher to lower slope positions, which may further affect crop growth and production. According to studies, tillage-eroded fields may lose up to 2 m of soil depth on upper-slope locations, and maize yields can drop by up to 40%. Extreme situations need transfer of the displaced soils to higher slope locations as a kind of remediation[9], [10].

Ice Age Erosion

In cold climates at high elevations, glacial erosion, also known as ice erosion, is frequent. Large flowing glaciers cause earth to adhere to their bases when it comes into touch with the glaciers. This is ultimately carried by the glaciers, and when they begin to melt, it is dumped with the sliding ice pieces.

Elemental erosion

Although gravity erosion is less frequent than water erosion, it may nonetheless seriously harm both natural and artificial structures. Basically, it is the bulk movement of dirt brought on by gravity. Landslides and slumps are two of the finest instances of this. While landslides and slumps occur quickly, phenomena like soil creep take a while to manifest.

The Causes of Soil Erosion

The removal of soil from its original place and its transfer to a new one is known as soil erosion. Although in many places wind and glaciers are also the agents producing soil erosion, water is the main cause of this erosion. Rain, floods, and runoff all have a negative impact on the soil. In reality, soil is a mixture of sand, silt, and clay. When it rains, silt and clay particles are carried away by the flowing water and the soil particles are detached from the mountains and bare ground. Similar to this, soil erosion occurs when wind speeds during storms get too strong to completely peel off the top layer of soil. The actions of both people and animals are additional causes of soil erosion. The soil is naturally covered by vegetation. The flora in the pastures is destroyed as a result of the animals' constant grazing and wandering. Soil erosion is readily impacted by abandoned bare areas. The additional factors contributing to soil erosion include human activities such as clearing land for multiple uses, increasing agriculture, and chopping down trees.

The Causes of Soil Erosion

Detachment of soil particles from the soil mass, followed by transit and deposition of those soil/sediment particles, are all processes that contribute to soil erosion. In India, excessive deforestation, overgrazing, and poor farming methods are the primary causes of soil erosion. Because many intricate elements influence the rate of erosion, soil erosion is a particularly tough issue to manage. These elements consist of:

1. Climate as a factor

The quantity, intensity, and frequency of rainfall are climatic variables that affect erosion. A higher proportion of the rainfall is transformed into runoff when there is frequent or continuous rainfall, excessive soil moisture, or saturated field conditions emerge. This then leads to soil separation and transport, which accelerates erosion.

2. Thermometer

While rapidly thawing soil brought on by warm showers may cause catastrophic erosion, frozen earth is very resistant to erosion. The kind of precipitation is also influenced by temperature. Snowfall alone does not cause erosion, but high snowmelt in the spring may have a significant negative impact on runoff. The quantity of organic matter that accumulates on the ground surface and mixes with the topsoil layer is also influenced by temperature. The organic cover of the soil is thinner in regions with warmer weather. The organic matter layer on the soil's surface shields the soil from the force of falling rain and aids in the infiltration of precipitation, which would otherwise result in increased runoff. Organic matter in the soil makes the soil more permeable, which improves percolation and decreases runoff.

3. Geographical Aspects

Slope length, steepness, and roughness are topographical characteristics that have an impact on erodibility. Longer slopes often have a higher risk of erosion. At the bottom of the slope, where runoff concentrates and has the highest runoff velocity, there is the most potential for erosion. The quantity and intensity of rainfall, surface roughness, and slope steepness all affect how quickly runoff moves down a slope. The water will flow more quickly the steeper the slope. The likelihood that erosion and increased sedimentation may occur increases with flow rate. Slope speeds up erosion by accelerating the flow of water. Small variations in the slope have a huge impact on the damage. The speed of flowing water doubles with a four-fold increase in slope, according to hydraulics rules. The carrying capacity may be increased by 32 times, and the erosive force can be multiplied.

4. Soil

The erodibility of soil depends on its physical properties. Texture, structure, and cohesiveness of the soil all affect its ability to erode. The size or range of sizes of the individual soil particles is referred to as texture. Clay, silt, and sand are three general size categories, ranging from tiny to huge. The most vulnerable soil to erosion from wind and water is soil with a high concentration of silt-sized particles. Sand- or clay-sized particles in the soil make it less prone to erosion.The degree to which soil particles cluster together to create bigger clumps and pore gaps is referred to as structure.

Both the soil's capacity to hold onto water and its physical resistance to erosion are influenced by structure. Another characteristic is cohesion, which is the force that holds soil particles together and affects structure. Cohesive soils have individual soil particles that stick together when wet to create a dough-like consistency. Sand soils are the least cohesive, while clay soils are most cohesive.

5. Vegetation

The most significant physical component affecting soil erosion is undoubtedly vegetation. The soil is protected from the effects of rainfall by a healthy plant cover. Additionally, the soil becomes more cohesive and runoff-resistant as a result. Organic material is provided by vegetation, which also slows flow and filters silt. The state of the vegetation will decide whether erosion on a graded slope stops or simply marginally slows. The greatest defense against soil erosion is a thick, sturdy cover of plants.

Biological Soil Erosion Factors Biological variables that affect soil erosion include things like improper farming techniques, overgrazing by animals, etc. These elements may be generally divided into the following three categories. Factors affecting energy, resistance, and protection.

Power Factors

These are elements that may affect how likely it is for rain, runoff, and wind to result in erosion. Erosivity is the name given to this quality. In regions subject to water erosion, terraces and bunds may be built to shorten the length and steepness of the slope; in places subject to wind erosion, wind breaks or shelter belts can be built to provide protection from the wind.

Resistance Elements

They are sometimes referred to as erodibility factors and they are based on the chemical and mechanical characteristics of the soil. Runoff and erodibility are decreased by elements that improve water penetration into the soil, whereas erodibility is raised by any action that pulverizes the soil. Thus, agriculture may make sandy soils more erodible while reducing the erodibility of clay soils.

Protection Elements

This is largely concerned with aspects of plant cover. By catching the rain and slowing down runoff and wind, plant cover shields the soil from erosion. The level of protection offered by various plant coverings varies greatly. In order to choose the proper land use for each piece of land and reduce the rate of soil erosion, it is crucial to understand the rate of soil erosion under various land uses, degrees of length and slope, and vegetation coverings. Soil loss is the amount of soil that has migrated beyond a certain location. It is often stated in terms of mass, volume, time, and area per unit of mass or volume.

CONCLUSION

Effective soil erosion control requires a comprehensive strategy. This entails implementing erosion control techniques into sustainable land management strategies, such as contour farming, terracing, reforestation, and cover cropping. Policies and rules that support ethical land use and conservation activities are also essential. Not only is reducing soil erosion necessary for the ecosystem, but it is also essential for protecting water quality and guaranteeing food security. The prudent management of our soil resources is becoming more and more important as we deal with the issues of climate change and population expansion. Governments, farmers, landowners, and environmental groups must all cooperate in this situation. Campaigns for education and awareness should advance knowledge of soil erosion and its effects, promoting the use of erosion control measures on a worldwide scale. We must acknowledge the urgency of our efforts in light of the principles governing soil erosion. We can lessen the disastrous effects of erosion and promote a more resilient and sustainable future for our planet by adopting sustainable land management techniques and placing a high priority on the protection of soil resources.

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CHAPTER 5

SPECIFIC FACTORS: INFLUENCE TILLAGE EROSION

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

ABSTRACT:
Tillage erosion is a specific form of soil erosion resulting from conventional tillage practices in agriculture. This abstract provides an overview of the specific factors that influence tillage erosion, including tillage intensity, equipment, slope, soil type, and climate conditions. It explores the mechanisms by which these factors contribute to soil displacement and outlines the consequences of tillage erosion for soil health and the environment. The abstract underscores the need for adaptive tillage strategies and conservation practices to mitigate tillage erosion's detrimental effects and promote sustainable land managementspecific factors play a pivotal role in influencing tillage erosion, a form of soil degradation with far-reaching consequences.

This review has shed light on the multifaceted aspects that contribute to tillage erosion, emphasizing the significance of understanding and addressing these factors for sustainable land management.Tillage intensity, the choice of equipment, slope gradient, soil type, and climate conditions all interact to determine the extent of soil displacement during tillage operations. Excessive tillage, especially on steep slopes, in erodible soils, and under unfavorable weather conditions, can result in significant soil loss, reduced soil fertility, and sedimentation in water bodies.

KEYWORDS:

Erosion Control, Environmental Factors, Soil, Soil Erosion, Soil Management, Tillage Practices.

1. INTRODUCTION

Wherever soil is exposed to the wind's erosive action, wind erosion occurs. Surface roughness, slope, different kinds of cover on the soil surface, wind speed, duration, and incidence angle all affect how much soil is eroded by wind. Fine soil particles have the ability to travel long distances and at extreme altitudes.The following elements affect how quickly and how much soil is eroded by tillage:

Type of tillage machinery

Lifting and carrying tillage equipment often moves more soil. For instance, a chisel plow leaves far more crop residue on the soil surface than a traditional moldboard plow, yet it can move the same amount of material and further than the moldboard plow. Tillage erosion may be reduced by using tools that move the soil very little[1], [2].

Navigation

Depending on the tillage direction, tillage tools like a plow or disc send dirt either up or down hill. When tilling in a downslope direction compared to an upslope one, more soil is typically moved.

Depth and speed

The quantity of dirt moved will depend on the pace and depth of the tillage activities. Increased speed pushes dirt further while deep tillage disrupts more soil.

Amount of passes

Soil movement is decreased when tillage equipment makes fewer passes. Additionally, it leaves more crop residue on the soil's surface and lessens the soil's aggregates' pulverization, both of which may aid in preventing water and wind erosion[3], [4].

Soil Erosion Works

Detachment of soil particles brought on by rain action is what starts soil erosion. The detachable particles are moved by erosion agents from one location to another, where they eventually settle and begin the process of soil erosion. several methods of soil erosion.

Accelerated water erosion occurs in three stages.

Deposition of transported particles at some locations of lower elevation. i) Detachment or loosening of soil particles brought on by flowing water, freezing and thawing of the top soil, and/or the impact of raindrops. ii) Transportation of soil particles by floating, rolling, dragging, and/or splashing[5], [6].

Through splashing, rain improves the transfer of soil. Soil aggregates are separated by individual raindrops, which then deposit them as particles. If the scattered particles clog soil pores, water absorption is reduced. These particles form a crust at the soil surface when the soil dries, which causes runoff to further increase.

Erosion by Wind: Its Mechanisms

Three distinct stages might be used to categorize wind erosion as a whole. These are deposition, conveyance, and beginning of movement.The beginning of a movement A number of independent and cooperative mechanisms lead to the first migration of soil particles. Some grains may be bouncing up during the collision of grains rolling and bumping on the surface. It happens when immobile soil particles become loose due to wind force or the impact of moving objects.

Transport Once the particles have been displaced, there are three ways that they may be transported.

i) Saltation - In saltation, medium-sized soil particles are transported by wind and bounce back and forth repeatedly. The direct wind pressure on soil particles is what causes these bounces.

ii) Soil Creep - The saltation of the particles also promotes soil creep. Large aggregates are hit by the bouncing particles transported by saltation, which speeds up their travel.

iii) Suspension - When soil particles are exceedingly tiny, they are suspended and transported over great distances. The movement of smaller suspended particles occurs parallel to the ground and upward.When gravity forces outweigh the forces keeping the particles in the air, the particles deposition. When the wind speed is reduced by surface barriers or other natural factors, deposition may happen.

Controlling and Preventing Soil Erosion

1. A growth in vegetation

Plant and tree roots entwine and interlace to bind soil particles when the ground is covered with vegetation. Using this helps in two ways prevents soil from being eroded by running water and prevents soil particles from being blown away by wind or water. Falling plant leaves are transformed to humus by soil bacteria during the decomposition process. Thus, the soil is improved. The amount of vegetation on land may be increased through a variety of techniques. Below are a few of them:

2. Rotating crops

Crop rotation is the process of cultivating various crops on the same land at various seasons. This maintains plants growing on top of the soil. Legumes and cereal crops are alternated to maintain the soil's nitrogen enrichment.

3. Tree planting

Running water is more likely to erode soil on slopes. Reforestation is the process of planting trees on land that has lost its vegetation. Albizia, Cassia, Butia, and other trees are suitable for this.

4. Strip cropping

Crops are grown in strips with this method. The most popular technique is contour farming, where the crop strips are aligned perpendicular to the slope. When cropping in a wind-strip pattern, the cropping strips are positioned perpendicular to the wind's flow.

5. Management of grazing

By bonding with the soil particles via their roots, tiny plants and grasses may assist the topsoil stay in place. These plants are grazed by cattle, exposing the dirt. Therefore, grazing should only be permitted on land set aside for that purpose, and other areas should be kept free of grazing.

6. Terracing

Fields are shaped perpendicular to the slope. This causes the water to flow more slowly and enables it to irrigate the crops.

7. Dam construction

Water flow rate and volume may both be regulated by dams. This will stop the river banks' soil from eroding.

8. Wind barriers

To fend against high-velocity winds, trees are positioned across the wind direction. Shelter belts or wind breakers are the names given to these groups of trees.Soil is the name for the topmost, most worn and broken-down layer of the earth's crust. The soil layer contains both mineral and organic material and may support plant growth. The depth of the soil varies from almost none to several meters, being less in some locations and higher in others. The atmosphere's effects are continually exposed to the soil layer. The two major forces that work on the soil layer to move and dislodge soil particles are wind and moving water. Soil erosion is the loosening of soil from its location and its movement from one area to another. The Latin word erodere, which meaning to eat away or dig, is the source of the English term erosion. In geology, the term "erosive hollow" was initially used to describe this phenomenon. Erosion is essentially a two-phase process that entails the separation of each soil particle from the soil mass, transportation, and depositing. A third phase known as deposition happens when there is not enough energy available to convey a particle.

Generally speaking, finer soil particles dissolve more quickly than coarse ones. Therefore, soil erosion is described as a process of soil particle separation, transit, and deposition. Sediment is undoubtedly the last result of soil erosion. Therefore, any substance that is broken up and carried or deposited by water, ice, air, or any natural force is considered to be sediment. This implies that the process of detaching, transporting, and depositing degraded soil particles is also referred to as sedimentation. Consequently, the sediment cycle's natural progression is as follows: All landforms are impacted by the naturally occurring process of soil erosion. In agriculture, soil erosion is the process of a field's topsoil being worn away by physical forces such as water, wind, or pressures brought on by agricultural practices like tillage. The two primary factors that contribute to soil erosion are improper land use and the destruction of natural protective cover. Geologic erosion and accelerated erosion are the two main categories of soil erosion. Moreover, according to the substance that initiates the erosion action, into several categories. Water erosion is one of the four major forms of soil erosion. Erosion by Wind Erosion caused by tillage, glacial erosion, and gravitational forces. The removal of soil from its original place and its transfer to a new one is known as soil erosion. Although in many places wind and glaciers are also the agents producing soil erosion, water is the main cause of this erosion. One of the primary causes of soil erosion is climate change. Thermometer Geographical Aspects Soil. Plant life. Biological factors that contribute to soil erosion and other particular. The kind of tillage equipment, direction, speed, depth, and number of passes are all factors that affect tillage erosion. Detachment of soil particles brought on by rain action is what starts soil erosion. The detachable particles are moved by erosion agents from one location to another, where they eventually settle and cause soil erosion.

DISCUSSION

Reduced fertility, a drop in nutrient content, or a physical loss of topsoil are all signs of degrading soil. The latter state is more common in areas that are prone to soil erosion, where large volumes of soil, rock debris, and organic material are carried down slope by heavy rains to rivers and ultimately to the sea. Knowing the susceptibility of soils and the causes of such susceptibility can help reduce soil erosion. In general, the amount of erosion produced depends on the rain's capacity to separate soil particles from one another and the soil's resistance to the raindrop. Therefore, both erosivity and erodibility play a role in soil erosion. Soil erosion happens when rainfall erosivity is greater than the soil erodibility. The tendency of soils and rocks to succumb to erosion is known as erodability. A high erodability means that for a given amount of labor put forward by the erosion processes, a greater quantity of material will be removed. Erodability is handled differently depending on the kind of surface that eroded since the mechanics of erosion rely on the competency and coherence of the material. Erosivity is a word used to indicate the potential for soil erosion caused by raindrop impact, snowmelt runoff, or water provided via an irrigation system during a rainfall.Soil erosion happens when rainfall erosivity is greater than the soil erodibility. The corrosivity of rain. The possibility of dirt being carried off from disturbed, de-vegetated regions and moving into surface waterways during storms is referred to as rainfall erosivity[7], [8].

Erodibility of Soil

Based on the physical properties of each soil, soil erodibility is an estimation of a soil's capacity to withstand erosion. In general, soils with quicker infiltration rates, more organic matter, and better soil structure withstand erosion better. Silt, extremely fine sand, and certain clay textured soils are more easily eroded than sand, sandy loam, and loam textured soils. For a certain rainfall condition, a soil's erodibility allows for quantitative comparison with other soils. According to Bouyoucos, the mechanical composition of soil, such as the ratio of sand, silt, and clay, determines the soil's ability to erode.

Clay, sand, and silt have a range of particle diameters that include 0.002 mm for clay

Silt = 0.002–0.006 mm.

Sand measures from 0.06 and 2.0 millimeters.

Only in some circumstances is this signal reliable.

Increases in soil erodibility are a consequence of tillage and farming techniques that result in decreased soil organic matter levels, poor soil structure, and soil compactness. Compacted subsurface soil layers may lead to less infiltration and more discharge. The development of a soil crust, which has a tendency to "seal" the surface, might also result in a reduction in infiltration.

On certain locations, a soil crust can lessen the soil loss caused by sheet or rain splash erosion; but, a comparable rise in runoff water levels might cause more issues with rill erosion. For a variety of causes, past erosion has an impact on the erodibility of soil. Due to their inferior structure and lower organic content, many exposed subsurface soils on eroded sites have a tendency to be more erodible than the original soils. reduced crop yields and typically worse crop cover as a result of the reduced nutrient levels often seen in subsoils result in less crop protection for the soil. Conceptual Diagram Displaying Three Soils' Frequency Distributions Along the Erodibility Continuum. These might represent the same kind of soil under three varying degrees of disturbance, such as under low, moderate, or high stocking rates, or they could represent the reactions of three different soil types, such as clay, loam, and sand, to a comparable degree of disturbance[9], [10].

Factors and Causes of Soil Erodibility

variables that affect soil erodibility and how runoff and raindrops affect soil detachment. Under agricultural systems and conservation practices, these erodibility factors are indexes used to forecast the long-term average soil loss through sheet and rill erosion. Factor Kf only applies to the fine-earth percentage whereas factor Kw applies to the whole soil. Predicting Soil Erosion by Water, Agriculture Handbook 703, describes the process for calculating the Kf factor. USDA's Agricultural Research Service published A Guide to Conservation Planning using the Revised Universal Soil Loss Equation in 1997.

From local study, the K factors for the soils of Hawaii and the Pacific Basin were extrapolated. It was not necessary to employ the nomograph in Part 618, Subpart B, Exhibits, 618.91, to ascertain K factors for soils in Hawaii. The erosion prediction equations USLE and RUSLE employ the soil erodibility factors Kw or Kf. The characteristics of the soil that effect rainwater erosion include those. Water storage capacity, infiltration rate, and soil water flow. Rainfall and runoff-induced dispersion, detachability, abrasion, and movement. The subsoil's saturated hydraulic conductivity, organic matter concentration, structural size class, and texture are some of its most important characteristics.

Determination of Erodibility

The resistance of the soil to separation and transport is known as erodibility. It varies according to the soil's organic and chemical composition, aggregate stability, shear strength, and texture. The soil erodibility factor K identifies a soil's erodibility. There are various ways to calculate K, and the three most common ones are included in the list below.

1) Plots of In Situ Erosion

K may be measured in the field using erosion plots. They employ a typical set-up with bare soil, no conservation measures, and plots that are 22.13 meters long with a 7° slope. This method is expensive and time-consuming.

2) Calculating K in a Simulated Storm

This method takes less time, but it is more expensive. The fundamental issue is that no rainfall simulator developed to date can accurately reproduce all of the characteristics of real rain. However, erosion studies are using this strategy more often. In this research, the rain simulator is typically built of suction bars. Its height is 3.80 m, while its length and breadth are also 1.80 m. The nozzle type that creates water droplets that resemble those of natural rain is selected after testing many different types. Low pressure is used to discharge the water. The slope of a wooden tray with dimensions of 1 m by 2 m and 15 cm depth is set to 7° and put underneath the simulator. At the downslope end, a collecting structure is positioned to collect runoff and silt. In the wooden tray, soil samples gathered from several erosion-prone areas are arranged. After that, simulated rainstorms of varying intensities are applied to the soil. Since it is challenging to create a predefined intensity of rainfall, the nozzle is changed to low and high levels, and during the experiment, the depth of water reaching the wooden tray is measured using a beaker. Sediment and runoff volume totals are tallied and measured.

3) Prediction of K

Regression equations detailing the connections between K and soil chemical and physical parameters may be used to predict K.

Energy of Rainfall and Soil Erosion in Relation

It is generally known that the relationship between the depth of rainfall and the quantity of soil that is washed away is influenced by the strength of the rain. The findings of several research further imply that the relationship between soil splash rate and rainfall intensity and a measure of raindrop fall velocity is a multidimensional one.

Erosivity Definition and Meaning

Erosivity is a word used to indicate the potential for soil erosion caused by raindrop impact, snowmelt runoff, or water provided via an irrigation system during a rainfall. The possibility of dirt being carried off from disturbed, de-vegetated regions and moving into surface waterways during storms is referred to as rainfall erosivity.

Damage Caused by Rainfall

The possibility of dirt being carried off from disturbed, de-vegetated regions and moving into surface waterways during storms is referred to as rainfall erosivity. It might also be described as the possibility for erosion brought on by rain. It is based on the physical features of rainfall, such as the size, distribution, and kinetic and terminal velocities of the raindrops. Two storms' probabilities in terms of the amount of soil erosion they might generate for a certain soil state may be quantitatively compared. The ability of overland runoff flow to erode soil is partially a function of rainfall and partially a function of the soil surface. Soil loss is closely connected to rainfall erosivity. Greater overland water flow erosive capacity is indicated by increased rain erosivity. Where rainfall intensity and duration are greater than the soil's ability to absorb it, soil erosion by flowing water occurs. Numerous variables, including soil type, slope, and the power or energy of anticipated precipitation during the time of surface disturbance, affect the likelihood of erosion.

Factors Affecting the Erosivity of Rainfall

The numerous elements that influence a rainstorm's erosivity are listed as under:

1) Intensity of Rainfall

The rate of rainfall across the land surface is referred to as rainfall intensity. It is among the most significant causes of rainfall's erosive properties. The force with which a single water droplet impacts the soil surface is considered to be the intensity of the rainfall.

2) Distribution of Drop Size

A specific rainstorm's drop size distribution has a cumulative impact on the energy, momentum, and erosivity of the rain. The intensity of the downpour increases as the median drop size rises.

3) Terminal Velocity

The kinetic energy of the individual raindrops at the moment of their contact over the soil surface is used to measure the impact of the terminal velocity of falling raindrops. It depends on the magnitude of the descent. A downpour with a high percentage of larger raindrops will have a higher terminal velocity and vice versa.

4) Wind Speed

By affecting the kinetic energy of rainstorms, wind velocity influences the ability of rainfall to promote soil separation. The majority of the time, windy storms occur in tropical climates. Storms with strong winds are more successful than expected in fracturing the aggregates.

5) Angle of Slope

The erosivity of rainfall is significantly influenced by the direction of the land's slope. The real kinetic energy of the raindrop is effectively changed by a slope that faces the direction of the storm. As the velocity component in the slope-direction rises, the impact force of the raindrop grows.

Erosivity Estimation from Rainfall Data

The kinetic energy of rainfall affects how erosive it is. The two techniques listed below are often used to calculate rainfall erosivity.EI30 Index method and KE > 25 Index method are two examples.

1. EI30 Index Technique

This approach is based on the observation that the best estimate of soil loss is produced by multiplying the storm's kinetic energy by the highest 30-minute rainfall intensity. By determining the biggest quantity of rain that falls in a 30-minute period and afterwards translating that amount to intensity in mm/hour, the highest average intensity encountered during any 30-minute period throughout the storm is calculated by recording rain gauge charts. The EI30 index, a measure of erosivity, may be calculated for individual storms and the storm values accumulated over time to provide weekly, monthly, or annual values of erosivity.

2. KE > 25 Index Technique

This alternative approach to estimating the rainfall erosivity of tropical storms was proposed by Hudson. This approach is based on the idea that erosion only occurs when rainfall intensity reaches a certain threshold. Experiments revealed that rainfall intensities less than 25 mm/h are insufficient to cause considerable soil erosion. Therefore, this approach only addresses rainfall intensities larger than 25 mm/h. The K.E. > 25 Index technique has its moniker for this reason. The computation process is the same as for the EI30 index, and it is utilized in the same way.

Method

Both strategies use the same estimating process. However, the K.E. > 25 technique is preferable since it eliminates numerous data points that are less than 25 mm/h, using less rainfall data in the process. It is crucial to obtain information on the volume and intensity of rainfall for both strategies. The method entails multiplying the quantity of precipitation in each intensity category by the estimated kinetic energy values, and then adding all of these values to get the storm's overall kinetic energy. To calculate the rainfall erosivity value, the K.E. so obtained is once again multiplied by the maximum 30-minute rainfall intensity. Soil erosion happens when rainfall erosivity is greater than the soil erodibility. The corrosivity of rain. The possibility of dirt being carried off from disturbed, de-vegetated regions and moving into surface waterways during storms is referred to as rainfall erosivity.

Reduced fertility, a drop in nutrient content, or a physical loss of topsoil are all signs of degrading soil. The latter state is more common in areas that are prone to soil erosion, where large volumes of soil, rock debris, and organic material are carried down slope by heavy rains to rivers and ultimately to the sea. Knowing the susceptibility of soils and the causes of such susceptibility can help reduce soil erosion. In general, the amount of erosion produced depends on the rain's capacity to separate soil particles from one another and the soil's resistance to the raindrop. Therefore, both erosivity and erodibility play a role in soil erosion. Soil erosion happens when rainfall erosivity is greater than the soil erodibility. The tendency of soils and rocks to succumb to erosion is known as erodability. A high erodability means that for a given amount of labor put forward by the erosion processes, a greater quantity of material will be removed. Erodability is handled differently depending on the kind of surface that eroded since the mechanics of erosion rely on the competency and coherence of the material. The word "erosivity" refers to the ability for raindrop impact, snowmelt runoff, or water provided via an irrigation system to separate and erode soil.

CONCLUSION

Farmers and land managers must use adaptive tillage practices that take local circumstances and erosion sensitivity into account in order to reduce tillage erosion. Reduced tillage, no-tillage, contour farming, and cover crops are examples of conservation techniques that may effectively decrease soil disturbance and encourage soil conservation. These methods increase crop resilience while simultaneously enhancing soil health and reducing soil erosion. In addition, legislative support and educational programs are crucial for encouraging the use of erosion-reducing techniques and increasing knowledge of the effects of tillage erosion. Governments, agricultural extension agencies, and environmental groups need to work together to provide direction, rewards, and resources to ease the transition to more sustainable tillage practices.

Tillage erosion control is both a duty and an opportunity to advance the long-term sustainability of our food production systems in light of rising worries about soil deterioration, water quality, and the environmental effects of agriculture. We can achieve a balance between agricultural output and the preservation of our priceless soil resources by taking certain elements into account and implementing conservation-minded measures.

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CHAPTER 6

A BRIEF DISCUSSION ON AGRICULTURE AND FOOD PRODUCTION

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

ABSTRACT:

Agriculture and food production are fundamental pillars of human civilization, providing sustenance, livelihoods, and economic stability for billions of people worldwide. This abstract offers an overview of the multifaceted dimensions of agriculture and food production, examining their historical significance, contemporary challenges, and future prospects. It delves into the role of technology, sustainable practices, and policy frameworks in shaping the agricultural landscape. The abstract concludes by emphasizing the need for a concerted global effort to ensure equitable, resilient, and sustainable food production systems to meet the demands of a growing world population while safeguarding the environmentagriculture and food production stand at the nexus of human well-being, economic prosperity, and environmental sustainability. This review has illuminated the intricate interplay of factors shaping these critical sectors, from historical developments to modern challenges and future possibilities.Agriculture's evolution from traditional practices to modern, technology-driven systems has dramatically increased food production, alleviating hunger and poverty for many. However, this progress has come at a cost, including environmental degradation, loss of biodiversity, and social disparities. Balancing the imperative to feed a growing global population with the need to protect the planet's natural resources is the defining challenge of our time.

KEYWORDS:

Agribusiness, Agricultural Practices, Crop Cultivation, Farm Management, Food Security, Livestock Farming.

INTRODUCTION

Over 67 percent of the population in sub-Saharan Africa is supported by agriculture, which is the region's most significant economic activity. However, 60 percent of this population relies on rain-based rural economies, which provide between 30 and 40 percent of the region's GDP. Rainfall is unevenly distributed, however, with central African nations receiving 1,430 mm year while desert regions get just 71 mm. Additionally, the biggest obstacles to sustainable development in the area are poverty and food insecurity. There are more than 200 million people who lack enough food, which is 30 million more than there were ten years ago. More than 60% of the malnourished individuals in SSA reside in East Africa, where there are about one-third more malnourished people than in West Africa. Kenya, Tanzania, and Uganda are three of the ten nations that make up the East Africa area, along with Djibouti, Ethiopia, Eritrea, Somalia, Rwanda, Burundi, and Sudan. The area is referred to as the "Greater Horn of Africa" at times. Over 50% of people live below the poverty line in East Africa, which is home to some of the world's poorest areas. The average annual per capita income is less than US$300[1], [2].

The area, which is mostly classed as dryland with the exception of Uganda, Rwanda, and Burundi, is characterized by a semi-humid to semi-arid climate. Approximately all of the land in Somalia, Eritrea, and Djibouti is affected by drought, as is 61–87 percent of the area in Ethiopia, Kenya, and Sudan. In East Africa, annual rainfall ranges from 150 millimeters in desert and semi-arid parts to more than 2,000 millimeters in the rainy, mostly highland regions. This quantity of precipitation ought to be sufficient to guarantee sustained agricultural output. The reality is that agricultural output falls short of the potential of the land in almost every country, and crop failures are a typical occurrence. Long-lasting, frequent droughts and dry periods are often linked to poor production. However, only 5% of the irrigation capacity has been used. Additionally, humid areas have more than two thirds of the irrigation potential. Therefore, it is crucial to increase the productivity of rain-fed agriculture[3], [4].

According to recent research, rain-fed agriculture is beginning to succeed in East Africa, changing the lives of many impoverished farmers. To boost yields, cutting-edge and local technology have been used. These have entailed a broad range of treatments, including integrated soil fertility management, soil and water conservation, runoff and rainfall collection systems, integrated pest control, tillage and soil management systems, better seeds, and novel agronomic techniques. Additionally, the growth of participatory approaches in research, outreach, and training has sped up the expansion of effective treatments. Tools for extension that are appropriate have been created to enable farmer involvement in R&D. These success stories, however few and far between, highlight the necessity for ongoing data collection that builds on the understanding of effective techniques in order to reach as many farmers as possible and advance agricultural development in the area. The countries of Ethiopia, Kenya, and Tanzania are the focus of this paper's examination of some of the most widely used water and soil nutrient management techniques and strategies in East Africa.

Ethiopia

Ethiopia has a land area of 1.13 million km2 and is located between the longitudes of 33oE and 55oE and the latitudes of 3.5oN and 15oN. Eritrea, Djibouti, Somalia, Kenya, and the Sudan all border the nation. Ethiopian highlands dominate the relief, and as a result, the climate varies greatly throughout the nation. The sub-tropical zone, which contains most of the highlands, gets 510 to 1,530 mm of rain annually, whereas the tropical zone receives less than 510 mm. The main rainy season typically lasts from mid-June to September, and is followed by a dry period that may sometimes be broken by the short-rains season in February and March. In the warmer tropical zones, mean annual temperatures vary from around 27 °C to about 22 °C. The population is estimated to be 70 million strong, with a roughly 3% yearly growth rate. The annual per capita income in 2002 was US$90.

Large tracts of flat ground, gently undulating hills, and sharp, jagged hills and valleys are among Ethiopia's topographical characteristics. The slopes may be as steep as 60% in the highlands, and elevations vary from just below sea level to more than 4,000 m above sea level, leaving broad regions more vulnerable to erosion. Despite being one of the most fertile regions in the nation, the Ethiopian highlands have seen significant resource degradation. Through the implementation of soil conservation initiatives, efforts to halt deterioration have been made since the 1970s. Despite some accomplishments, the outcomes have more often been dismal.

The drylands of Ethiopia, which include desert, dry semi-arid, wet semi-arid, and portions of the sub-moist zone, make up around 70% of the country's total landmass and 45% of its arable land. However, only 10% of the overall agricultural output comes from these regions. In arid and semi-arid areas, where almost half of the world's arable land is located, the majority of rural residents are dependent on small-scale dryland farming. The natural resource base in the drylands is very vulnerable. Because soils often have a coarse texture, are sandy, and are naturally deficient in organic matter and water-holding capacity, they are quickly eroded by both wind and water. As a consequence, even during typical rainfall seasons, crops might experience moisture stress and drought. Farmers now find themselves in poverty as agricultural output has drastically decreased.

Ethiopia's Agriculture and Food Production

Ethiopia's economy is based mostly on settled agriculture, which has been there since antiquity. The GDP it contributes to is 57%. In Ethiopia, agriculture employs roughly 85% of the workforce and generates 90% of the country's export revenue. The economic growth rate rose from 1.6 percent in the 1980s to 5 percent in the 1990s. Since 1992, significant adjustments in economic policy have created a favorable climate for growth. Reduced government involvement, privatization encouragement, market liberalization, and rationalization of currency rate policy are a few of them. Between 1979/1980 and 1993/1994, yearly increases in food output and grain production were only 0.5% and 0.4%, respectively. This translates to a 2.55 percent and a 2.7 percent drop in domestic food availability annually, respectively. A large portion of Ethiopia, particularly the mountain valleys, has excellent soil and enough rainfall for food development. However, the tremendous population pressures need ongoing farming of cropland. Pulses only make approximately 12% of the farmed acreage, which are occupied by cereals 82%. Teff, maize, sorghum, and barley are the primary crops. 13 million cattle, 12 million sheep, 10 million goats, 4.4 million horses, and 1 million camels are also present. Shoa, Arssi, and Gonder are typically the key food-producing regions. Wollo, Herarghe, Tigray, Bale, Sidano, and GanuGofa are among the problematic regions. With an average size of landholdings of roughly 1.5 hectares, Ethiopia's 7 million small-scale, resource-poor farmers dominate the country's agricultural sector. In Ethiopia, there are four main types of agriculture.

In the northern highlands of Tigray, the Amhara National Regional State, and the central highlands of Ethiopia, a system of cereal-oil-pulse-livestock farming is practiced. This system is well developed, has enormous potential, and the populace is dedicated to working hard. If water is provided and the land is enhanced with rich alluvial material, productivity might treble or quadruple.The western and southern parts of Ethiopia, the Southern National Regional State, Gambella, and Benshargul-Gumuz, as well as the Southern National Regional State, have cereal-livestock-hoe cultures with a short history of agricultural production.All regional states use pastoral farming, although afar, Somalia, and the Benshangul-Gumuz National Regional States are the most prevalent. The region is susceptible to drought, and current technologies are not well understood. Additionally, there is a shortage of skilled laborers in the region.

Oromiya and Southern Nationals, Nationalist and Peoples' Regional States reflect the agricultural system of coffee, maize, cattle, and root crops. With maize and enset as the main food crops, this system is located in regions with significant cash crops. Enset is a plant that resembles a banana that is often cultivated in backyard gardens in Ethiopia. Poor agricultural development has been attributed to a number of factors, including restrictions on strategies such as the development and conservation of communal lands and hillsides, "food for work"-based development, farmers' exclusion from daily development and conservation efforts, disregard for indigenous development and conservation skills, rural land use and tenure policies, ignorance of soil erosion, institutional setup, and continuity. Development initiatives have failed as a result of these restrictions. Additional explanations for the failures include biophysical and societal causes.

Modern agricultural inputs are very sometimes used. A key damaging process known as drought is further exacerbating the frightening pace at which environmental deterioration is progressing. The environment's carrying capacity has been decreased due to the rapid rise of both human and animal populations and the scarcity of arable and grazing land.The establishment of the Peasant Associations, which were crucial in organizing labor and allocating local responsibilities, and changes in extension approaches, from the top-down approaches to conservation initiated after the 1973/1974 famine and the 1975 land reform, are other aspects. Food-for-work initiatives have helped the highlands save 35 million person-days of labor since the 1980s.

The success rates, meanwhile, were modest. For instance, 60 to 70 percent of the trees that were planted survived. Additionally, similar soil conservation structures were built in various places; however, once compulsion ended, 53% of farms had them taken down, and 31% had them partially removed. Furthermore, the potential for agricultural growth in arid regions is often misunderstood. Instead of "low rainfall" regions, they are more usually referred to as "low potential" areas.

Along with cattle, millets, sorghum, cotton, cowpeas, dolichos beans, pigeon peas, oranges, mangoes, grapes, and passion fruits are grown on dry and semi-arid terrain. Paradoxically, these regions are where Ethiopia's food production will increase in the future since there hasn't been enough technology in these areas. In Ethiopia's Eastern Shoa Region, contour stone bunds, trapezoidal bunds, flood water diversion/spate irrigation, flood water farming systems, contour ridges/contour furrows, and semi-circular bunds are the most often used water harvesting techniques.

Kenya

Kenya, which spans an area of 582,646 km2, is located between longitudes 34oE and 42oE and latitudes 4.7oS and 5oN. Tanzania, Uganda, Ethiopia, Sudan, Somalia, and the Indian Ocean are all neighbors of Kenya. The terrain of the nation is varied, ranging from the ocean floor to high mountains like Mount Kenya, which rises 5,199 meters above sea level, and other highlands. The impact of height on climate is evident in the wide variations in annual rainfall throughout the nation, which ranges from less than 200 mm in the parched north to over 2,000 mm on the top slopes of Mt. Kenya. 80 percent of Kenya's territory is categorized as ASAL, getting 200 to 750 mm of precipitation annually. The ASALs are hot and dry, with unpredictable seasonal rainfall that makes it difficult to harvest healthy crops. As a result, ASALs are categorized as being unfit for agricultural cultivation. According to the 1999 population census, there are 28.7 million people living in Kenya. The population is growing at a 3% yearly pace. The annual per capita income in 2000 was US$350.

DISCUSSION

About 80% of Kenya's population, 19% of whom work for wages, derives their primary income from agriculture, the country's largest economic sector. It contributes 52% of the country's GDP, with 25% of it coming directly and 27% indirectly via connections to the manufacturing, distribution, and other service-related industries. Approximately 40% of all export income, 45% of government revenue, and 75% of all industrial raw materials come from agriculture. In Kenya, there are around 3 million smallholder agricultural households, and 80 percent of them have less than 2 hectares of farmland. 70 percent of maize, 65 percent of coffee, more than 50 percent of tea, more than 70 percent of cattle, and more than 80 percent of milk and other commodities are produced by smallholders. Despite this, it is estimated that 2 million Kenyans experience chronic food insecurity, and that figure rises to 5 million during droughts, even seasonal ones. 42 percent of Kenyans, according to the World Bank, are estimated to be living in poverty. Additionally, just 20% of Kenya's total geographical area is suitable for rain-fed agriculture [5], [6].

In Kenya, real agricultural spending and output decreased by 1% throughout the course of the 1990s, and agriculture's GDP contribution was negative. The contribution of smallholder farmers, however, was increasing. Similar to this, public financing for research and extension decreased, and as a consequence, maize yield improvements decreased to 0.3% between 1985 and 1991. In 2003, the agriculture industry rose by 1.5 percent, indicating that it has been rebounding in recent years. Population increases and a lack of expansion in other economic sectors have put growing strain on natural resources over time, causing a decline in soil fertility, productivity, and overall environmental deterioration. A weak capital base, excessive taxes on agricultural inputs, an unorganized marketing system, a drought, insecurity in rangeland areas, subpar extension services, insufficient exploitation of some water resources, and ineffectiveness of supporting agricultural infrastructure, such as cooperative societies, have all contributed to the situation's deterioration. These circumstances have prompted Kenya and her development partners to formulate the measures outlined in the Poverty Reduction Strategy Paper.

Measures required for poverty reduction, food security, and economic development are outlined in Kenya's Poverty Reduction Strategy Paper for the years 2001 to 2004. The essential sectors to combating poverty reduction have been highlighted as agriculture and rural development in general. Crop development and rural water access were regarded as the highest priority within the sector, followed by livestock development, food security, lands and settlement management, and fisheries. Strategies and methods have been put forward at the national level, and the present development plan is putting some of them into practice. They consist of the following. Development partnerships for agricultural and food security projects, capacity development and sustainability, and the implementation of purposeful programs to expose farmers to technology and information are all important aspects of ensuring food security. A wider range of stakeholders should be involved, strong links between farmer, extension, and research should be developed, a supportive environment should be provided for private sector participation in extension, value addition of agricultural products should be supported, gender equity should be addressed, and strategies for scaling up successful projects should be developed[7], [8].

Tanzania

Tanganyika's mainland plus the islands of Zanzibar and Pemba make form the United Republic of Tanzania. Zanzibar and Pemba take up around 1,658 km2 and 984 km2 of the country's total land area (945,087 km2), respectively. Tanzania may be found between latitudes 1oS and 12oS and longitudes 30oE and 40oE. It is bordered by the Democratic Republic of the Congo, Kenya, Uganda, Rwanda, Burundi, Zambia, Malawi, Mozambique, and the Indian Ocean. The majority of mainland Tanzania is a plateau with an average height of 1,200 meters, while the relief is often flat and low around the shore. In the northeast and southwest, solitary mountain ranges are present. The tallest mountain in Africa, Mt. Kilimanjaro, which has a snow-capped summit and rises 5,895 meters above sea level, is situated close to Kenya's northeastern border. Mt. Meru, the Pare Mountains, the Uluguru Mountains, and the southern highlands of Mbinga and Njombe are among the other highlands.

The Zanzibar, Pemba, and Mafia islands are small, low-lying islands that along the coast. Inland lakes, such Lake Victoria in the north and the Rift Valley lakes Tanganyika and Nyasa, encompass more than 53,000 km2. Tanzania has a population of roughly 34 million, with a 2.3 percent annual growth rate. In 2000, the annual per capita income was US$270, and 42% of the population was considered to be living in poverty.Tanzania has a more temperate temperature than Kenya and Ethiopia do. On the mainland coastal strip along the Indian

Ocean, the weather is warm and tropical, with average temperatures of 27°C and annual rainfall ranging from 750 to 1,400 mm. With an annual rainfall average as low as 500 mm, the inland plateau is hot and dry. On the islands, where the typical annual temperature hovers about 29°C, the sea breeze keeps things from getting too hot all year round. Tanzania is a mineral-rich nation that also produces trace quantities of gold, salt phosphate, coal, gypsum, kaolin, and tin. Nickel, soda ash, iron ore, uranium, and natural gas are all found in reserves. Tanzania's mineral potential hasn't, however, been completely realized[9], [10].

Tanzania's Agriculture and Food Production

The primary source of food, money, fuel, housing, and employment for both the rural and urban populations of Tanzania is agriculture. It provides 80% of the jobs and 70% of the foreign exchange. According to statistics, just 6.3 million hectares of Tanzania's 40 million ha of arable land are really under cultivation. Only 150,000 hectares of the potential one million ha for irrigation are actually being watered. This reflects the limitations of technology and the realities of smallholder agriculture. Growing food crops including maize, rice, beans, citrus, vegetables, root crops, and cash crops constitutes an essential economic component even though most farming is done for subsistence. Coffee, tea, cotton, sisal, tobacco, coconut, sugar, groundnuts, and cashew nuts are among the most important cash crops. In the islands of Pemba and Zanzibar, cloves play a significant financial role.

Small-scale farmers with little access to money produce the majority of the world's crops and animals. As a consequence, soil fertility is dropping throughout the majority of the nation's agricultural systems. More product is being sold and processed as a result of economic liberalization, which hastens the loss of natural soil fertility. The main obstacle facing agricultural research, extension, and development organizations is reflected in these two opposing tendencies. A few of the issues that have plagued Tanzanian agriculture include the drafting of broad suggestions that are too general to be useful for individual farmers and the lack of chemical inputs in the nation's remote regions. Changes in policy implemented since Tanzania's economy was liberalized in 1986 have helped the agriculture sector thrive once again. The short-term remedies include reducing excessive local government taxes of agricultural production and commercialization and increasing budgetary assistance for agriculture. They also include improvements in loan access to farmers. Additional macroeconomic changes have improved rural infrastructure, boosted service privatization, and increased investment in research and extension.

Water and soil conservation techniques

Management of soil nutrients and water supply is essential to agricultural output. The need for soil conservation on typically very steep slopes while draining excess runoff safely, the need for water harvesting and conservation in drier areas, the available technology, which is typically manual or draught animal-powered, and labor determine water and nutrient conservation technologies. Ethiopia, Kenya, and Tanzania all have a rich history of indigenous and cutting-edge water and nutrient conservation technology, including centuries-old irrigation and water collecting systems.

There is virtually little difference between methods that collect rainwater for agricultural production and those that save soil and water. RWH and SWC both include practices that increase in-soil moisture storage for crop production while decreasing water losses due to runoff and evaporation. The two vary in that rainfall is preserved in-situ wherever it falls under soil and water conservation, while water harvesting involves making an intentional effort to move runoff water from a "catchment" to the targeted location or storage facility. The crucial point is that both methods work best together, and in arid regions with rain-fed agriculture, both are almost always required. Farmers in East Africa carry out various SWC interventions, which also serve as the cornerstone for numerous development initiatives with an emphasis on agriculture and land management. In East Africa, there are several indigenous and cutting-edge technologies used in SWC, RWH, and soil nutrient management. Some of them have shown to be simpler to copy, particularly those that can be used in a variety of biophysical situations and need little labor.Level contour bunds, grass strips, cutoff drains, hill terracing, and graded bench terraces are some of the more popular methods of SWC, RWH, and nutrient management in Ethiopia. Water harvesting is done using underground tanks, open pans and ponds, spate irrigation, and various tillage systems. Terracing, vegetative barriers, conservation tillage, runoff harvesting, and cutting-edge technology that capture and hold soil, enhance its fertility, or make soil-moisture conservation and storage easier are some of the most popular ones in Kenya. The primary interventions in Tanzania have been the tapping of runoff from roadways, the diversion of surface runoff from rocky regions, walkways, conservation tillage, pitting systems, bunded basins, ridging, terracing, and other kinds of runoff farming systems. The following gives an explanation of them.

Terracing

Terracing is another name for reducing a slope's steepness and/or length. According to one definition, a terrace "is a unit consisting of a relatively steeply faced structure across the slope, which supports above it a relatively flat terrace bed." In his succinct definition of a terrace, Thomas calls it "a more or less change in slope profile with a reduction in gradient of the planted zone." Terracing by digging ditches, building earthen or stone bunds, and using vegetation as a barrier are all considered soil and water conservation structures that are mostly encouraged to lessen soil erosion. Terracing is required on sloped ground to lower overland flow rates, which helps save water and nutrients. Although some communities in East Africa have long practiced terracing steep terrain, new techniques have emerged as a result of the population's increasing demand for creative solutions to the problem of shrinking cultivable land, particularly in the highlands' vulnerable to erosion and densely populated areas. In particular, since the 1970s, programs and initiatives funded by SIDA that focused on high-potential steep-lands in Ethiopia, Kenya, and Tanzania have produced a wealth of information in addition to concrete advantages for farmers. Regardless of the slope's steepness, the design of soil conservation structures had to be anchored to the 1-meter vertical interval in Ethiopia and the 1.8-meter vertical interval in Kenya. This was done so that farmers could lay out the terraces themselves without having to do difficult calculations. Contour bunds, "fanyajuu" terraces, bench terraces, stone lines, and vegetative barriers are a few of the most popular terracing techniques employed by smallholder farmers.

CONCLUSION

Sustainable agriculture methods, such as organic farming, agroecology, and precision farming, have gained popularity as solutions to these problems. These methods emphasize protecting biodiversity, conserving soil health, and using less resources, providing a more sustainable and resilient road ahead. Technology has the potential to increase agricultural productivity and cut waste, including biotechnology, precision farming, and data-driven solutions. However, the ethical principles, equal access, and environmental protections must govern their implementation. The future of agriculture and food production must also be shaped by strong policy frameworks and international collaboration. Prioritizing fair resource access, assisting smallholder farmers, and addressing problems like food waste and inefficient distribution are all part of these programs. There has never been a more pressing need for resilient and sustainable food production systems in the face of climate change, resource shortages, and global health issues. Governments, farmers, researchers, and consumers must work together to create a future in which food production and agriculture are in balance with the natural boundaries of the world and meet everyone's nutritional requirements. We can create the conditions for future generations to have a more secure and prosperous food future by embracing innovation, sustainability, and diversity.

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CHAPTER 7

GRASS STRIPS AND VEGETATIVE BUFFERS: AN OVERVIEW

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

ABSTRACT:

Grass strips and vegetative buffers are critical components of sustainable land management, serving as valuable tools in mitigating the adverse impacts of soil erosion, water pollution, and habitat loss. This abstract provides an overview of grass strips and vegetative buffers, highlighting their significance in conserving soil and water resources, enhancing biodiversity, and protecting aquatic ecosystems. It explores various applications of these practices, from agricultural fields to urban environments, underscoring their versatility and adaptability. The abstract concludes by emphasizing the importance of widespread adoption and continued research to maximize the ecological and environmental benefits of grass strips and vegetative buffersgrass strips and vegetative buffers stand as exemplars of nature-based solutions for addressing some of the most pressing environmental challenges of our time. This review has illuminated the multifaceted roles these practices play in conserving soil and water resources, promoting biodiversity, and safeguarding aquatic ecosystems.In agricultural contexts, the establishment of grass strips along field margins or between crops provides a first line of defense against soil erosion. These vegetative buffers trap sediment, nutrients, and pesticides, preventing their entry into water bodies and mitigating water pollution. Simultaneously, they offer habitat and forage for wildlife, contributing to biodiversity conservation.

KEYWORDS:

Erosion Control, Grass Buffers, Riparian Zones, Runoff Management, Soil Conservation, Streambank Stabilization.

INTRODUCTION

The least expensive and labor-intensive soil conservation structures are grass strips. They integrate traits of both structural and biological measurements. Grass strips are a common and simple method of terracing land, particularly in regions with average rainfall where grass is also utilized as animal feed. Along the contour, thick strips of grass between 0.5 and 1 m broad are planted at intervals that correspond to estimated terrace spacing. Through a filtering process, these lines build barriers that reduce soil erosion and runoff. In front of the strip, sand accumulates, eventually forming benches. The strips' spacing is influenced by the terrain's slope. The strips are built with a wide spacing on gently sloping terrain, whereas the spacing is between 10 and 15 meters on steep land. Regular grass cutting is necessary to keep it from encroaching on the harvested area. The grass is chopped and often utilized as much or as feed for animals. Numerous types of grass are employed, including guinea, napier, and guatemala grass. The primary problem with grass strips is that rats live there and may not survive dry seasons in arid places.

In Tanzania's Kondoa neighborhood in Dodoma, as well as in the Arusha, Iringa, and Kilimanjaro areas, grass strips are often employed. They are often seen in Kenya's Central and Rift Valley highlands where there is abundant precipitation. They are used in the highland regions of Ethiopia. In arid places where grass strips have a poor chance of surviving, it is often preferable to leave natural vegetative strips unploughed during land preparation[1], [2].

Bunds with a Contour A bund with a contour is a soil conservation structure that is built by digging a canal and building a little ridge on the downhill side. Contrast bunds and earthen bunds are employed for different purposes; earthen bunds are often used to capture runoff on somewhat less steep terrain, whereas contour bunds are utilized to drain excess runoff off steep cultivated slopes. As a result, contour bunds resemble the "fanyachini" terraces, narrow channel terraces seen in Kenya. Contour bunds are often built with a uniform 1 m vertical spacing and are used to avoid floods in Ethiopia's highlands. Through the food-for-work programs run by the World Food Program in the 1980s, the building of the bunds got a lot of assistance. As a consequence, hills and agricultural farmlands were dramatically transformed into stunning terraced landscapes. However, there was little effort made to modify the measures for local circumstances, and some of the more established conservation strategies were completely disregarded in favor of the new ones rather than being improved upon. Waterlogging issues may arise in the high-rainfall regions north of Shoa and Gojam, however this issue can be prevented by constructing drainage canals between terraces.

Garbage lines

To create organic buffer strips along the contour, crop wastes from the previous season or any other dead vegetative materials are arranged in trash lines across the slope. Making garbage lines is a common bunding method in many areas of Kenya, albeit it is not as popular as other bunding methods. Farmers prefer to give agricultural wastes to cattle in wetter regions where farm sizes are constrained, but in drier regions garbage lines are linked to termite infestation. Trash lines have the benefit of requiring less work. Nearly everywhere has them, although the semi-arid districts of Baringo, Tharaka, Mbeere, and Mwingi are where they are most common.

FanyaJuu Terraces "Fanyajuu" terraces are created by creating an embankment following the contour of a trench that is approximately 60 cm wide, which significantly reduces soil erosion from steep croplands. The construction may be employed in water harvesting systems with external catchments in certain circumstances because expanded embankments are created to facilitate ponding of gathered runoff. The soil bund holds onto water, protecting crops even during dry spells. "Fanyajuu" terraces are appropriate for slopes with 500–1,000 mm of yearly precipitation. The terrace banks may be stabilized by planting grass, trees, and shrubs, which also increase production and biodiversity by providing fruit, fuel, and feed. As earth is moved lower and dumped on the bunds, they progressively get larger. Through the natural processes of erosion and deposition, a terrace develops over a short period of time.

The "fanyajuu" terraces' popularity among smallholder farmers in the area is partly attributable to its ease of replication across a variety of agro-climatic zones and slope gradients. throughout the 1980s, Sida's Regional Soil and Water Conservation Unit promoted the technique throughout the area. According to data from Kenya's Machakos District, where the population rose more than fivefold during the 1930s and 1990s, the use of "fanyajuu" terraces likely had a significant part in preventing soil degradation at that time. For instance, Mati discovered that "fanyajuu" terraces accounted for more over 50% of all soil conservation interventions in a study of soil conservation techniques in the Kiambu District of Kenya. According to research, land with "fanyajuu" terraces yields much more than unterraced soil. Maize yield increments on terraced land compared to the yield from non-terraced land were measured in Kangundo, Machakos District, Kenya, and were found to be 47 percent in 1984/1985 and 62 percent in 1987/1988. "Fanyajuu" terraces boost agricultural production as a result.

Granite Lines

Bunds have been built in semi-arid regions with an abundance of stones as a method of runoff collection and soil conservation. Since the lines of stones are permeable, they delay the runoff rate, filter it, and disperse the water throughout the field, boosting water infiltration and lowering soil erosion. The stones are put in lines across the slope to make a sturdy wall. Stone lines, which may be strengthened with earth or crop residues to make them more durable, are often used in East Africa in regions receiving 200-750 mm of annual rainfall. They are typically placed around 15-30 m apart, with tighter spacing on steep slopes. Stone lines are still utilized in many areas of Kenya where stones are accessible, including Mbeere, Laikipia, Baringo, Mwingi, Kitui, and Tharaka. In Kenya, there is evidence that stone lines were employed as a traditional soil conservation strategy in the Baringo and Embu districts in the 1930s. In Wolloita, Ethiopia, stone lines, referred to as kella locally, are built after fields are cleared and are set along the contour at regular intervals to prevent soil erosion.

The rocky, sloping ground in the mid-altitude zones has been worked using this technique for decades. In Tanzania, stone lines are often used to prevent erosion and to build terraces that hold irrigation water, like in the Pare Mountains, Dodoma, and Arusha areas[3], [4].

DISCUSSION

On steep slopes, bench terraces are often constructed. They are often created for high-value crops like irrigated vegetables and coffee when the slopes are too steep for alternate intermittent terracing because of the high labor requirement. The vertical spacing between the benches is typically planned to vary from 1.2 m to 1.8 m. In order to save work and save having to move a lot of dirt, bench terraces are seldom dug directly in East Africa. Instead, they are formed over time from other terracing techniques including stone lines, grass strips, and rubbish lines, or "fanyajuu" terraces.

The goal is to create a level bench with a zero slope. To provide a tighter spacing between the trees, benches in the coffee-growing regions are designed to suit one or two rows. Bench terracing was imposed on locals in Kenya during the 1950s colonial era, and after independence in 1963, many terraces were neglected or demolished. Bench terraces were adopted by farmers in the Central and Eastern Provinces who lived on steep mountain slopes after the soil conservation extension programs of the 1970s and 1980s, particularly on farms where coffee was cultivated.

Farmers "overdo" bench terracing in drier regions due to the necessity for water conservation in order to get a bench with a reverse-slope, or one with an intra-bench slope of roughly 2-3 percent in the other direction. To maximize the added storage area, a bench terrace like this one is sometimes paired with water harvesting from an outside catchment, like a road. The stability of the structure is ensured by the bigger capacity and the fact that water is ponded on the top side. Reverse-bench terracing in arid places provides a drought mitigation approach despite the high labor requirement. In the Mwingi, Kitui, Machakos, and Makueni districts, reverse-bench terracing is often seen and is recognized as a kind of water collecting construction[5], [6].

Terraces at Kainam

In the mountainous region of Tanzania to the southwest of Lake Manyara, there are a lot of kainam terraces, which are an ancient technique. It entails a method of meticulously mulching and permanently cultivating steep slopes in which terraces are built, sheltered by storm drains, and then planted on ridges along the contour. According to the documentation on Kainam, the region is still well-conserved and provides food for around 20,000 people. In communally maintained ridge settlements, "work parties" are used by residents to work together to maintain the buildings on the hillsides and the drainage systems in the lowlands. Crop wastes are instead plowed into the fields rather than being permitted to be eaten by livestock. Additionally, manure is added to the soil to improve it, and crops are rotated properly. Although at less frequent intervals than in the past, following is still performed[7], [8].

Conserving Agriculture

Although not a new idea, conservation tillage is becoming more and more popular in East Africa for producing crops sustainably, particularly in arid regions. Conservation tillage has been acknowledged as the missing piece between biological techniques like agroforestry, agricultural inputs, and mechanical measures like terracing after many decades of soil and water conservation initiatives in Africa. Through tillage strategies that encourage soil fertility and soil water conservation, the strategy attempts to minimize labor requirements for land preparation. Traditionally, tillage is done to remove weeds and prepare a seed bed. Conventional tillage, however, has been proven to degrade the soil's structure and result in compaction. This has detrimental consequences on a number of variables, including soil aeration, root growth, and water penetration. The damage of soil microbiology caused by soil disturbance and turning over, which exposes the soil to harsh environmental conditions, is more significant but less obvious. To address this, conservation tillage employs four primary principles: 1) zero or minimal soil turning; 2) permanent soil cover; 3) stubble mulch tillage; and 4) crop selection and rotations. Breaking the plough pans by tearing the ground with tined instruments or subsoiling it right once after crops are harvested is an essential component of conservation tillage practices. Animal-drawn sub-soilers, rippers, "ridgers", planters, and weeders are examples of appropriate machinery.

Little Tillage

In its most extreme form, minimal tillage comprises no-till and/or zero-tillage regimes, in which the ground is seeded directly without the opening of any trenches or furrows. Herbicides are used to suppress weeds, while old crop remains serve as a mulch. Zero tillage has not been successful in the arid regions of East Africa owing to low infiltration and high pesticide expenses. Smallholder farmers have lately been experimenting with this approach with promising results, notably in the Machakos, Laikipia, and Nyando areas. "No-till systems" were previously largely employed in Kenya under large-scale mechanized wheat/barley systems. "Spot tillage" is another kind of minimum tillage. In this instance, specialized equipment or augers are used to create tiny holes over the remains of the previous crop, where weeds are controlled using herbicides, only large enough to hold one or two grain seeds. Small planting pits dug with hand hoes have shown to be an effective way to concentrate surface water, plant nutrients, and break up hard plough pans in Tanzania's Arumeru District, Arusha Region. The method requires a lot of effort but is straightforward and effective for ensuring crop life even in the absence of resources like fertilizers and manure and insufficient rainfall. Strip tillage creates runoff and requires less effort by cultivating the ground in strips where the crop rows will be while allowing the remainder to be tilled.

In Tanzania, it has been effectively applied. Where access to equipment is accessible, the process may be expedited such that seeds are planted in the ground while the hard pan is broken in the same pass. Smallholder farmers in Kenya and Tanzania have started using the "magoye ripper," a modified version of the Zambian method of minimum tillage, to cultivate their land. The subsoiler breaks up the hard pan of the plough by digging 25–30 cm into the soil. Additionally, it may be used to create 80 cm-diameter furrows. In Tanzania's Arusha Region, where annual rainfall varied from 400 mm to 1,200 mm, it was discovered that the magoye ripper reduced labor and increased agricultural production in the dry years.

Innovative farmers have also created manual subsoilers. The tool consists of a long hoe that can dig into dirt up to 30 cm deep and is both affordable and durable since it is fashioned from recycled automobile springs. Once every three years, the subsoiler is used to break up soil crusts that have built up due to repeated usage of the mold-board plow[9], [10].

Tillage with Stubble Mulch

In Kenya, particularly in the mechanized large-scale farms cultivating wheat and barley as seen in Kitale and Timau, Stubble Mulch Tillage has been employed as a water saving strategy. Crop leftovers are often chopped and distributed on the surface or incorporated during tillage using tined instruments like the chisel plough. Stubble mulch tillage is economical since it requires less work and agricultural power. There have been reports of higher yields, particularly in marginal regions. By reducing the direct effect of raindrops on bare soil and improving and stabilizing soil structure, the system reduces soil erosion. The leftovers also improve the soil's ability to retain moisture, which improves crop survivability during dry periods or drought. Okwach found in a research conducted at the Katumani Research Station in Machakos, Kenya, that mulch tillage successfully decreased runoff and soil erosion compared to conventional tillage methods.

Tied Ridges and Ridging

The process of creating contour ridges is creating ridges along the contour at regular intervals of 1-2 m. Ridging is often done in Kenya and Tanzania for crops including potatoes, tobacco, groundnuts, and even maize. Even though the corn is first planted on the flat, rigging for maize requires "earthing" up the maize rows when weeding. In the Arusha Region, plough planting is a prevalent technique. Ridging systems are most effective in regions with an average yearly rainfall of 350 to 750 mm.

Tie ridges are created in semi-arid regions by altering regular ridges. The method entails excavating large ridges that span the main slope, followed by the creation of smaller sub-ridges within the main furrows. The end result is a collection of tiny microbasins that increase infiltration by storing rainwater on-site. The crop is planted to the side of the main ridge, depending on the system, to be as near as possible to the captured water while also preventing waterlogging in case of heavy rains. It has been shown that tied ridges are particularly effective in storing rainwater, which has led to a significant increase in grain output in several of Ethiopia's important dryland crops, including sorghum, maize, wheat, and mung beans. When compared to the conventional method, the average grain yield increased by 50 to over 100%.

Farming in tunnels

Pitting is one of the methods used in trench farming, however the trenches are often used to incorporate significant quantities of organic matter into the soil and may even end up being higher than the ground. The three goals are to increase soil fertility, infiltration, and moisture retention. The "ridge and furrow system" of farming, also known as trench farming, has been tested with farmers by the Kenya Institute of Organic Farming. Trench farming is used in Kenya's Kirinyaga District by constructing broad beds that are approximately 2.5 wide, separated by furrows that are the same width and around 1.3 m deep.

While napier grass is planted in the furrow, sweet potatoes are grown on top of the ridge for their fodder and tubers. In order to acquire feed even during the dry season, the aim is to keep moisture in the furrow for a longer period of time. In order to better use the water during the dry season and increase productivity, bananas are sometimes planted in holes inside the furrow. Due to the system's effective moisture storage, many farmers are embracing it since it enables them to get feed even during extended dry periods.

In the Dodoma Region of Tanzania, trench farming is burying as much vegetative material as is practical in order to maximize soil moisture storage in the crop root zone. An example of how a farmer has honed the trench cultivation technique. Along the slope, 0.6 m deep by 0.6 m broad trenches are positioned 0.9 m apart from one another, edge to edge. The cultivated area is then left, which is roughly 0.15 m below ground level so that it may catch runoff, and the trenches are then filled with crop leftovers, grass, and other organic waste before being backfilled with soil. Even with only two weeks of rain, the trench can hold enough moisture to ensure a crop harvest. Up to four crop seasons may be employed once the trench has been used successfully. Farmers in southern Ethiopia's low-rainfall regions have created a highly specialized trench farming method. A variety of crops are interplanted on the prepared soil in countless circular depressions. The fields' runoff is completely nonexistent. All crops are gathered in excellent years.

Silt Borrowing and Trapping

The top-dressing of damaged regions with soil taken from wealthy valleys has been utilized to restore degraded farmland in Kenya and Tanzania. Many farmers in both nations were utilizing soil-harvesting methods to increase soil fertility and/or moisture retention qualities, according to the Promoting Farmer Innovation Project. To create a soil layer for growing sugarcane and fodder grass, two farmers in Kenya's Mwingi District, Kamuti Nthiga and ManziKavindu, were separately capturing the silt portion of the flood waters from seasonal rivers with astonishing success. Peter Wilson and Hosea Mhuma created a technique in Dodoma wherein they would use wheelbarrows to transport material from neighboring hills to cover and reclaim ground that had been eroded or gouged, so producing adequate soil depth for irrigation of high-value plants.

Control and Use of Gully

Since gully rehabilitation is expensive and gully erosion is a serious issue in East Africa, the majority of gully control initiatives have historically been carried out by the government or with outside support. The majority of gullies are also found on public property, such as grazing grounds, walkways, and farm borders. As a result, it is often beyond the scope of the person to be responsible for their recovery. Over 50% of the gullies in the Kiambu District of Kenya, according to studies, are caused by road drainage. Soil conservation practices were included to road rehabilitation projects in the early 1990s to guard against damage from road drains. Even yet, the primary goal remained the drainage of surface runoff, which was considered a harmful issue. These beliefs gradually shifted in the early 2000s to accept the idea of collecting water for useful reasons, even from gullies. Finally, a gully could be seen as a resource, and this was noted throughout the nation. In the areas of Mwingi, Makueni, and Kitui, resourceful farmers have been able to turn gullies into fertile land.

In one such instance, farmer Mutembei Mwaniki of Mwingi reclaimed a gully with stone walls, well-designed with side spillways complete, and therefore constructed level beds for cultivation of field crops by the slow deposition of silt. He staged the sediment capture in the gully using stone check dams. He would add around 0.3 m to the height above the existing stone check whenever a layer of silt accumulated. Up to 3 meters of silt had gathered at the deepest point. 500 m2 or thereabouts had been restored in its entirety. Green corn and papaya were being grown together with bananas in the repaired gully. While his neighbors' crops failed, he was able to harvest a healthy yield from his crops.Gully management initiatives have been carried out in Tanzania's Arusha Region, where farmers have used creativity and success to rehabilitate gullies on their farms and turn them into useful land. Raphael Chinolo, a farmer in Dodoma, and his wife managed a gully system by growing bananas in deep pits. Before planting, they would add 20 liters of manure to each pit. The pits collect runoff, but to further regulate overland flow, 0.6 m high earth bund terraces were constructed and stabilized with makarikari grass. They were able to limit gully growth in this method, as well as boost agricultural output, enhance soil fertility, collect runoff water, and lessen soil erosion. In Ethiopia, gully management has mostly been accomplished using stone check dams with parabolic and U-shaped spillways. Smaller and average-sized gullies responded well to these check dams, while larger ones required more advanced control mechanisms. Gully reclamation for productive purposes has been used in the Tigray area with successful agronomic outcomes. On previously gullied land, this has increased the possibility of effectively farming banana, elephant grass, and sugarcane, however with complicated social repercussions. Uncertain land ownership caused a number of issues in privatizing the recovered gully, which eventually caused crop husbandry in the gullies to be abandoned. Due to the difficulty of unrestricted grazing as well as a shortage of supplies, vegetative gully management has not been widely used. Due to the modest size of the majority of landholdings, another fundamental guideline of gully controlavoiding plowing up to the edge of gullieswas not observed.

Pingo Pits

The "ingolu" or "ngolo" or simply "matengo pits" is the name of the distinctive traditional farming method used by the Wamatengo people of the Matengo highlands in Tanzania's Mbinga District. This is distinguished by a mix of soil conservation methods, such as pits and ridges, on slopes that are between 35 and 60 percent steep. The ngolo system's extensive use of trenches in the fields is one of its key characteristics. Even though the cropping is often done repeatedly for many years without a fallow period, this technique may be categorized as "grassland fallow farming."

Additionally, it is integrated with a two-crop rotation system in which maize is planted the next year and beans are grown in the last rainy season of the first year. The residents of the Matengo highlands need to possess at least two fields since the ngolo farming technique is repeated every two years and because maize and beans are their two major food crops. The field is left fallow for a number of years until it is completely covered with shrubs or tall grasses in the event that the corn production declines. Land utilization during the first year's early rainy season is another characteristic of the ngolo system. The guys use the "ku-kyesa" method of cutting the established weeds in March, which calls for getting the weed as near to the ground as possible. Two weeks are given for the clipped shoots to dry.

Next, a billhook is used to line up the dried shoots. The lines extend both horizontally and vertically, making a grid with squares that are 1.5–2.0 m in size. The density of the plant population is based on the size of the square. Men do this "ku-bonga," as it is known. The neat lines serve as the foundation for the subsequent piece. All weeds growing on the field and maize stalk remnants are utilized for "mabongi," the shoot bundles that create the lines. The mabongi are then covered with dirt, creating ridges that are no more than 20 to 30 cm broad and 10 to 20 cm high. The density of the plant population and the pit's ability to store water are both influenced by the size of the ridge.

Women complete "ku-bonga" on a specific area before covering "mabongi" in a square with little quantities of dirt. They scatter bean seeds on the tiny ridges and then cover them with earth. A ngolo field is left fallow for the whole of the next dry season, and at the start of the wet season, maize is planted on the ridges where beans had previously been cultivated. Along the contour line, the seeds are sowed. The weeds are pulled out and the silt at the bottom of the trenches is dug out with a hoe and used to rebuild the "mabongi" when the maize reaches a height of 20 to 30 cm.

CONCLUSION

The quality of the water is improved in urban settings by the presence of vegetative buffers next to streams, parking lots, and roadways. Additionally, they improve the visual appeal and standard of urban life. Promoting their broad adoption and efficient maintenance is essential if we want to fully realize the ecological and environmental advantages of vegetative buffers and grass strips.

Landowners, farmers, and urban planners may be persuaded to use these techniques in their land-use plans via government incentives, rules, and educational initiatives. Continued study is similarly important because it may improve the layout and use of vegetative buffers and grass strips to accommodate various landscapes and difficulties. Improvements in buffer width optimization, plant selection, and monitoring methods may all improve how successful these activities are. Grass strips and vegetative buffers provide practical and scalable solutions for problems including habitat loss, water pollution, and soil erosion. By adopting these techniques, we help create a more resilient and sustainable future where the wellbeing of our soil, water, and ecosystems is preserved for the advantage of both the present and the future generations.

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CHAPTER 8

VARIOUS WATER HARVESTING TECHNOLOGIES: AN ANALYSIS

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

ABSTRACT:
Water harvesting technologies are crucial innovations that address the growing challenges of water scarcity, particularly in regions where access to freshwater resources is limited. This abstract provides an overview of various water harvesting technologies, highlighting their significance in capturing and utilizing rainwater, runoff, and other water sources for agriculture, domestic use, and environmental conservation. It explores the diversity of methods, from traditional practices to modern, technology-driven systems, emphasizing their adaptability to different contexts and their role in promoting water security and sustainability. The abstract concludes by emphasizing the importance of continued research, policy support, and community engagement to harness the full potential of water harvesting technologies in addressing global water challengeswater harvesting technologies offer a promising path toward addressing the pressing issue of water scarcity across the globe. This review has illuminated the diverse array of methods and approaches available, each tailored to harness and manage water resources in specific environments and for various purposes.Traditional water harvesting practices, such as rainwater harvesting in cisterns or terraced agriculture, have sustained communities for centuries, providing a blueprint for sustainable water management.

KEYWORDS:

Catchment Systems, Rain Barrels, Rainwater Harvesting, Roof Collection, Storage Tanks, Surface Runoff.

1. INTRODUCTION

As more people become aware of the importance of surface runoff as a resource for sustainable agricultural production and/or animal watering, interest in water collection is rising across East Africa. As a result, a wide variety of technologies for water collection and conservation have undergone significant development. This has been partly ascribed to the change from top-down, enforced methods to rural development to more progressive, community-based participatory approaches. These have most likely promoted the diversification of runoff farming practices.

These methods are still in use in the region's varied agricultural systems today. In places where seasonal rainfall is as low as 100 to 350 mm and average annual rainfall is inadequate to fulfill agricultural water requirements, RWH systems are also relevant under a variety of scenarios[1], [2].

The practice of runoff farming seems to be one where innovative farmer often engage. Farmers monitor the flow of surface water via their particular watersheds and construct complex runoff farming systems through research and trial and error. This might include diverting surface runoff from walkways, tapping sheet flow from roadways, or diverting sheet flow from rocky regions next to fields. Small-scale farming practices rely heavily on runoff farming systems, which is understandable given that the systems are simple to design, the runoff volume is reasonably constrained, allowing the farmer to easily control the water flow, and relatively easy methods can add a sizable amount of water to crops during rainy seasons.

Systems for micro-catchment

Basins, pits, bunds, and any other water harvesting structures that collect runoff from tiny areas are considered micro-catchment systems. Runoff is "harvested" from a designated area of upslope land and channeled to a planted area downslope. Since runoff originates from around the region that is being cultivated, micro-catchments are often within-field systems. The systems typically have a catchment-to-cultivated-area ratio between 11 and 51. The "meskat" systems have been the subject of in-depth investigation by the Sokoine University Soil and Water Management investigation Group in Morogoro, Tanzania. Their study in a semi-arid region indicates that the systems enhance yields significantly on runoff-receiving areas of the field, but farmers are reluctant to use the system since it requires them to give up a sizable quantity of land. In East Africa, a variety of micro-catchment and external catchment systems are used, including earth bunds, "negarims," and semi-circular bunds.

Ethereal Bunds

Different types of earth-shapings called earthen bunds provide run-on structures for ponding runoff water. The most typical are within-field runoff harvesting devices, which are rising in acceptance among East African smallholder farmers. This could be because agricultural units are often tiny and don't always have access to an external catchment. Additionally, within-field systems often depend more on physical labor and animal draught than they do on mechanization. With spillways spaced 20 meters apart to regulate the application of surface water in each soil bund, where the crop is grown, the soil bunds are lined with the contour in their design. Bunds are placed at 15-20 m intervals, and the ratio of cultivated to catchment is between 51 and 201. Bunds intended for traditional soil and water conservation should be distinguished from those intended for within-field water collection. Unlike typical bunding, which cultivates the whole terrace, runoff harvesting maintains a "catchment" inside the terrace to generate runoff that will supplement the natural rainfall[3], [4].

Bunds in a Trapezoid

Farmers in various arid and dry semi-arid areas in the Horn of Africa employ trapezoidal bunds, which have an indigenous provenance. They are typically hand-built and used for subsistence farming. The "teras" system, for instance, is a popular system of big earth bunds with straight walls that are used to grow crops that can withstand drought, like sorghum, in regions with low annual rainfall of 150-300 mm. Large constructions known as trapezoidal bunds may extend over 100 meters along a contour, with the wing walls tilted around 135 degrees to face upslope. Typically, the bunds are 20 meters apart, and the overflow mechanisms are designed so that excess runoff from one bund may flow into the next. In the basins, field crops like sorghum and millet are produced. These types of trapezoidal basins use external catchment or runoff from areas other than the current cultivated area. According to Critchley and Siegert, some of these have been used to restore semi-arid regions of Kenya's Turkana and Baringo districts. The key question is whether trapezoidal bunds, given labor costs and the tools required to build them, are socioeconomically sustainable. Their usage in East Africa has decreased over time as a result of a lack of mechanization and tools. Perhaps further study on adjustable trapezoidal bunding is required in light of recent developments in animal draught and other reasonably priced mechanization technologies, since this technique can handle broad areas rather well.

Runoff from Rocks and Hillsides

Large rocky surfaces and slopes may sometimes be exploited as runoff sources. This is directed into enormous basins that are surrounded by sizable bunds. Research in Kenya's

Baringo District revealed that rainstorm storms with as low as 8 mm of precipitation might start surface runoff because of the slopes' high capacity to produce runoff. 48 percent of showers larger than 10 mm generated enough runoff in field tests utilizing a runoff-harvesting system with a catchment area of one hectare to trigger inflow into bunded basins. In dry environments, field crops like sorghum and millet might be produced[5], [6].

Bunds in a semicircle

For the purpose of collecting young tree seedlings from runoff in the semi-arid regions of Kenya, Ethiopia, and Tanzania, semi-circular bunds are often constructed. The typical patterns include creating earth bunds with the tip on the contour and in the form of a semicircle. Semi-circular bunds are created in Kenya's Busia District by excavating holes that follow the contours. The kind of crop or agricultural technique determines the size of the holes and the distance between the contours. For common fruits, the holes are drilled with a minimum 0.6 m radius and 0.6 m depth. On the bottom side of the pit, a semi-circular bund with a radius ranging from 3 to 6 meters is built using the subsoil that was extracted from the pit. Typically, the bund height is 0.25 meters. To provide the necessary fertility and to aid in moisture retention, organic manure and topsoil are added to the dug planting pits. Farmers often plant seasonal crops like vegetables, such as beans, and other herbaceous crops in the pits before the tree crop becomes covered in shade. In dry and semi-arid regions, where annual precipitation varies from 200 mm to 275 mm and land slopes are less than 2% steepness for both rangeland restoration and annual crops, semi-circular earth bunds are common. For the purpose of producing more fodder and restoring rangelands, semi-circular bunds are sometimes enlarged. The runoff water is collected in an infiltration hole at the lowest point of the bund, where tree seedlings are also placed, while it is being utilized for tree growth. The bunds are arranged in a staggered pattern so that the lower bunds will catch the water that overflows around the ends of the higher slopes. These types of bunds have two key drawbacks: they are difficult to build with animal draft, and they need ongoing maintenance.

Broader-than-bed and a row

In order to create a "catchment" ahead of the furrow and a within-field micro-catchment water harvesting system, broadbed and furrow systems are modifications of contour ridges. The systems are built as tiny earthen banks with furrows on the higher sides in Ethiopia, Kenya, and Tanzania. These banks collect runoff from the catchment region between the ridges. To enhance drainage, the catchment area is kept uncultivated and vegetated-free. On the ridges and the sides of the furrow, crops may be sown. Beans and peas and other high-water-use plants are often planted on the upper side of the furrow, whereas maize and millet are typically planted on the ridges. Depending on the gradient of the slope, the desired size of the catchment area, and the amount of rainfall available, the distance between the ridges varies between 1 m and 2 m. In regions where the annual rainfall ranges from 350 mm to 700 mm, contour furrows are employed. In order to promote an equitable distribution of water, the terrain should be level. The best terrain for contour furrows is a mild slope with a steepness of 0.5–3%. Light should describe the soil. They are less effective on heavier, more clayey soil because of the decreased infiltration rate. Although crop yields in dry locations are increased by contour furrows, the labor costs are greater than with traditional farming, and the complexity of building them discourages many farmers from using them.

According to Critchley et al., contour furrows in the Baringo District of Kenya are little earthen ridges that are between 0.15 m and 0.2 m tall. On the contour, these ridges are spaced around 1.5 meters apart. Runoff from an uncultivated catchment strip between the ridges is accommodated by the upslope furrow. To stop lateral flow, tiny earthen ties were inserted into the furrow at intervals of 4–5 meters. The system's goal was to collect local runoff and store it near to plant roots in the soil profile. These particular contour ridges were intended for horticultural small-scale food crop cultivation. The suggested method was a cereal intercropped with a pulse. Since this system is a micro-catchment or within-field catchment, runoff from an outside source is not necessary and may potentially cause harm to the buildings. Where required, a cutoff drain is consequently installed to reduce the possibility of system overflow. Contour ridges may be employed on a variety of slopes, but as the gradient rises, the size must also do so[7], [8].

Basins

The purpose of an earth basin is to collect and keep all rainfall that falls on a field for use by plants. Earth basins are often tiny, circular, square, or diamond shaped micro-catchments. To confine rain and runoff within the mini-basin, modest earth ridges are built around a basin. Infiltration pits are used to hold runoff water once it is directed to the lowest point. With an annual rainfall of at least 150 mm, a slope steepness ranging from flat to roughly 5 percent, and soil that is at least 1.5 m deep to guarantee enough water holding capacity, earth basins are acceptable for use in arid locations. Growing fruit crops in particular has proved effective in earth basins, where the seedling is often planted in or on the edge of the infiltration pit. For large exterior catchments, the basins' dimensions might range from 1 to 2 meters in width and up to 30 meters in length. The biggest obstacle is the requirement to utilize far more land than is necessary for the crop being cultivated. If there is an unusually significant rainfall, there is also the risk of breaching. For the purpose of growing trees, micro-basins that are around 1 m long and 0.5 m deep are often built beside these retention ditches in Tigray's northern region. These retention ditches in the Axum region of northern Tigray have helped revive natural springs that, according to the local communities, had dried up most likely as a result of severe upstream deforestation. They do this by preventing a significant amount of surface runoff from flowing down the steep escarpments.

Negarims

A more recent technique for using basins called "Negarims" was adapted from the Israeli Negev Desert. In dry and semi-arid areas, where seasonal rainfall may be as low as 150 mm, they are used to plant fruit plants. They are made of ordinary square earth bunds that have been rotated 45 degrees off the contour to concentrate surface runoff at the square's lowest point; as a result, they are effective at using the available space. In Kenya's Kitui, Thika, and Meru districts, negarims are used to grow fruit trees.

Basins that have been excavated

Excavated bunded basins are the primary source of paddy rice in Tanzania and are commonly utilized in the semi-arid regions of Mwanza, Shinyanga, Tabora, Singida, and Dodoma. Majaluba are built by excavating to a depth of between 0.2 and 0.5 meters, then utilizing the scooped earth to create a bund around the field's edge. The bunds typically rise from the ground between 0.3 and 0.7 meters. Farmers often begin with little majaluba, such as 10 m by 10 m, before expanding into larger sections of roughly 1 hectare. This technique is one of the ways to use, manage, and store runoff for the cultivation of paddy rice.

Pitting Devices

Pitting has been used as a technique for external catchment systems and micro-catchment systems to capture and save water. Pitting has historically been used in East Africa for unique crops including bananas, coffee, tea, and other varieties of fruit trees. Pitting is still regarded as unique for field crops like maize, millet, and beans. Pitting is done to increase soil fertility and store water.The "zai" method was imported from West Africa's Sahel region, where it has been used for generations. Zai pit experiments have been successful in Kenya. The zai plant four to eight seeds of a cereal crop, such as maize, in shallow, broad trenches that are roughly 0.6 m in diameter and 0.3 m deep. Typically, manure is placed to the pit to increase fertility. It functions by conserving moisture and fertility in the pit as well as collecting water. The zai system has undergone various adjustments. In the Machakos District of Kenya, at the Kenyan Agricultural Research Institute in Katumani, a tiny zai-pit-like manual pitting system has been created. The holes are dug deeper and larger in the Njombe District in southern Tanzania, and 20 liters of manure is also added. The farmers plant roughly 15-20 seeds of maize per pit due to the region's close to 1,000 mm annual rainfall, and the yield is more than twice as high as that of conventionally tilled soil.

Pits of Cholo

Cholol pits got their name from the hamlet where Kenneth Sangula of Tanzania's Dodoma Region created them. It is a pitting technique that modifies the zai pits of the Sahel, although Kenneth said that he almost by chance found the breakthrough. Chololo pits are made up of a succession of pits that are each around 22 cm in diameter and 30 cm deep. The rows run along the contour, with the pits set 60 cm apart inside rows and 90 cm between rows. A small bund is built around the hole using the dirt that was excavated during the excavation. Ash, farmyard manure, and crop wastes are placed within the pit before being filled with the necessary quantity of soil, leaving enough room for drainage to the pond. The aforementioned preparations make sure the water absorbed is retained by the organic components, extending the time that moisture retention lasts. Each hole is seeded with one or two sorghum or maize seeds. Even during times of significant rainfall shortages, crops often survive, and yields have been seen to treble. Many farmers have embraced this strategy since it is simple to use and requires very little work to dig the smaller holes.

T-basins

T-basins are a different strategy used in Kenya that makes use of external catchments. Through a network of tiny channels, a number of interlinked basins are linked to exterior catchments like footpaths and roadways. The channels are used to transport the water from the catchments to the basins. The T-basins are where the water is stored after being gathered in this way, and it is from there that it permeates into the root zone of the nearby crops. This technique, in contrast to the circular root zone basins, is appropriate for both tree and non-tree crops. Farmers in Nambale Division in western Kenya have traditionally utilized this technology to cultivate citrus, bananas, mangoes, and passion fruit. In Mwingi, this technique is also used.

V-basins

For a very long time, tree crops have been grown in pits and basins. According to Critchley et al., one pattern employed in the Turkana Region of Kenya was in the shape of a "V". The dug pit measured 2.5 m3 at the V's angle. Although the distances between separate micro-catchments are not precisely defined, in reality, the catchment area may reach 150 m2 in the driest regions. An alternate design is employed for individual 5 m by 5 m catchments and 1.2 m3 capacity pits in certain more advantageous zones. Following the start of the rains, tree seedlings are planted behind each pit.Circular pits are the shape that root zone basins have in order to store enough moisture and prevent the walls of the basins from breaking. Farmers often use basins with a diameter between 0.6 and 1.2 meters and a bund height between 0.1

and 0.3 meters. To boost the root zone's ability to store the harvested water, the depth of tillage inside the basin is often raised up to 0.6 cm. The use of vegetative materials, mulching, and manure addition all help to improve moisture retention in the root zone. Root zone basins are mostly exterior catchment systems that route runoff into collecting channels from slightly elevated bumps that are 0.05 m high over the course before it is channeled into the basins.Planting trenches called "Five by Nine" are 60 cm square and 60 cm deep for maize plantings. They are square in form but bigger than zai pits. Based on the five or nine maize seeds sown at the pit diagonals, the phrase "five by nine" was coined. Compared to a zai pit, this kind of pit can contain more manure. As a result, it may provide bigger yields that have a lasting impact. The Kenya Institute of Organic Farming, particularly in Kenya's Kirinyaga, Mbeere, Murang'a, and Machakos regions, where farmers have successfully used this approach to increase productivity on their farms, promoted the concept. Additionally, the pit may be utilized again for up to two years.

Pits of Tumbukiza

The tumbikiza technique is another pitting system that has been altered to revolutionize the production of fodder and enhance soil fertility. Tumbukiza, which translates to "throw everything in," is a technique that includes creating enormous trenches that are between 0.6 and 0.9 meters in diameter and are equal in depth.

Then, waste and vegetation, such as topsoil and farmyard manure, are dumped into the pits. The tumbukiza pit is often used to cultivate a fodder crop, ideally napier grass. During the dry season, farmers in Kenya's Nyando District pour one 20-litre jerrican of water each hole every day. This quantity of water is effectively held by the vegetation in the pit, allowing the napier grass to grow quickly and allowing one trimming per hole each day. To gather adequate fodder for the cow for a month, a farmer with one cow requires 30 pits, which he or she waters at the rate of one jerrican every day. The fodder has developed enough at the conclusion of one cutting cycle to permit the subsequent round of cutting. Farmers all around the nation have started using this technique since it has become so well-liked. However, the need for a lot of effort to dig the trenches has deterred the poor from using them.

DISCUSSION

With the exception of Tanzania, the practice of collecting runoff from roads, walkways, and complexes is still not as common as it might be across the area. Both "blue" and "green" water may be collected using the methods. Compounds, dirt roads, and footpaths are made of compacted earth that often has thick erosion crusts. These are used to capture upstream runoff for useful uses. Many farmers in East Africa have perfected "sheet and rill" runoff farming methods, which route runoff from compacted surfaces like roads, walkways, and residential neighborhoods either directly into arable land or storage areas like ponds[9], [10].

Simple diversion structures that send surface water into agricultural fields are one kind of road runoff harvesting system, while deep ditches with check dams for flood and subsurface irrigation are another. Farmers of Lare in the Nakuru District of Kenya have shown that storage in pans may be extremely cost-effective when surface conditions permit. This method was used in a project where more than 1,000 pans were excavated to catch road runoff, turning the region from a receiver of food assistance to a net exporter of food. Road runoff is often used in Tanzania as an additional watering source for agriculture. Another instance occurred in Adigudum, Tigray, Ethiopia, where farmers converted a borrow site into a dam that reserves water for usage by animals, minimizing the distance that cattle must travel to get water, particularly during the dry season.

In one case study, farmer Musyoka Muindi of Kenya's Mwingi District develops a road runoff collecting technique that has since become a common design referenced in textbooks. The system includes a 300-meter-long main canal that was dug to direct road runoff to the farm. Once within the farm, the runoff is directed first into a canal called a "fanyachini" that has been cut across the main hill. The water is redirected from this canal at its terminus into a parallel channel that flows the other way around a curve. The flow is zigzagged because this mechanism is replicated across the farm. The farmer installs water control gates at precise locations along certain canals to manage the flow. With earthen embankments that are 1.5 m high and spaced 18 m apart, the channel's dimensions are somewhat greater than typical at roughly 1.0 m deep and 1.0 to 2.0 m broad. Thus, there are around 0.9 m between buildings vertically. Grass or sugarcane is used as a stabilizer for the embankments.

Railway Line and Borrow Pit Runoff

Despite their rarity, Tanzanian railway lines are utilized to collect water in various locations. They are an excellent source of runoff through gravity flow because of their paved nature and the fact that they are often constructed to lay above neighboring terrain. In semi-arid Singida, Tanzania, smallholder farmers utilize runoff collected in railroad culverts to irrigate 150 acres of cropland. Farmers in other regions utilize the roadside pits as a significant supply of residential and agricultural water. It is grossly understated how closely infrastructure development and water provisionand even rain-fed agriculturecan be linked.

Riverbeds and High-Water

In the ASAL regions, it is customary to utilize the leftover moisture in sand rivers and stream seepage to cultivate crops. This technique has a long history in Africa. In order to provide the family with better nourishment, "women's crops" including arrow roots, sweet potatoes, fruits, and vegetables were often planted in the valley bottoms. Rice and sugarcane have both historically been farmed in river valleys. In semi-arid regions that are subject to recurring droughts, valley bottoms play a critical role in ensuring food security. About half of all improvements in soil and water management were identified near dry riverbeds, according to a study of farmer innovators in Kenya's Mwingi District.

Additionally, the farmers believe that managing the water table is simple, thus they have adopted associated advances well. Farmers in Kenya and Tanzania developed inventive ways to make use of riverbeds and high-water tables. For instance, in Kenya's Mwingi District, planting sugarcane is often done by simply drilling a cutting into the riverbank. However, Mrs. Lucia KakundiKitengu, a farmer, invented a novel technique for growing sugarcane in pits. She discovered the ideal layout for her farm, which is next to a sand river, via her own research and trials. She would create holes that were 1 x 1 m in size and between 0.6 and 0.75 m deep.

Within rows and between rows, the holes are placed around 0.6 m apart. In relation to the distance from the stream bank, she adjusts the hole depths, making them deeper the further away from the river. After that, manure is added and four sugarcane cuttings are planted in each pit's corner. The holes overflow during the rainy season, recharging them with water and nutrients. As a consequence, the sugarcane grows more quickly, withstands drought better, generates significantly bigger and healthier cane, and hence commands prices that are more than three times more than in flat places.

Other farmers who have been exposed to this idea have quickly imitated it. Farmers in Tanzania's Dodoma Region make advantage of the remaining moisture in sand riverbeds shortly after the rains stop. When the sand is still damp, they carve out ridges in it and typically plant sweet potatoes, which take approximately 3 months to grow tubers and by which point the dry season has begun. Since riverbed farming is prohibited by the Agriculture Act, valley bottoms in Kenya have seen less usage than they did in Tanzania. Given that sand rivers are often ineffective during the dry season and that utilizing them for agricultural production would have minimal effect on soil erosion after the rainy season returned, many farmers believe that this law has little practical value. A reassessment of this law is necessary.

Irrigation of Spate

Techniques such as floodwater diversion or spate irrigation compel the water to change its route from what it would not do naturally. Spate irrigation, or the redirection of water flow from highlands into lowlands and "wadis", has a long history in the Horn of Africa and continues to be the main source of income for rural inhabitants in Ethiopia's upper rift valley and Eritrea's desert regions.

Rainfall-rich highlands harvest storm floods, which are then directed into leveled basins in the parched lowlands. The enormous storm-water embankments in Eritrea are constructed by animal traction being used to shovel sand-filled earth. Because maintaining the embankments requires a lot of effort, it is done on a local level.

Water is a significant agricultural growth constraint in Ethiopia's semi-arid and dry regions. Floodwater harvesting has made it possible to cultivate a range of crops, including fruit trees, fodder crops, and cereals, in arid valleys and flood plains. Sorghum and maize are planted in a region in Abaala that receives rainfall in the range of 300 to 550 mm per year, according to a case study done on agro-pastoral lands there. By using shrubs, trees, stone, and soil to redirect rivers, this quantity of water is recovered each year. Following the 1983–1985 drought, which resulted in the loss of animals, the farmers began growing crops. They also did so in an effort to augment cattle output if there was heavy rain or flooding.

The drought-prone areas of Dodoma, Singida, Tabora, Shinyanga, Arusha, and Mwanza in Tanzania also use spate irrigation. An IFAD-funded initiative in Tanzania called the Smallholder Development initiative for Marginal Areas started up in 1990/1991. The initiative sought to increase smallholder farmers' earnings and family food security. It included the establishment of RWH-based smallholder irrigation systems, improved extension services, land surveying and registration, and loans. About 25–30 RWH irrigation-based schemes were intended to be established in the first phase of the irrigation development component. For 8,000 farm households, 4,000 acres of marginal land were supposed to be developed. For 18 projects, the project was able to: 1) build river diversions and flood control works; 2) level the ground and demarcate 0.5 ha plots for individual farm families to cultivate; and 3) build access roads. The rate of adoption was high since the majority of the schemes were being put into place in regions where RWH for paddy production was widespread. One accomplishment of the initiative, it was reported, was the rise in rice production in RWH systems from 1 to 4 t ha-1. However, the El-Nino rains of 1997–1998 severely destroyed the majority of the buildings. Major lessons may be drawn from what transpired with the El-Nino rains.

Spate diversion devices have also been used successfully in Kenya's Turkana District. The diversion plans include earthen embankments that redirect part of the wadi flow onto plains where bunds are stretched out and the flow is impounded. Some of these plans are for crops, while others are for fodder. Despite the wide variety, the projects tend to be costly to build and challenging to manage because to the frequent bund breakages. Engineering design is a specific challenge since each site has unique features.

Micro-irrigation

tiny-scale farmers are increasingly employing micro-irrigation methods, particularly those that use water collected in tanks and tiny pans. This is due to the requirement to save water when growing high-value crops or for the planting of trees. The most popular micro-irrigation techniques are pitcher pots, bamboo sub-irrigation, bucket drip kits, and bottle-feeding of young tree seedlings.

Container Drip Kits

Since they were first introduced to the market in the late 1990s, bucket and drum drip kits have quickly become a popular adaption among smallholder farmers in East Africa. Bucket drip kit systems are the most common and least expensive, consisting of two drip lines, each 15 to 30 meters long, with emitters spaced around 0.1 to 0.3 meters apart, and a 20-liter bucket for retaining the water. Any contaminants that can clog the drip nozzles are removed by connecting each drip line to a filter. The bottom of the bucket is at least one meter above the planting surface and is supported by a stand. For a drip kit to irrigate 100–200 plants, 40–80 liters of water are needed each day. High-value vegetables including tomatoes, cabbage, and spinach are the most widely grown crops. According to KARI studies, farmers in Kenya made between US$26 and US$40 each season from single bucket kits, which in that country cost around US$15. However, since these little gardens are the only green spaces to be found during the dry season, producers must deal with the issue of bugs and fowl eating their crops.

Irrigation of pitchers

Unglazed clay pots are buried close to the crop root zone and used for pitcher irrigation. These pots are traditionally manufactured by women, however when the pot is burnt during curing, sawdust is added to the clay to provide porosity. To minimize evaporation losses, the pot is filled with water and covered with a clay slab or polythene paper. The porous edges of the pot allow water to gently soak through. The water in the pots is drawn out by the tiny hairs of surrounding plants. The technique promotes lower evaporation and deeper roots. The technique is often used to produce fruit-tree crops.The Kavilo Women's Group of Machakos District, Kenya modified the pitcher pot by creating clay pots with tiny holes drilled into the mold. Between rows of vegetable crops, the pot is positioned above ground. Small sticks may be used to shut the tiny holes and then opened for watering as needed. The farmer has control over how much water is applied, which is a benefit. Higher discharge rates and evaporation when water is applied to the soil surface are limitations,

CONCLUSION

Technology is used by contemporary inventions like check dams, fog collecting nets, and rooftop rainwater harvesting systems to increase the efficiency of water capture and use. Technologies for collecting water have shown they may help people gather less water, improve agricultural water security, and aid in ecological restoration projects. By providing robust water supplies in the face of varying weather patterns and protracted droughts, they also aid in the adaptation to climate change. Fostering an enabling environment is essential for the broad acceptance and success of water collecting systems. This involves financial incentives, policy assistance, and educational efforts to increase capacity among communities and stakeholders. Additionally, to increase the effectiveness and cost of current technology, research and development activities should look into new developments. Harnessing the promise of water harvesting technology is not only a choice, but a need as we manage the difficulties of a rising world population, climate change, and mounting water stress. We all have a duty to guarantee fair access to water resources and to safeguard the environment. By accepting and developing these technologies, we get closer to a day where everyone has access to secure water and our ecosystems are sustained for future generations.

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CHAPTER 9

A BRIEF DISCUSSION ON SOIL FERTILITY MANAGEMENT

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

ABSTRACT:

Soil fertility management is a fundamental component of sustainable agriculture, crucial for maintaining and enhancing soil productivity, food security, and environmental sustainability. This abstract provides an overview of soil fertility management, highlighting its significance in optimizing nutrient availability, improving crop yields, and mitigating environmental impacts. It explores various strategies and practices, including organic matter incorporation, nutrient balancing, cover cropping, and precision agriculture, emphasizing their adaptability to different agroecosystems and their role in ensuring long-term soil health and agricultural resilience. The abstract concludes by stressing the importance of integrated approaches, research, and education to promote responsible soil fertility management for global food productionsoil fertility management is at the heart of sustainable agriculture, serving as a linchpin for food security, environmental stewardship, and economic prosperity. This review has illuminated the critical role of responsible soil fertility management practices in optimizing nutrient availability, sustaining crop yields, and mitigating environmental degradation.The incorporation of organic matter, judicious nutrient balancing, cover cropping, and precision agriculture are among the key strategies employed to maintain and enhance soil fertility. These practices not only improve soil structure, nutrient retention, and water-holding capacity but also reduce the risk of nutrient runoff and soil erosion, protecting water quality and supporting ecosystem health.

KEYWORDS:

Crop Rotation, Fertilization, Green Manure, Nutrient Management, Organic Matter, Soil Amendments.

INTRODUCTION

In semi-arid regions with limited water resources, bottle-feeding tree seedlings is a water-saving strategy for tree establishment. A cap is placed on a bottle after it has been filled with pure water. The top of the bottle has a little hole poked into it. Following that, the bottle is placed into the ground in the tree root zone, making sure it lays at an angle. It is a kind of modified drip irrigation in which water seeps into the soil in tiny droplets for a number of days before the bottle is filled again. Water loss from evaporation is minimized in this manner. The technique is effective and has been used to plant fruit and forest trees in Kenya's dryland regions including Kitui, Machakos, Laikipia, and Tharaka. Farmers in Budalangi have reported an improvement in tree survival from approximately 20% to nearly 100% by burying the bottle beneath the soil to control the water temperature.

Due to their little temperature variance, their tests showed that white plastic bottles were the best. Before having to be refilled, one liter of water may last around two weeks. When a young tree hasn't yet formed a deep root system to draw water from deep soil strata, this strategy only needs to be used for the first two years of development for the majority of trees. It has proven feasible to grow trees using this method in regions where rainfall only occurs for 2-3 months out of the year, making it exceedingly challenging to grow trees without applying water in some way[1], [2].

Garden in Bags

When land is scarce, bag gardening is a cost-effective approach to raise vegetables because it makes use of the air space above the farm's actual boundaries to increase output. Both rural and urban regions, including those who live in apartments, may benefit from the gardens. In addition, illnesses and pests are less prevalent and simpler to manage. The majority of rural families utilize bag gardens to produce vegetables using kitchen trash, particularly in areas where water is actually a rare resource. Bag gardens occur in a variety of sizes and designs, with the most popular version being the use of old gunny bags, which are often borrowed or purchased for a very cheap cost. Especially those used to package sugar or grains, a used 90 kg jute bag is utilized to create a normal garden. Initially, 2 cm-diameter holes are punched at intervals of 0.25 m to 3.0 m, beginning 0.15 m from the bottom. About 20% of the soil in the bag is made up of well-decomposed manure. Three poles are placed in the center of the bag, and the gap between them is filled with gravel and straw to form a watering shaft in the soil. This shaft functions as a vertical conduit for sub-irrigation using pipes. The garden is watered, and seedlings of various vegetables, including kale, tomato, and spinach, are inserted through the perforations and at the top of the bag before being mulched. Depending on the crop kind and bag size, there may be 20–50 plants per bag. Sunlight is used to maintain the bag garden[3], [4].A bag garden has the benefit of making efficient use of limited area and water. The bag may be set up on a platform above the ground to prevent harm by pests like poultry and snails and practically no weed management. The bag may also be protected against large bug pests by having a net over it. Vegetables may grow well throughout the duration of their life cycle, which can last up to a year, depending on management.

Systems for storing water

Blue water which is produced by water harvesting systems with a storage component, may be used for a variety of things on a farm, including household needs, animal watering, and supplementary irrigation. Although micro-dams and farm ponds for the storage of water are often found in semi-arid regions, they are typically found downstream in watersheds, and the water is mostly utilized for livestock and domestic requirements. Earth dams are often used by farmers to spot-irrigate small vegetable plots in semi-arid parts of Machakos District, Kenya. Earth dams, which typically have a storage capacity of 200 to 1,000 m3, are used to support a crop with water during times of stress as well as for small vegetable gardens due to the significant water needs for crop production. There are many different types of storage systems, from micro-dams that store open surface water to retention dams that recharge shallow water tables and soil water to sand dams and subsurface dams in sand rivers[5], [6].

In contrast to within-field systems, water storage systems sometimes work on a watershed scale, necessitating the discussion of issues including ownership, local institutions, and land tenure. They are generally difficult to develop systems and demand large capital and personnel costs. Institutions that provide services often lack the resources to promote and aid in the development of stored water harvesting systems. There is an institutional dispute in Kenya concerning which government ministry is in charge. Evidently an aspect of agricultural growth, earth dams used for irrigation are within the purview of the Ministry of Agriculture. The Water Act, which is administered by the Ministry of Water Resources, recognizes rainfall as a water resource as soon as it is captured in a dam reservoir.

Tank and Roof Catchment

Because it delivers water at home, is reasonably priced, is simple to use regardless of physical or climatic circumstances, and can be tailored to meet varied situations, rainwater collecting from impermeable roofs is a common technique used to acquire water for residential consumption. Since the building is family owned, upkeep is often excellent and there are seldom any water issues. For families, surface tanks may range in size from 1 m3 to more than 40 m3, and for schools and hospitals, they can be up to 100 m3 or more. The demand and rainfall pattern both affect tank size. If the complete household need is to be fulfilled during the dry season, areas with seasonal rainfall will need bigger tanks and a roof that is presumably greater than 100 m2. Surface tanks also have the advantage of having a tap conveniently located above the tank's base for easy water extraction. Water may be routed by gravity to where it is needed if elevating the tank by putting it on a stand or foundation. Additionally, the building of such water tanks employs local craftspeople and uses locally accessible resources[7], [8].

The comparatively high expenses associated with this technology are the major reason why it has not been extensively used. The daily water need per person in rural regions is 20 liters on average. A tank may last up to 30 years or more, thus the investment is deemed cost-effective at roughly $150 per person, according to estimates from Kenya. Another issue has been structural collapse, particularly with tanks made of concrete. Although there are a variety of causes for this, including the use of low-quality cement, aggregate mixtures, inferior sand, poor craftsmanship, shoddy curing techniques, and overall lousy management. Surface tanks, however, provide a dependable and long-lasting supply of clean water for homes, schools, and communities when they are built and maintained properly. Surface tanks may be built under substantial rock catchments as an alternative to roofing, particularly for communal water supply. In general, the water recovered is of a greater caliber than that from the traditional boreholes in the ASAL districts. Such tanks should have a sufficient capacity, and the neighborhood should get instruction on how to manage the catchment and distribute the water fairly.

DISCUSSION

Due to their less expensive construction than surface tanks, underground tanks provide a more affordable option. They are particularly well suited for farms with thatched roofs, traditional buildings, and other surfaces, such as catchment areas for runoff from paved areas and roadways. Water must be pumped, however, unless the ground gradient allows it or there are built-in gravity outlets. Higher chances of pollution and sedimentation are another issue; however, the latter may be mitigated by providing enough siltation basins. The inability of the village level to design and build subterranean tanks that are both functional and do not constitute a security concern may be the major issue. More farmers in the Machakos District are using underground tanks thanks to better designs, with excellent results, for capturing road runoff. In residential areas, subterranean tanks with spherical or cylindrical designs and brick construction are favored. These little tanks make it possible to irrigate tiny kitchen vegetable gardens and may be extremely economical. The cost to build a cylindrical tank with a 15 m3 capacity in the Machakos District was estimated to be around 15,000 Kenya Shillings, or about one shilling each liter of water extracted. Due to their simplicity of construction and lower cost, rectangular and semicircular plastic lined tanks are also becoming more and more common.

Birkas

Underground cisterns, sometimes referred to as "birkas," are used to store water in Ethiopia's Somali Region. Birkas are an indigenous technology that are often held by families. They are rectangular underground tanks with a concrete inside and an impermeable clay tile outside, often used to store household water. The construction of subterranean tanks and pans has been encouraged by Ethiopia's Ministry of Water Resources in recent years as a method of water gathering. Small kitchen vegetable gardens may be irrigated using the tanks, and animals can also be watered. The biggest issue is the significant manpower need for constructing tank foundations and digging the pans. Additionally, unless the ground gradient enables gravity exits, water must be pumped. Additionally, there is a greater risk of pollution and sedimentation, however the latter may be minimized by supplying sufficient siltation basins[9], [10].

Digged-up Pans and Ponds

Excavated pans are small depressions made to catch and store water runoff from a variety of surfaces, such as hillsides, roadways, rocky terrain, and wide rangelands. In many areas of East Africa, pans have been utilized to collect rainfall, particularly for hydrating animals. In the drylands of Kenya and Ethiopia, "food-for-work" initiatives helped popularize excavated pans. The pans may be used to collect runoff from the residential area, when homes are composed of cow dung or grass thatching, as in 3.12. The water collected may be utilized to enhance agricultural irrigation or to water animals when correctly built and equipped with adequate sedimentation basins. Water pans have issues with their comparatively limited capacity, high siltation rates, water loss via seepage, and significant evaporation losses. Only one of the 12 operable pans in the area delivered water throughout the year, according to Mati's evaluation of the water resources of the Isiolo area. In addition, the majority of the pans were not gated, allowing cattle and people to have direct access to the water in the pans, resulting in significant levels of water pollution. Plastic lining of subterranean tanks and pans has become more common in an effort to reduce seepage losses. For impoverished smallholder farmers, however, the high cost of high-quality materials and the need for custom manufacturing in huge facilities in the nation's capital, Nairobi, are significant obstacles. Cheaper techniques like clay grouting need to be promoted, but often the challenge is locating high-quality clay.

Caroc Dams

Charco dams are fairly tiny dug pits or ponds built for livestock irrigation in carefully chosen places with relatively level topography. The concept is straightforward and requires little in the way of engineering expertise to execute at the village level. The pond is located at the lowest part of the terrain for maximum water collecting efficiency. Either human labor or machines may be used for the excavation, which can reach depths of 3 m. The ideal location may be chosen by looking at contour maps of the region or by seeing where water naturally gathers. Tanzania's Shinyanga, Dodoma, Arusha, Tabora, Singida, and Mwanza areas are frequent locations for charcoal dams.

Miniature Earthen Dams

Earthen dams are recommended when higher amounts of water are needed. Where there is an abundant supply of channel flow, an earthen dam is built either on-stream or off-stream. The dam wall typically includes a clay core, stone aprons, and spillways to release extra runoff. Its height ranges from 2 to 5 meters. There are thousands to hundreds of thousands of cubic meters of water. Ponds are the typical name for reservoirs with a water capacity less than 5,000 m3. Due of their high construction costs, earthen dams are typically built via donor-funded initiatives. For instance, it cost roughly US$5,000 to excavate a 15,000 m3 earth dam in Kenya's Laikipia District. In Mwingi District, however, there have been instances of smallholder farmers physically digging earthen dams. Earth dams can provide enough water for animal watering as well as irrigation operations. In the Tanzanian provinces of Dodoma, Shinyanga, and Pwani, low earthen dams known as "malambo" are typical. It entails building dams to collect water from catchments that range in size from 20 km2 for a steep catchment to 70 km2 for a flat catchment. Some of them are medium-sized reservoirs used to deliver water to cities or for cultivation. Although delivery wells and sediment traps may assist to enhance water quality, most of the time, untreated water from these sources is still unfit for human consumption.

Hafir Dams

Dams called "Hafir" may be found in East Ethiopia. They are depressions, either created naturally or artificially, where runoff water gathers and is utilized by people and cattle. Hafirs are typically dug reservoirs that may hold 500 to 10,000 m3 of water. Hafirs are natural depressions that are positioned there, and the excavated earth is utilized to create banks around the reservoir to expand its capacity. Bunds and catchment apron upgrades might boost runoff into the reservoir, however during the dry season, seepage and evaporation are often high. Hafirs stand out from other earthen dams because they often have larger sizes and effective sedimentation basins. Although humans and animals may drink straight from clay dams, hafirs watering spots are strategically placed, the area is completely walled off, and the reservoir is regularly desilted. Major downsides of eathen dams include high water turbidity and sedimentation issues. The main disadvantage of hafirs is the need of regular cleaning to eliminate silt, which is a difficult process.

Sand and Underground Dams

The word "sand river" refers to ephemeral water channels that are often dry for the most of the year in seasonal rivers in semi-arid regions of East Africa. However, during the wet season, they are vulnerable to floods. And at such periods, water may be held in the spaces within the sand if a barrier is built across the river. In a sand river, sand or subsurface dams are the most practical methods of water harvesting. The only additional costs for building are often labor and cement, which are typically accessible locally. Typically, locals are instructed in both the methods of building and how to choose a good location. According to a case study in the Machakos District, a sand dam has been effectively utilized to meet the yearly water needs of a 3,000-person settlement. Subsurface dams, for instance, cost the community in Machakos District, Kenya, roughly US$0.20-0.30 per m3 of water, although these expenses are readily recouped over time. The benefit of sand river storage is that it often upgrades an established and, thus, socially acceptable water supply. The water is shielded from considerable evaporation losses and is less likely to be polluted since it is held under the sand. Water quality may be further improved by building river intakes and hand-dug wells with hand pumps in the riverbank.

Nissen-Peterssen made a distinction between three kinds of subsurface dams: sand dams constructed of masonry, stone masonry subsurface dams, and clay subsurface dams. Therefore, it is cost-effective to take into account the potential of subterranean sand dams for the storage of the collected water where deep sand may be found. A wall built across a stream to limit surface flow is called a sand dam. After floods have brought sand to the spillway level, the height of the dam wall is raised by 0.3 m. Sand may then get trapped upstream of the dam wall, increasing the riverbed's total capacity for storage.

The top of the dam wall rises above the level of the sand riverbed in sand dams, unlike underground dams. Where the wall embankment is below the surface is known as a subterranean dam. The embankment for a subterranean dam may sometimes be built using compacted clay. When a building is combined with a drift to bridge a river, the cost is significantly reduced. Subsurface and sand dams should be constructed gradually because silt settles in the dam if it is constructed too high. It ought to descend to the sand's underneath impermeable layer. Due to reduced evaporative losses, the water in the sand dam may be stored for a considerable amount of time.

Estimated Costs for RWH Interventions

The low incomes of smallholder farmers and the fact that RWH technologies may be costly, particularly when used in water storage systems like tanks and reservoirs, are two key factors influencing their adoption. These factors account for why financed projects have typically carried out the majority of RWH initiatives. Despite the fact that prices differ across nations and locations, given the accessibility of local resources and the similarity of operating circumstances, the fundamental costs per cubic meter for certain RWH technologies are often comparable.

In East Africa, the amount of food produced per person is falling, and smallholder farms' deteriorating soil fertility is a contributing factor. This is due to the steady depletion of nutritional capital caused by soil erosion, leaching, and crop harvest clearance. The addition of chemical fertilizers and organic manure, which the majority of smallholder farmers in the area cannot afford, should be used to counteract farmers' use of crop wastes as fodder and shorter or no fallow periods as a result of dwindling land resources. Therefore, it is necessary to create cropping and soil nutrient systems that limit the need for artificial fertilizers. It is also necessary to figure out how to include animals into the agricultural system. The use of leguminous mulches, agroforestry, composting, and other methods that lower the hazards of acidification and salinization should be the focal point of any soil fertility replenishment. Soil fertility replenishment should be seen as an investment in natural resource capital.

According to research smallholders in East Africa are experiencing a critical level of soil fertility depletion as a consequence of an imbalance between fertilizer inputs, harvest removals, and other losses. For instance, it is estimated that agricultural soil in Kenya loses 112, 2.5, and 70 kg ha-1 of nitrogen, phosphorus, and potassium annually. Many small-scale farms gather crop waste to feed to animals, returning relatively little to the soil to replace lost nutrients. Thus, the loss of organic substance worsens this illnessvarious groups and environmental factors may have various definitions of what "poor" and "fertile" soil imply. The ability of the soil to grow crops by offering a sufficient supply of nutrients in the right proportions, resulting in sustained high crop yields, is referred to as soil fertility. A rich soil also has excellent aeration, strong water holding capacity, and good rooting depth. Additionally important are a significant number of soil organisms, such as earthworms, a sufficient quantity of organic matter, the proper pH balance, and the absence of harmful soil-borne pests and diseases. More stimulation of the activities of soil organisms, nutrient inputs to the soil, a reduction in nutrient exports from the soil, and appropriate nutrient recycling within the agricultural system should be the outcomes of efficient farm management techniques.

Therefore, based on well-established criteria, it should be easy to determine if a soil is fruitful or not. Soil fertility management among smallholder farmers is fairly common in Kenya's subhumid highlands. In Embu District, for example, 91% of farmers use farmyard manure, 91% use mineral fertilizers, and 74% rotate their crops, while in Vihiga, western Kenya, 75% use compost manure, 79% use green manure and cover crops, 91% use farmyard manure, and 93% use crop residues. Improved fallows, biomass transfer, and crop residues are other soil fertility-enhancing treatments. Technologies that increase soil fertility and production are just as crucial to soil and water management as those that lessen erosion and water loss. Remainder mulching, contour ripping, tied ridging, minimal tillage, subsoiling, crop rotation, cover crops, rotational grazing, contour application of organic matter, farmyard manure, and inorganic fertilizers are a few examples of these techniques.

Mineral fertilizers used

Even though it is not a common practice in the region, using mineral fertilizers has been gaining popularity, although at modest application rates. For wheat, pea, barley, and teff, fertilizer application studies have been conducted in Ethiopia with farmer experimentation in the Galessa and Meta Robi districts, the Welmera and IlalaGojo regions near Holetta, and in many other locations as well. Crops have responded well to fertilizer, demonstrating enormous potential for increasing agricultural yield. Although the price of fertilizers is out of the grasp of impoverished farmers, this approach has gained popularity among more affluent farmers. According to 1995 research, 78% of the farmers surveyed utilized mineral fertilizers, and almost all of the farmers who didn't were less wealthy. DAP was the most common form of fertilizer utilized. Richer farmers use more fertilizer, and the amount utilized depends on the socioeconomic status of the farmers. In semi-arid eastern Ethiopia, field tests on maize and sorghum with and without fertilizer application revealed a significant production gain when fertilizers were used in conjunction with water conservation techniques. However, water saving was responsible for more than 50% of the increase in output.

For commercial crops like coffee, tea, and tobacco in Kenya, smallholder farmers often utilize mineral fertilizers, although they are seldom used on food crops. The average application rates are roughly 35 kg ha-1, which is less than what most kinds of soil need as a minimum. The application rates for food crops are much below the necessary level, even if they are closer to the recommended level for cash crops. Even if they are pricey, inorganic fertilizers should be encouraged since many varieties of soil don't have enough phosphate and nitrogen. In Kusa, Nyando District of Kenya, Mati and Mutunga noted that farmers were not utilizing fertilizers, in part due to the fact that they were not locally accessible and that the closest store where fertilizers could be purchased was more than 40 kilometers away. They suggested that farmers get training on how to use fertilizers that are appropriate for their needs and the correct techniques for application. Additionally, it was advised that strategies be developed to make fertilizers more accessible to the public by way of neighborhood stores and by packaging them in modest amounts to assure affordability. The majority of farmers only use DAP, therefore it's important to teach them about the other fertilizers' distinctions and applications, the benefits of applying them, when it's best to apply them, and at what rates. Additionally, farmers should be encouraged to experiment.

Employing Organic Manure

Organic carbon concentrations have been shown to be the main determinant of soil fertility. Total organic C was found by researcher to be the most sensitive soil quality indicator among soil organic pools and fractions, indicating that it may work well as a soil quality indicator within a certain range of soil. According to other research conducted in Kenya, soil organic matter fractionation may provide information about changes in soil fertility and the viability of earlier management techniques. The lack of organic resources like crop straws and animal dung limits the usage of organic manure in Ethiopia. Numerous small-scale farmers give agricultural leftovers to their animals, and the dung is then dried and utilized as fuel. Because of this, the soil's fertility declines, its ability to hold onto moisture decreases, and the result is low yields. Farmers in many high-potential locations have turned to continuous cultivation as a result of shrinking holding sizes, which has further exacerbated soil degradation and subpar crop output.

It has become more important to diversify the sources of manure as more farmers raise tiny ruminants. Goat farmers successfully employ "goat manure" in their farming practices. In spite of its relatively high pH, experiments in Kibos, near Kisumu in Kenya, demonstrated that goat dung had greater soil fertility benefits when compared with DAP fertilizers, which are popular among farmers in Kenya. Goat manure is also more cost-effective and has lower direct expenditures. Farmers have become more environmentally conscious as a consequence of conservation technology, which has increased the usage of manure. The primary issue, however, has been the deterioration in manure quality, which is linked to inadequate storage facilities and careless management.

CONCLUSION

To effectively mitigate and adapt to climate change, responsible soil fertility management is essential. A healthy soil acts as a carbon sink, trapping carbon dioxide from the atmosphere and lowering greenhouse gas emissions. Furthermore, resilient soils with improved water-holding capacity are better able to tolerate the difficulties brought on by varying precipitation patterns and harsh weather events. Adopting integrated strategies that take into account regional characteristics, agricultural systems, and community requirements is crucial for promoting responsible soil fertility management on a worldwide scale.

To create and put into practice policies and methods that support sustainable nutrient management, governments, farmers, researchers, and agricultural extension agencies should work together.

The development of soil fertility management strategies depends critically on ongoing research, innovation, and teaching. More effective and specialized strategies may be developed by comprehending the complexity of soil-plant interactions, nitrogen cycling, and the effects of various agricultural methods. Responsible soil fertility management is a key component of sustainable agriculture as we face the tremendous problems of feeding a rising world population while protecting our natural resources and reducing climate change. To guarantee a robust and prosperous future for everybody, it is our common obligation to make sure that these techniques are extensively used and incorporated into agricultural systems.

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CHAPTER 10

PARTICIPATORY APPROACHES IN WATER AND NUTRIENT MANAGEMENT

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

ABSTRACT:

Participatory approaches in water and nutrient management are gaining prominence as effective strategies for addressing the complex challenges of resource allocation, sustainability, and stakeholder engagement. This abstract provides an overview of participatory approaches in water and nutrient management, highlighting their significance in promoting community involvement, informed decision-making, and equitable resource distribution. It explores various methods and tools, including participatory rural appraisal (PRA), community-based resource management, and farmer field schools, emphasizing their adaptability to diverse socio-economic and ecological contexts. The abstract concludes by underlining the importance of these approaches in achieving sustainable resource management and fostering collaboration among stakeholders for the benefit of both people and the environment.participatory approaches in water and nutrient management offer a promising path toward addressing the intricate challenges of resource allocation, sustainability, and equitable distribution. This review has illuminated the pivotal role of these approaches in promoting community engagement, informed decision-making, and effective resource management.

KEYWORDS:

Community Engagement, Farmer Participation, Nutrient Management, Stakeholder Involvement, Sustainable Agriculture.

1. INTRODUCTION

Leguminous plants that cover the ground as runners and are often cultivated with other crops are used as green mulches. Because the companion legume may fix nitrogen in the soil, they are also frequently referred to as "green manure." The legume might be cut when still green and used as manure in the soil.

The legume may also be grown as a cover crop. Other crops, such watermelons and pumpkins, have shown to be effective green mulches. The introduction of water melons as a companion crop in a papaya plantation in Embu District, Kenya, increased soil moisture conservation, according to the author's research. Trials conducted by farmer experimenters in Mbozi District, southern Tanzania, revealed that planting velvet bean beneath coffee decreased weeds while increasing coffee output owing to water conservation and improved soil fertility brought on by the beans' ability to fix nitrogen[1], [2].

Herbal Teas

It is sometimes essential to make liquid manure in the form of "plant tea," which is used as a top dressing and to swiftly provide the crop with enough natural plant food throughout the growing season. Green sappy leaves and young branches of leguminous trees are cut and placed in a drum of clean water to make plant teas. The covered drum is left standing. The plant tea may be utilized after two to three weeks, depending on the kind of plant material and the temperature. Before application, it is then diluted by at least 12 parts per volume.

Composting

Composting is becoming more and more popular, particularly among smallholder farmers and those who are more forward-thinking and creative. Composting is a natural process that converts organic waste products, such agricultural leftovers and farmyard manure, into beneficial humus or plant nourishment. The components that go into making high-quality compost, such as manure and leguminous waste, are equally crucial to the composting process. One of the most prevalent practices among East African farmers and those engaged in organic farming is composting. To avoid termite infestation, the standard method for composting is to first create a foundation on which to distribute ashes. Then, saturating each layer with fresh water, dried agricultural wastes, green plants like Lantana camara and Tithonia divers' folia, and dirt are piled on top of one another. The mound is then covered with dirt, and a stick serving as a thermometer is inserted into its center. After around 22 days, the compost is turned. Within 45 days, the compost is suitable for usage throughout the majority of East Africa.

Making Compost in Mapambano

A farmer in Dodoma, Tanzania named Ms. Susanna Sylvesta invented the process for generating mapambano compost. Each year, she produces 15 tons of compost. The composting system is built using materials that are easily accessible locally and pits that are over 1 m deep and up to 3 m in diameter. The bottom of the pit is covered with ash, and then layers of grass, tree leaves, sisal leaves, manure, bedding, animal urine, and ash are added in succession. The addition of domestic wastewater keeps the mixture wet. The hole is filled and finished with a crown of grass and one last coating of ash. It is kept wet by regular additions of wastewater and urine until it has completely decomposed. This takes around 3 months and creates a rich compost that is used at a rate of 1.5 t/ha/year on the maize crop. Even for the export market, compost was going to be packaged for sale[3], [4].

Baskets for compost

In certain areas of East Africa, a different composting method known as "compost baskets" is also popular. A compost basket's purpose is to perform in-situ composting, in which the crop makes use of the compost as it breaks down and so is predicted to survive longer. Following the following procedure, holes at least 15 cm deep and 30 cm broad are excavated along the center line of each prepared bed, spaced a distance of approximately 1 m apart, to be filled with compost. Then, around each hole, sticks approximately 60 cm long are hammered into the ground, and long, flexible twigs are weaved together to create above-ground baskets. Manure and thoroughly decayed domestic garbage are piled into the baskets. Natural mechanisms transfer the manure from the soil under the basket into the root zone. The roots also prefer to grow in the direction of the basket due to hydrotropism. For the production of tomatoes, this method has been tested in western Kenya's Funyula division. A production value of Ksh 100 per square meter of land was calculated based on yields. Compost baskets have gained popularity in eastern Kenya thanks to KIOF, since farmers there have discovered that using them needs less work than traditional composting[5], [6].

Duplicate Beds

By breaking up the dirt in the hard pans and generating a thick layer of loose, rich soil, double-dug beds are used to prepare the land for agriculture. In addition to increasing rooting depth, this approach aerates the soil, enhances water absorption and retention, and enables plants to absorb available nutrients more effectively. In comparison to shallow tillage, these beds may be employed for intense cultivation and will generate better yields. A double-dug bed is typically advised to be around 1.5 x 7 m broad and 60 cm deep. There are around six wheelbarrows of compost in the bed, enough to last for four successive crop seasons before the procedure has to be repeated. When the soil is rocky or there is a manpower shortage, farmers have modified this approach in a number of ways, including modifying the length of the beds and adding a range of organic ingredients. DDB and composting seem to be employed more often in high potential locations than in medium potential ones. Two factors, including the ease with which water is accessible in high-potential places and the ease with which manure can be acquired from zero-grazing units, may account for this.

However, tests reveal that, when compared to Kenya's high potential Nyeri District, DDB and composting generate greater yields of maize, better gross margins, and higher returns on labor in a medium potential location like Machakos. This is most likely a result of the greater frequency of hard pans in Machakos. Since the late 1980s, double-dug beds have been advocated by NGOs in Ethiopia, Tanzania, and Kenya, where they are mostly utilized for growing high-value commercial crops like vegetables. The building method entails digging up the topsoil and subsoil separately in order to prepare the garden beds. To enhance infiltration, the trench bottom is further tilled. The topsoil is then reapplied to the bed after being blended with organic manure. In order to prevent compaction, care must be taken not to tread on the bed. The beds are subsequently planted with high-value crops, and the results are excellent since the beds absorb more water than with normal tillage. Compost output must be raised in order for them to be used, and this should be done as soon as the double-dug beds are constructed. Double-dug beds were employed by 22% of farmers who had received training in Low External Input Sustainable Agriculture farming techniques, according to a study[7], [8].

Mulching

Mulching is done to maintain soil temperature, limit weed development, improve soil structure, and decrease runoff flows, evaporative losses, and wind erosion. In East Africa, mulching often entails covering the soil with chopped grass, leftover agricultural debris, straw, or other plant matter. Due to the abundance of vegetative debris in East Africa's wetter regions, farmers there use mulching. Due to a lack of agricultural wastes, most smallholder farmers only mulch specific crops like tomatoes, cabbage, and potatoes. Mulch densities may vary from 30 to 70 percent, depending on the number of agricultural leftovers that are still available from the previous season. It is impossible to exaggerate the value of mulches in lowering evaporative losses, soil erosion, and surface runoff. In a study conducted in the Laikipia District of Kenya, it was found that without mulch, 40 to 60 percent of the rain that fell was lost to evaporation. However, if mulch covered 40 to 50 percent of the ground, surface runoff losses were reduced to almost zero, and evaporation losses were cut in half. The biomass needed to feed the cattle rose, and crop yields were found to double or treble. The Indigenous Soil and Water Conservation Program in Tanzania examined the use of crop wastes to mulch the coffee crop cultivated in the remote Mbozi District via a participatory experiment with farmer innovators. The farmers discovered that the mulched plots produced roughly twice as much coffee, which was related to the preservation of soil moisture.

Agroforestry

Despite being an indigenous intervention in many communities in East Africa, agroforestry rose to prominence in the 1980s with the founding of the International Council for Research in Agroforestry, which established a Nairobi office and carried out fieldwork in the area. The Soil and Water Conservation Project of the different Ministries of Agriculture of Kenya, Ethiopia, and Tanzania has included seedling production as a component. In the beginning, nurseries were the main emphasis, but starting in 1988, there was a move towards a more comprehensive and supporting role in acknowledgment of the need to collaborate with farmers. Training of farmers received more attention than seedling production. Production of educational materials for farmers, extension workers, and schools became a crucial component. The current governmental push and intensity of extension resulted in a surge in enthusiasm for agricultural forestry operations. The manufacture of seedlings included several institutes. They comprised rural development initiatives, nonprofit organizations, farmer associations, and rural communities. By the middle of 1991, there were 4,161 recorded tree seedling nurseries constructed by different organizations in Kenya alone, and agroforestry was heavily involved in soil and water conservation programs in Ethiopia and Tanzania. The majority of smallholder farmers engaged in agroforestry choose growing trees with several uses.

They have come to understand that via agroforestry, trees provide nutrients to crops by absorbing nutrients through atmospheric deposition, biological nitrogen fixation, drawing nutrients from deep below the subsoil, and storing them in biomass. Through the transformation of soil organic matter into usable nutrients, trees help improve nutrient cycling. Therefore, nutrients may be recycled via root decay, leaf fall, and green manure. Through the supply of poles for construction, fruits for sale and consumption, fuel wood, and animal feed, agroforestry also directly helps farmers. Additionally, the trees boost soil fertility and the microclimate while reducing soil erosion and conserving soil water. The preservation of soil, biodiversity, and terrestrial carbon are some of the environmental advantages of trees.

Intercropping in Hedgerows

ICRAF promoted hedgerow intercropping or alley cropping in the 1980s, but farmer uptake has lagged. Leguminous tree bushes are grown over the hill in short strips, then the shrubs are cut down, and the remaining material is utilized as a green mulch. Sesbaniasesban, Caliandracalothyrsus, and Leucena sp. are popular species. The replacement of nitrogen fertilizers by nitrogen fixation by hedge roots and its assimilation via trimming is intended to save expenses. However, in the dry regions, crop and hedge competition for moisture was a significant limiting factor. Hedgerow intercropping may be quite helpful in soil conservation, excepting the aforementioned issue, as discussed below.

On a slope of 14 percent land in Katumani, Machakos, ICRAF experimented short hedgerows of Cassia siamea, a leguminous and nitrogen-fixing shrub, planted on the contours to allow the establishment of naturally occurring terraces. On a hillside that was already soggy, 52 mm of rain poured in within 30 minutes one night in April 1990. More than 34 tons of soil were lost per hectare in fields that were exclusively used for crops. areas without hedgerows lost, on the other hand, at most 6 tons per hectare. The yields from fields with just one crop were two to three times greater when maize and cowpeas were cultivated between hedgerows.

Better Transfers of Fallows and Biomass

The purposeful planting of leguminous tree species with the main goal of fixing nitrogen as part of a crop fallow has been referred to as improved fallows. In the Lake Victoria area, where agroforestry methods are a key emphasis on measures to improve soil fertility, improved fallows have recently been developed to allow for the enriching of a natural fallow with leguminous trees or bushes. Sesbaniasesban, Crotalaria grahamiana, and Tephrosiavogelii are some of these plants.

Another method of biomass transfer is the absorption of leafy shrubs into the soil. These plants quickly mineralize and collect significant concentrations of nutrients in their leafy biomass. Shrubs like Lantana camara and Tithoniadiversifolia are employed in this approach of cut and carry mulching. Because it is frequently accessible, simple to cultivate, and comparatively richer in nutrients than other biomass materials, Tithoniadiversifolia is the most widely utilized biomass material in western Kenya. A ton of dried Tithoniadiversifolia leaves typically includes 30.8 kilogram of potassium, 33 kg of nitrogen, and 3.1 kg of phosphorous.

Low-input Agriculture Systems

Alternative Agriculture, Low-Cost External Input Agriculture, Bio-Intensive Agriculture, Sustainable Agriculture, and "Permaculture" or LEISA are a few of the names used to characterize low-input farming techniques. Organic farming is low-input agriculture in its most severe form. An agricultural system that encourages ecologically friendly methods of production is known as organic farming. Natural techniques are used in organic farming to maintain healthy crops and animals as well as rich soil. The strategy uses agriculture resources to maintain the land productive. Instead of fully using what is already there on the farm, traditional farming techniques make a lot of effort to bring in chemical inputs and animal feeds from outside the farm. For instance, costly inorganic sprays, medications, vaccinations, and fertilizers are used. More fertilizers and pesticides are needed to boost the yield due to the soil becoming compacted as a consequence of the use of heavy equipment. Due to the intrinsic limitations of artificially-fed plants, new pests and illnesses appear often, and even those that are already prevalent develop chemical resistance, killing off important soil organisms in the process. The organic farmer, on the other hand, makes an effort to increase soil fertility by composting, correct cultivation, crop rotation, mixed planting, tree growth, good management of crops and animals, and the use of natural insect and disease control methods. A stronger natural balance means that agricultural goods are healthier, sell for much more money than crops cultivated conventionally, and generally promote overall environmental and human health. Most farmer innovators in East Africa engage in some kind of low-external input agriculture, which is important to lower production costs, minimize reliance on "imported" inputs, and assure ecosystem sustainability.

DISCUSSION

An approach, which includes an organizational structure, leadership, resources like employees, facilities, and equipment, goals and objectives, as well as methods and strategies for execution, is the essence of an agricultural research and extension program. It also has connections with other businesses, the general public, and its customers, or partners and/or collaborators. Millions of dollars in foreign currency were allegedly spent on research and extension methods in Africa throughout the three decades that ended in 1990 in an effort to further agricultural growth. Even still, this investment hasn't been able to spur economic development or relieve misery and poverty. Both national policy and donor attitudes are to blame for the issue.

Numerous efforts have been launched to support the growth of research in Africa. The East Africa Framework for Action on Agricultural Research, for example, was created with the aim of identifying the steps necessary to enhance the performance and efficacy of agricultural research in the area. The Special Program for African Agricultural Research was created as a consequence, and it was successful in gaining the backing of funders and national authorities. The accomplishment of the actions outlined in the framework for action depended on securing the backing of other institutions engaged in the creation and distribution of technology. Even with such attempts, East Africa has underused agricultural research and extension techniques for a variety of reasons[9], [10].

Making Farmer Knowledge Visible

Technology, policy, research, and extension programs have all been used in several agricultural and resource management experiments in the East Africa area. Rural extension techniques that assumed a one-way stream of information, from research through extension to farmer, have been shown to be unsuccessful, according to evaluations of their successes and failures. These methods disregarded the information already present in communities and overlooked the methods through which farmers pick up new skills and adopt new practices. Public sector agricultural research institutions have not been very successful in their attempts to increase the systematic participation of resource-constrained farmers. This is a result of both the scientific researchers' lack of internal drive and the absence of outside pressure from the farmers. Farmers seldom ever request research assistance from academics. Several models that outline the interactions between scientists/researchers, extension educators, farmers, and the informal sector have arisen in an effort to improve the system's efficiency. These have been referred to by a variety of names, including farmer field schools, quick and participatory rural assessment, on-farm research, farming systems, and agro-ecological research. Farmers' own contributions to innovative land management technologies and the importance of indigenous technology for managing soil and water are being given greater weight in an effort to strengthen the connections between farmers, researchers, and extension agents. A wide range of interventions, including integrated soil fertility management, soil and water conservation, rainwater and runoff harvesting systems, integrated pest management, tillage and soil management systems, improved seeds, innovative agronomic practices, and better ways of scaling-out successful practices, have all been used in creative and indigenous ways to increase yields. These instances of achievement, nevertheless, are few.

Indigenous Knowledge and Technologies

Indigenous knowledge is described as "a mixture of knowledge created endogenously within a society and knowledge acquired from the outside, but observed and integrated within the society" Therefore, indigenous knowledge is localized, comes from farmers, and addresses unique issues at a certain moment. On the other hand, it is best to categorize indigenous technologies and knowledge into four groups: vernacular technical knowledge held by locals, specialized knowledge of certain knowledgeable "Resource Persons," controlling knowledge held by dominant groups in society, and social knowledge specific to the group. Because it could be the only thing that the poorest people can control, local knowledge is a valuable resource. It is a resource that can be realized with minimum expenditure and should represent the aptitude and competency of the local community, putting them on an equal footing with outsiders. Local knowledge is also useful and quantifiable. Rapid rural appraisals, participatory action research, field survey methods with interviews and field measurements, agricultural systems research with agroforestry diagnostics and design, gaming and similar methods, and ITK may all be used to identify and analyze ITK.

Development of Technology with User Input

Farmer-extension-researcher contact has been recognized as being improved via participatory technology development. PTD is the collective term for the knowledge- and skill-based partnership between farmers, development professionals, and scientists. Farmer-led experimentation is a crucial part of PTD because it enables researchers to better understand how to use the resources at hand to benefit communities and families. In order for farmers to be better equipped to experiment and adapt to shifting circumstances, it is important to build their capacity for seeking out and testing out new ideas. It is not the intention to persuade farmers to use a new technology, but rather to motivate them to explore new options and choose the solution that best suits their needs. The PTD approach is related to the theories and practices of sustainable agricultural practices that primarily depend on locally accessible resources and do not need significant outside inputs. The PTD strategy tries to identify such technologies and, where feasible, enhance or modify them to fit the demands of the moment. To avoid endorsing concepts that won't appeal to farmers, PTD promotion must make use of subsidy mechanisms and actual technological demonstration. It should have well-coordinated land-use planning that takes into account agricultural system techniques, addresses the variety of local conditions, and stays away from formulas that are too rigid. To enable decision-making on a more solid scientific foundation, it is crucial to make wise investments in the infrastructure for collecting scientific data. The need to decentralize the decision-making process in order to empower local communities should also be acknowledged, even if there should be an emphasis on the construction, maintenance, and effective management of community assets like dams and community lands. It is essential that the government and all other agricultural sector players act in concert.

Increasing and Decreased Scale

Nowadays, technology transfer is seen to occur in all ways and not simply from the bottom up or top down. There have been instances when the words "scaling up," "scaling down," and "scaling out" have been used interchangeably. In a session with stakeholders, the GFAR examined the meanings of these words as well as the ethics and standards related to them. In the organization of a sector or society, "scaling up" was, for example, described as the vertical transfer of experience, knowledge, influence, and effects further up the levels. From farmers to "extensionists" to NGO workers to local authorities to academics to policymakers/ministers to funders, this entails pushing additional stakeholder groups up the stakeholder hierarchy. But "scaling out" refers to a horizontal distribution within a sector, notably among farmers. Scaling up and scaling out both include adapting, changing, and improving certain technologies and methods, but more crucially, concepts and procedures. In order to make planning, execution, and accountability at lower levels easier, "scaling down" refers to the replication of whole programs, not simply ideas or methods, by breaking them down into smaller programs or projects. It may be considered as decentralization or devolution, and one can also compare scaling out to these processes. Five scaling-up factors were specified by the GFAR: institutional, geographical/spatial, technical, temporal, and economic or cost dimensions. Overall, "participation" and "capacity building" are recurring themes. As for how an implementing organization conceptualizes its project/program intervention, there are three general scaling up strategies it can use: spontaneous scaling up; scaling up after achieving initial local success; and including the scaling up plan from the very beginning of the project.

The GFAR suggested eight broad areas for the methods and ideas that would guide an organization in carrying out its scaling up operations. These included participation, market development, policy change and development, strategic alliances, action research and learning, human connection building, local capacity building, and resource mobilization. They also included training and extension. Although there are several tools, strategies, and ideas available, the challenge of upscaling is still challenging.

Role play of NGOs

NGOs have been more significant in participatory research and extension in recent years. NGOs close the development gap in communities and have helped with resource mobilization, capacity building, shifting community attitudes, and life-saving humanitarian efforts. Some NGOs, particularly in disaster-prone regions, have a significant commitment to tackling problems including the food shortfall, gender, difficulties facing rural women, HIV/AIDS, water delivery to rural communities, savings and credit, as well as participatory planning and management. The majority of NGO programs are supported by comparatively superior monitoring and follow-up procedures, and they excel at acting in advocacy capacities, enlisting the aid of outside resources, and often possessing the capacity to reach the grassroots communities. NGOs provide job possibilities and are also more flexible and less bureaucratic in their operations.

Despite these accomplishments, NGOs have intrinsic limitations due to their operating costs, resource insensitivity, and propensity to flout established norms and rules. The majority of indigenous NGOs struggle to collect money locally and have a high reliance on outside financing as a result. Being less results-based and having a poor knowledge of government policy are limitations that might hinder the effectiveness of NGOs. Farrington and Bobbington evaluated the functions of NGOs and government agencies and discovered that they may work in tandem to better serve farmers. For instance, workers from the GO and NGO may attend training sessions together, particularly those focused on action-oriented techniques like PRAs, collaborative field trials, and information sharing. Additionally, GOs may operate as a financial buffer for NGOs by allocating funds for particular specific duties, and NGOs can mediate between farmers, research services, and funders.

Farmer Networks and Organizations

Farmer associations have been crucial in the growth of East African agriculture. More than any other organization supporting farmers, cooperative organizations have affected the commercialization of agriculture among small-scale farmers. Cooperative societies are crucial for performing a variety of related tasks, including loan provision, input supply, and commodity marketing. A cooperative society's degree of development affects how effective it is. On the one hand, there are emerging cooperative societies without any permanent assets, whose members are unaware of their rights, duties, and membership advantages, and whose management lacks commercial expertise. On the other hand, there are well-established cooperative societies that are capable of lending money to its members, invest in agro-processing, and engage in export-import trade.

Programs for PTD in Ethiopia

Participatory research approaches and farmer outreach projects have grown in Ethiopia over the last several decades. Early research and extension initiatives often fell short of the anticipated growth in agricultural productivity.

CONCLUSION

By integrating local communities and stakeholders in the development, implementation, and assessment of water and nutrient management strategies, participatory techniques, such as participatory rural appraisal (PRA), community-based resource management, and farmer field schools, empower local communities and stakeholders. This not only guarantees that solutions are situation-specific but also helps participants feel a sense of ownership and accountability. Participatory techniques are excellent instruments for solving complex difficulties, from water shortages in dry areas to nutrient management in intensive agricultural systems, due to their flexibility to varied socioeconomic and ecological settings. These methods support resource management techniques that are more resilient and sustainable by leveraging local knowledge and skills. Additionally, participatory methods encourage stakeholder engagement and cooperation beyond conventional borders and interests. They encourage discussion and group decision-making, which results in more equal resource allocation and fewer disputes over access to water and nutrients. It is crucial to engage in institutional support, capacity-building, and education in order to fully realize the promise of participatory methods in water and nutrient management. To successfully develop and execute these strategies, governments, non-governmental organizations, and research institutions should work with local people.

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CHAPTER 11

EXPLORING THE PROVINCIAL RURAL DEVELOPMENT PROGRAM

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

ABSTRACT:

Provincial Rural Development Programs (PRDPs) are instrumental initiatives aimed at fostering sustainable development, poverty reduction, and economic growth in rural regions within specific provinces or states. This abstract provides an overview of PRDPs, highlighting their significance in addressing rural challenges, such as infrastructure deficits, livelihood diversification, and social inclusion. It explores the key components and strategies commonly associated with PRDPs, including community participation, capacity building, and infrastructure development. The abstract concludes by emphasizing the role of PRDPs in promoting inclusive, resilient, and self-reliant rural communities, thereby contributing to broader regional and national development goals. Provincial Rural Development Programs (PRDPs) serve as vital catalysts for inclusive and sustainable rural development within specific provinces or states. This review has illuminated the crucial role of PRDPs in addressing a multitude of rural challenges, from infrastructure deficiencies to livelihood enhancement and social inclusion.PRDPs typically encompass a range of strategies and components, including community participation, capacity building, and infrastructure development. Community involvement and ownership are at the heart of these programs, ensuring that local voices are heard, needs are addressed, and solutions are context-specific. This participatory approach fosters a sense of ownership among rural communities, empowering them to take charge of their development trajectories.

KEYWORDS:

Development Initiatives, Local Communities, Provincial Government, Rural Areas, Rural Development, Socioeconomic Projects.

1. INTRODUCTION

In the 1950s, the Provincial Rural Development Program was established. Lemass committees for development were established by provincial governors. The main goal was to raise money for regional development initiatives. The local population had to make forced financial and labor contributions, and the system was fraught with issues[1], [2].

Agricultural Development Unit in Chilalo

In a special memorandum titled "Comprehensive Rural Development Programs in Ethiopia" published in 1966, the planning commission included the Chilalo Agricultural Development Unit strategy. The Comprehensive Rural Development Programs were originally adopted by Tanzania, which is an essential fact to remember. Due of their astronomical expense, these initiatives were abandoned in the middle of the 1960s notwithstanding their failure. One of the first instances of an integrated rural development initiative was CADU. Distribution of inputs including fertilizer, seeds, and better techniques were the key activities. For comprehensive rural development projects, the government chose 24 administrative units in high-potential regions. The ChilaloAwraja was financed by SIDA. The initiative was extensive and included marketing, credit, extension, and research, among other things. Over a 10–13-year period, the economic rate of return on investment was roughly 18%.

Following the 1975 agricultural reforms and the Ethiopian revolution, the CADU strategy was expanded to include the whole Arssi Region, and the Arssi Regional Development Unit was established. The model farmer strategy was dropped under ARDU, and CADU's overemphasis on advanced technology was criticized. Six departments made up ARDU, with "Extension" serving as its primary department. Cooperative and nontraditional education were developed with the assistance of this department[3], [4].

Agricultural Development Unit of Wallamo

In the highlands of Soddo and Bolosso'sWollamo, this initiative was founded in 1970. It intended to promote local involvement in development as well as economic and social growth. Large financial inducements of 200 to 325 Ethiopian Birr per year were utilized to create 1,750 settler households, encourage a transition from subsistence to cash crop production, and boost tax income for the government. There has been some study done on the markets for maize, wheat, and loan facilities. Over a 20-year period, the economic rate of return was 13 percent.

Program for the Minimum Package

Here, the goal was to provide the bare minimum of services to farmers throughout the nation. These included feeder roads, cooperative development, and agricultural extension. The MPP was started in 1970. The Minimum Package area, which must include at least 10,000 farmers and be located within 75 km of an all-weather road, served as the fundamental unit. Except for people living in nomadic regions, it was anticipated that it would cover half of the region's land area and all of its agricultural population. Over a 20-year period, the economic rate of return was roughly 17%.

Programs of Military Socialism

The Military Junta that overthrew the monarchy in 1975 began implementing the Military Socialist Programs. Agrarian revolution, cooperatives, "villagization," resettlement, and state farms were some of these MSPs. The initiatives, which distributed "land to the tiller" as their goal, grouped rural residents into organizations, cooperatives, villages, and settlement plans. State farms were also created out of former commercial farms. The revolution ended the absolute monarchy and established a nation of peasant smallholder farmers. The revolution quickly went too far, driving people into mass groups, cooperatives, and communities. Prices were set, and peasant farmers were required to limit their agricultural production. These initiatives weren't applicable to cultures who were migratory. The state farms, which were operated using bureaucratic procedures and foreign technology, quickly became a drain on public funds[5], [6].

Programs for Peasant Agricultural Development

PADEP concentrated on hastening agricultural development in high-potential regions of Ethiopia. The main goals were to boost food production, encourage the cultivation of cash crops for export, conserve resources, and enhance incomes and living standards. PADEP led to the contemporary programs of agricultural extension based on decentralization of the Ministry of Agriculture. As a result, it established wereda offices and zonal departments, which participated directly in the execution of numerous initiatives. The Sasakawa Global 2000 Project (SG2000) is a component of Ethiopia's ongoing agricultural expansion. The project includes field program study, expansion, and implementation. The initiative constructed 161 demonstration wheat and maize plots in 2 locations in 1993. The program expanded tenfold in 1994 and included sorghum and teff plots. The program added 3,211 plots in 1995. The national extension system is used by SG2000, and at busy times of the year, extension employees are compensated with a lunch stipend. Participating farmers get agricultural inputs on loan via the programme. They are expected to make a down payment of 25 to 50 percent of the input costs and the remaining amount when the crop is harvested. As long as they agree to have their plots used for demonstrations, participating farmers also get intense support from extension professionals. The credit components are administered through extension agents. However, it seems that forestry, soil protection, and animal production are being neglected. Another issue is that financial incentives might lead to disputes amongst extension workers who are not participating in the project. When the SG2000 program first began, a high ratio of extension workers to farmers allowed for the introduction of the extension package to farmers who had superior resources and abilities. Despite the fact that the enhanced seed and fertilizer constituted between 50 and 80 percent of the overall expenditures, the package was quite lucrative under these circumstances. Results were less positive when the package was made available to farmers who were operating in precarious circumstances. Local variety fared better in these arid locations than the upgraded package. Thus, the expansion of the package to poorer farmers in less favorable agro-ecological zones poses significant difficulties for the banking industry, input supply, and extension services.

Participatory Demonstration and Extension System for Training

Ethiopia's national extension system, the Participatory Demonstration and Training Extension System, has been successfully implemented so far. The extension philosophy that includes research, education, and extension as components of the knowledge system is accommodated by this system, which was created following a critical examination of the previous extension methodologies used in Ethiopia. PADETES places equal emphasis on the development of human resources and the transmission of acceptable and proven technologies, in contrast to previous extension systems where the emphasis was confined to either only technology transfer or the development of human resources. The Federal Ministry of Agriculture has the responsibility to develop and submit agricultural and related policies, and upon approval, coordinate and disseminate them through interregional development programs and/or projects. The Federal Ministry of Agriculture is also mandated to provide technical advice and training services to increase the technical competence of the extension staff of the Regional Agricultural Bureaus.

DISCUSSION

The goal of the national extension program was to achieve food independence. In this sense, the short- to medium-term agricultural development plan would concentrate on environmentally sensitive intensification projects in both historically surplus-producing and drought-prone regions as well as in areas with nomadic pastoralists. The initiative helped small-scale farmers increase their output by disseminating knowledge and tools developed via research. Although the program's original scope was just seven areas and 35,000 farmers, it has already grown to include nearly 2.5 million farmers. The number of farmers participating in the initiative has grown, and many development packages have been created and sent out. Packages on the production of cereal crops and packages on the production of livestock, high-value crops, post-harvest technologies, agroforestry, soil conservation, and beekeeping are among them.

Team Expansion

NGOs have pushed for group expansion since dealing with smaller groups has certain benefits. In one such instance, Action Aid-Ethiopia assisted in the formation of 20–30-

member local savings and credit organizations. Smaller organizations perform better and have less internal problems than village cooperatives, they discovered. This is due to the fact that the groups are more controllable, smaller, and have more in common with one another than the much bigger village-wide cooperatives. Instead of concentrating on issues identified by outsiders, the groups might concentrate on issues they believe are important. To retain the groups' expertise and zeal, it was discovered that frequent meetings and refresher sessions were required. The organizations received guidance in growing coffee from Action Aid. In each group, one or two farmers offered to set up nurseries to grow coffee seedlings of several types that are immune to the berry disease. The farmers received subsidized seeds as well as training in forestry, coffee production, and nursery management. On their own property, these "resource farmers" created nurseries where they produced seedlings for their personal use or to sell to their neighbors. One of the resource farmers, AtoAlemayeAdyeko, sold coffee seedlings for 1,200 Birr in 1996. Action Aid started using the same strategy in 1997 to introduce forest-tree seedlings. Fifty farmers in five groups started producing forest tree seedlings in the first year[7], [8].

Villagization

As part of a government effort to improve rural life and agricultural productivity, villagization is the process through which rural residents are relocated from dispersed houses into villages. Over 12 million people were impacted by Ethiopia's first villagization process, which began in 1977 and continued until 1988. Showa and Heraregha were worst hit, with Tigray, GamoGoffo, and Wello suffering the least. Villagization has a number of detrimental effects on food production, such as the National Villagization Coordination Committee's 1986 decision to give priority to regions cultivating food crops rather than income crops. Following rules like paying particular attention to farmlands, pesticides, water resources, roads, etc. in site selection became challenging since these things weren't really present in the same location.

Ethiopian training and visits

In the Tiyo and Hetosasubdistricts of the Arssi Region and the Ada and Lume subdistricts of the Shoa Region, the T&V system was first implemented as a test project in June 1983. In the Shashemene and Arssi-Negellesubdistricts in the southern section of Shoa, it grew into a third pilot project. The initiative employed around 80 front-line extension employees. The T&V method was distinguished by a structured, time-bound staff training program and farm visits. The efficacy of the extension services was enhanced by discipline, a focus on agricultural issues, a single line of command, and intentional connections with researchers. The T&V pilot project was built on the premise that widespread adoption of new technologies depends on the effective dissemination of pertinent information. With the exception of the chain of command above the district level, the T&V system in Ethiopia had a comparable organizational structure to that of other nations. The chief of the T&V pilot project unit in Addis Abeba, who was in charge of the T&V system overall, received information from the AAEO about expansion in his area. The T&V Pilot Project Committee, which was led by the head of the Department of Peasant Organization and Agricultural Development, received his key concerns and he made the majority of the choices necessary at the top. Bypassing the typical regional organization for agriculture, this method explained the extended chain of command[9], [10].

PTD Initiatives in Kenya

In Kenya, a number of extension programs have been explored, including the PFI, the National Agricultural and Livestock Extension Project, the Farmer Field Schools Approach, the Training and Visits of the 1980s, Farming Systems Research, Catchment Approach Systems, and the Training and Visits of the 1980s. Despite significant drawbacks, each of these strategies has helped smallholder agriculture to some degree. These programs are some of the most popular ones.

Visits and Training

The Training and Visits was a World Bank-funded extension project that was carried out in two stages, NEP-I and NEP-II, as part of the National Extension Program. T & V, which was implemented in 41 districts, was designed to take the role of the existing extension system, which was hampered by excessive bureaucracy and had failed to increase productivity in smallholder farming. The idea of the "model farmer" was advocated by T & V. It was decided where research studies and demonstration plots would be placed on the farms of the progressive farmers under this idea. The frontline extension workers would pay the model farmer frequent visits, and field days would be arranged on the farmer's property. It was intended that the visiting farmers would see the model farmer's initiatives and take note of them. Adoption rates were disappointing, however, since the visiting farmers were unable to relate with the model farmer for whatever reason. Gautam attributes this failure to the fact that the FEWs were unqualified junior employees who focused on progressive farmers, who made up 10% of all smallholder farmers.

Regional Planning

A participatory extension planning technique known as "Local Level Planning" included asking farmers in a particular region about their issues, demands, objectives, and ambitions. An extended basket of solutions is then built for that particular agro ecological zone based on the feedback obtained. Once the program is in place, it is monitored and assessed by both the police and the farmers. The goal is to educate small-scale farmers about farm forestry. Numerous gatherings and seminars for farmer training were organized during the implementation.

Catchment Method

In Kenya, the catchment method to soil conservation was used from 1987 to 1997, a period of ten years. Planning and management of farms within a certain hydrologically defined watershed were handled, preferably within a single fiscal year. However, this did not necessarily apply to the whole watershed region. Even beyond individual farms, the concept was intended to establish conservation infrastructure. The major focus was on on-farm conservation methods and farm-by-farm planning and execution. Wider community-based engagement in this initiative was constrained by the program's overemphasis on private property as opposed to public land and on farm measures as opposed to off-farm measures. Through their Soil Conservation Committees, the communities' level and kind of participation was comparatively low. Even though a lot of effort was put into spreading the catchment-area approach's principles, its success rates were considered to be low.The following findings came from an examination of the Catchment Approach Program in Kenya's Embu, Siaya, and Nandi districts.

District Planning Teams handled the early process of determining catchment limits in a haphazard way due to a lack of rules;the three districts' Land Treatment Plans lacked consistency in their preparation;The DPTs' staffing was likewise uneven;in two of the districts, only Technical Assistants handled the layout work;In Embu, "fanyajuu" terraces and napier grass strips with cut-off drains and infiltration ditches were often employed soil conservation techniques. In Nandi, unplowed strips and napier grass strips were utilized. In

Siaya, on the few farms where soil conservation had been undertaken, a type of experiment with all sorts of techniques was conducted;In Nandi and Embu, it was the individual farmer's obligation to put the suggested procedures into practice. In Siaya, community organizations were used to execute measures on the few farms; andFollow-up work went easily in the successful catchments from Embu and Nandi, where active SCCs were in existence.

Agricultural and Livestock Extension National Program

The Ministry of Agriculture and Livestock Development in Kenya now employs a participatory extension system called the National Agricultural and Livestock Extension Program. The initiative primarily focuses on reducing poverty and empowering small-scale farmers by improving the extension staff's ability to address farmers' needs. The goal of NALEP has been to assist over 300,000 farmers in 900 focus regions over the course of three years. The National Soil and Water Conservation Program, which ran for 26 years starting in 1974 and ended in 2000, served as the basis for the majority of NALEP's features. The Catchment Approach Program's "Shifting Focal Area Approach" is used by NALEP. As a result, the initiative concentrated its efforts over a certain time period on a particular area. In addition to formal supervision, reporting, monitoring, and evaluation, it includes bottom-up stakeholder engagement in decision-making, planning, and activity execution.

In order to access a larger variety of services than those provided by the previous Catchment model, the NALEP model combines farmers into common user groups. It supports water and soil conservation, beekeeping, livestock management, agro-processing, etc. Through participatory rural appraisals, the communities are first enlisted to help identify projects and create action plans. Each focus region has a development committee that is democratically chosen. Voters are sent to specialized training. To promote better dissemination of research findings, NALEP works with research organizations like KARI and ICRAF.

Farmer Innovation Promotion

In order to meet Agenda 21 of the United Nations effort on the Conventions to Combat Desertification, the PTD project Promoting Farmer Innovation was conducted in Kenya, Uganda, and Tanzania. PFI's main goals were to identify, validate, and spread indigenous solutions in soil and water conservation, water harvesting, and natural resource management in order to sustainably enhance rural lives and ecosystem dynamics. To accomplish its goals, PFI launched a program to encourage farmer-to-farmer exchange visits as a key tool for accelerating the diffusion and adoption of novel and improved land management, water harvesting, and soil and water conservation practices; to increase the ability of supporting organizations to experiment and innovate; and to promote a national policy that takes into account the need to enhance the innovative capacity of land users and to use new technologies.PFI chose a strategy based on the knowledge and experience that are dormant within the community and from realizing that farmers are better able to learn and accept new ideas when they see others who have comparable amounts of land, labor, and money doing so.

Field Farm Schools

The Farmer Field School, a participatory approach to technology creation and dissemination, is referred to as a "school without walls." It offers the farmer the chance to make knowledgeable choices about agricultural techniques via inquiry-based learning. The school works with 25–30 farmers in a particular area to help them solve their challenges. FFS's major goal is to unite farmers in a learning environment where they may participate in practical training over the course of an entire season. Field observations, practical exercises, and season-long research are the main priorities. The focus is on giving farmers the freedom to carry out their own choices on their own fields. Participants in this kind of training learn to recognize and address any difficulties they may face in the field since problems are seen as challenges rather than restrictions.

Farming Methods

The goal of farming systems research, often referred to as on-farm adaptive research, was to find ways to enhance the well-being of rural families in particular local circumstances. FSR had four main characteristics: it involved multidisciplinary teams of researchers; it worked on-farm with households/farmers; it was locale-specific, so each subprogram related to a small number of similar farms in a given locale; it was holistic and thus more interested in the whole farming systems and its interdependence than with individual elements. FSR was introduced in Kenya by KARI.

Basically, FSR used interdisciplinary forensic teams. It used quick reconnaissance techniques to pinpoint interventions and tiered packages to accommodate various management and resource levels. FSR's implementation was hampered by the fact that it tried to accomplish too many objectives at once, leading to its extreme complexity. FSR prioritized technological transmission from scientists to farmers while giving local wisdom little consideration. It required ongoing access to agricultural areas since adaptation experiments conducted on farms needed to be closely monitored. This started to use up resources faster than the research stations could handle. The studies conducted on farms included extension agents as a means of coping. At certain levels, it seemed that direct two-way connections between researchers and district extension employees were against policy. Furthermore, the expansion line of command may not be compatible with the division of FSR into units stationed at certain research sites. How to synchronize FSR with the T & V expansion, which was already operating, was a different problem. Joint discussions helped to find a solution, and by 1985 the Ministry of Agriculture had incorporated FSR into its systems for extension. Despite these issues, FSR established the practice of doing research with farmers, and its success was based on seeing the farm as a whole, with integrated problems and answers.

CONCLUSION

Rural communities are given the information and abilities required to take advantage of opportunities and overcome obstacles via capacity development, both at the individual and institutional levels. As a result, they become more resilient and self-reliant, which helps them adjust to shifting socioeconomic circumstances. Roads, water supply systems, educational and hospital facilities, and other infrastructure are developed as part of PRDPs, which not only improves access to necessary services but also encourages economic activity, reducing poverty and raising living standards. PRDPs contribute to regional and national objectives in addition to provincial or state development by fostering inclusive, resilient, and self-sufficient rural communities. They are essential for lowering urban-rural inequality, preventing rural-urban migration, and improving a region's general socioeconomic structure. It is crucial to provide open governance, efficient resource allocation, and strong monitoring and evaluation systems in order to optimize the effectiveness of PRDPs. In accordance with national development objectives, PRDPs should also be included into larger rural development programs. PRDPs serve as examples of how focused interventions may reshape rural landscapes, empower people, and contribute to sustainable and equitable development as we address the difficulties of rural development in a world that is becoming more urbanized. We can create a future that is more inclusive and resilient for everyone if we recognize the special potential of rural communities and invest in their development.

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CHAPTER 12

AGRICULTURAL TECHNOLOGY AND INFORMATION RESPONSE INITIATIVE

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

ABSTRACT:

The Agricultural Technology and Information Response Initiative (ATIRI) is a pivotal program designed to bridge the gap between agricultural technology advancements and their effective dissemination to farmers and agricultural stakeholders. This abstract provides an overview of ATIRI, highlighting its significance in accelerating agricultural innovation, enhancing productivity, and promoting food security. It explores the key components and strategies commonly associated with ATIRI, including technology transfer, capacity building, and information dissemination. The abstract concludes by emphasizing the role of ATIRI in fostering agricultural resilience, improving livelihoods, and contributing to sustainable agriculture and rural development.The Agricultural Technology and Information Response Initiative (ATIRI) represents a crucial vehicle for ushering in a new era of agricultural innovation, productivity, and food security. This review has illuminated the central role of ATIRI in facilitating the effective transfer of agricultural technology advancements to the grassroots level.ATIRI typically encompasses a range of strategies and components aimed at bridging the gap between research and practical implementation. This includes technology transfer mechanisms, capacity building programs, and innovative information dissemination approaches. By connecting farmers and agricultural stakeholders with the latest knowledge and tools, ATIRI empowers them to enhance productivity, reduce risks, and improve their livelihoods.

KEYWORDS:

Agricultural Technology, Initiative, Information Response, Technology Adoption, Farming Practices, Information Dissemination.

INTRODUCTION

KARI's current participatory research initiative is called the Agricultural Technology and Information Response Initiative. The goals of ATIRI are to strengthen farmers' bargaining power with agricultural service providers and increase the efficiency with which intermediary organizations and farmers' groups can satisfy the informational requirements of their members and customers. In contrast to earlier research initiatives, when suggestions were created by scientists, the ATIRI model involves farmers' organizations creating recommendations via local CBOs. However, authorized intermediate groups like NGOs and colleges may be of aid to CBOs.The identification, application, and promotion of new technologies and methodologies, as well as the preservation and transmission of ITK, are the main focuses of all efforts under ATIRI. The main initiatives that ATIRI supports consist oftraining programs for leaders of farmers' organizations and staff members of intermediate institutions that are short-term and non-academic in nature. activities that point out ITK components that may be replicated and technology testing courses. Supply of "pump-priming" inputs, such as basic seeds for farmers' organizations to multiply and sell, equipment, or small-scale civil works for testing, may be provided either as matching grants subject to cost sharing by CBO or as seed money for cooperatively run savings and lending institutions. When a sizable scale of operation is needed to test their viability for broader replication, technologies and institutional structures should be piloted. creation, distribution, and other networking operations of information items. keeping track of, assessing, and reporting on experiences, including creating publications, films, etc.The SFRRP carried out in Maseno, close to Kisumu, by ICRAF, KARI, KEFRI, and NGOs is another example of a KARI research project. The major reason farmers are urged to establish village committees is to evaluate innovations created by KARI and other research groups. At the sub-location and location levels, the committees elect members to serve on higher-level committees that serve as avenues for two-way communication between researchers, extension personnel, and farmers[1], [2].

Programs for PTD in Tanzania

The PFI technique and the Indigenous Soil and Water Conservation Project are two examples of participatory research and extension trends that have been seen in Tanzania. Tanzania, like Ethiopia, saw significant policy shifts from socialist villagization initiatives in the 1970s to an economy liberalized in the late 1980s. As a result, both agricultural and economic development have improved noticeably, which is good for the nation's research and extension[3], [4].

The SCAPA Method

A project extension in Tanzania's Arusha Region was the Soil Conservation and Agroforestry Project-Arusha. It was designed to make it easier for extension workers and specialists in agriculture, forestry, and animal husbandry to collaborate and create integrated extension packages that would improve productivity and conservation. The "Catchment Approach" approach was used by SCAPA, which reached 4,500 agricultural families. The project required the following actions: Initial meetings with farmers and stakeholders; preparation and organization; identification of needs, starting with small groups of 5–20 committed farmers; contact with local leaders; survey of the catchment; planning of the activities; training of local leaders and SCC members; implementation of field activities; and supervision and follow-up.

Program for Land Management

With "increased productivity in the use of natural resources in a sustainable way" as its development goal, the Land Management initiative was a district-based land husbandry initiative in northern Tanzania financed by SIDA. It began in 1991 and initially focused on two divisions of the Singida Rural District as well as the semi-arid districts of Babati, Kiteto, and Simanjiro in the Arusha Region. These districts may be classified as semi-arid since they have a bimodal pattern of rainfall. Babati, Kiteto, and Simanjiro districts get 790 mm, 609 mm, and 487 mm of rainfall annually, respectively. The distribution of rainfall is rather erratic. LAMP achieved its goals by mechanizing agricultural processes and using conservation tillage. However, Babati has above-average mechanization and has done so for more than 30 years. 60 percent of the land was plowed by tractors, 30 percent by oxen, and 10 percent by hand, with the exception of Singida, where hand-hoeing and ox-cultivation are the norm. Studies conducted in Babati revealed that most farms developed crust pans. When compared to traditional plowing, deep tillage with tine instruments was tested, and the results were quite promising.

LAMP did not function as a typical development initiative but as a fundraising agency. With technical assistance from the consulting company Orgut, the implementing agency was the Babati District Council. The overarching goal of enhanced productivity in the sustainable use of natural resources served as the foundation for the LAMP assistance. These included agroforestry, enhanced livestock management, post-harvest methods, conservation tillage, and soil fertility management for dryland farming. A significant obstacle was the Singida Region's insufficient rainfall, which sometimes prevented farmers from coping with the impacts of drought.

Dodoma HifadhiArdhi

With financial support from SIDA, the Tanzanian government started the HifadhiArdhi Dodoma project in 1973. The Kondoa Eroded Area in Kondoa District, Mpwapwa District, and starting in 1986, the Mvumi division of Dodoma rural district were the three physically distinct places in the Dodoma Region where HADO was put into practice. The project-built soil bunds for gully management using mechanical means, including graders and other equipment. The forcible removal of all cattle from the Kondoa Eroded Area in 1979 was the most extreme part of the operation, since it helped the damaged soils recover more quickly. Programs for soil protection and reforestation were also sponsored by the initiative. As a result, the initiative created several hundred hectares of central woodlots. In the latter years, the organization focused more on providing seedlings from the nurseries it ran. Additionally, the initiative promoted training, education, and extension. The Swedish International Development Agency and the Ministry of Tourism and Natural Resources evaluated HADO in 1995, and they presented instances of several intriguing flaws.

Crop yields in the Dodoma Region are affected more by soil moisture deficiency than by soil erosion. Therefore, rather than emphasizing erosion control, HADO ought to have focused more on managing rainfall inside the croplands. HADO's goals and tactics were focused on the land rather than the residents in the project area. The study on croplands was primarily concerned with water runoff disposal, with less attention paid to significant elements of rainwater production. The main extension themes were quite conventional, including better seed and row planting. The messaging did not focus much on soil-water management.The focus on the "fanyachini" contour ridging proved ineffectual in managing erosion since there was very little follow-up to ascertain the survival rate of thousands of seedlings supplied free to communities, schools, other institutions, and people. vii Due to poor design or upkeep, many of the gully control structures failed, and gully growth persisted in numerous areas. the need to switch from a limited emphasis on erosion management to a more comprehensive, all-encompassing approach to land husbandry.The HADO experience offers useful guidance for formulating land use and water resource planning policies. The fact that HADO suffered from a lack of coordinated and clear policy direction is a useful lesson. As a consequence, one sector took over what ought to have been a multisectoral and interdisciplinary enterprise. There is no proof of a rigorous planning phase that carefully considered all the options and thoroughly vetted them. The focus should be on empowering people to manage soil, water, and plant resources in ways that promote conservation while boosting production when developing land resource initiatives. Despite these restrictions, the HADO project provides several insights that might be used to build initiatives of a similar kind.

DISCUSSION

A study technique was created by the ISWCP to locate and collaborate with Tanzania's creative farmers. It outlines eight steps: identifying and analyzing farmer innovators and their innovations; training for farmer innovators; farmers learning from farmers, i.e., cross visits among farmer innovators; following up on cross visits; developing themes for joint experimentation; learning together, i.e., joint experimentation; and reflection and planning. ISWCP did a great job of integrating farmer, extension agent, and researcher testing, which led to high adoption rates among non-participating farmers[5], [6].According to the ISWCP methodology, farmers received training on experimental procedures while researchers and extension staff received training on the use of instruments for participatory learning. ISWCP put a high value on farmer knowledge and aimed to empower and inspire them via sharing and learning in collaboration with academics and extension specialists. ISWCP included training as a key element, which was followed by quick surveys to find creative farmers. At the workshops organized with innovators, the theories and techniques of participatory technology development were presented and used. Results of studies were discussed through farmer-to-farmer visits and in village workshops with the help of extension workers. Farmers set up experimental plots, which they monitored in conjunction with researchers and "extensionists." ISWCP was one of the programs that had a significant PTD component and had high adoption rates among non-participating farmers as well as considerable commitment from farmers in terms of farmer experimentation.

Innovations in Soil and Nutrient Management to Double Farm Income

India is now the seventh largest exporter of agri-products in the world and is self-sufficient in terms of food need. It is a leading producer of grains, legumes, fruits, vegetables, dairy products, meat, and marine seafood. India is presently the world's second-largest producer of fresh fruits and vegetables, milk, important spices, a variety of crops including jute, staples like millets, and castor oil seed. It also ranks second globally in terms of agricultural production. Additionally, it is the second-largest producer of rice and wheat. 50% of the workforce was engaged in agriculture and related industries like forestry and fisheries, which together made for 13.7% of the GDP in 2013. The nation became self-sufficient in food during the 1960s' Green Revolution, which also contributed to a decrease in hunger and poverty. India still has over 250 million people who live in poverty and roughly 45 million malnourished children under the age of five, despite a five-fold increase in food grain production compared to a four-fold rise in population.

Additionally, 50 years after the Green Revolution, the nation is now dealing with second-generation issues like declining factor productivity, unhealthy soil, loss of soil organic carbon, ground and surface water pollution, water-related stress, increased incidence of pests and diseases, rising input costs, declining farm profits, and the unfavorable effects of climate change. The removal or burning of crop residues, decreased manuring, intense cropping, uneven and excessive fertilizer and pesticide application rates, and sub-plough soil compaction are all factors that contribute to the loss in soil fertility and health in various regions of the nation[7], [8].

It is sometimes said that the Green Revolution primarily assisted the nation in achieving food self-sufficiency at the national level while seeming to have overlooked the bulk of smallholder farmers who had less than 2 ha of land. While many have far less than even 1.0 hectare, which is unsustainable for a farm family, the average land holding is around 1.1 ha. In addition, farmers today confront two major worldwide difficulties in addition to the second generation of Green Revolution issues: 1) global climate change and 2) globalization of agriculture. The capacity of farmers to implement necessary coping and adaptation strategies is already being hampered by climate change. India's average yields for the majority of crops at the world level do not compare well because of technological weariness, which showed up as yield plateaus.

Additionally, the markets cannot guarantee the farmer will get a profit for his goods. In addition, regular natural catastrophes including droughts, floods, cyclones, storms, etc. contribute to agricultural misery. The majority of farmers live subsistence lives; therefore, such calamities may be very distressing and difficult. As a result, the sustainability of agricultural expansion is seriously questioned, and the agrarian problem has arisen as a key issue even in the midst of surpluses. These farmers thus need innovative technologies that may reduce the cost of agricultural inputs while boosting productivity as well as governmental assistance in the form of low-interest loans and increased incomes by connecting them directly to the markets in order to make farming a profession.

Indian Food Security and Livelihood Threats

The most crucial element affecting humankind's existence is access to food. A country cannot expect its citizens to live better lives without food security. The green revolution that took place in India in the late 1960s made a significant contribution to cereal output throughout time, leading to a significant rise in the net per capita availability of food grains. Due to a general feeling of complacency brought on by this, agricultural output growth throughout the 1990s was somewhat slowed down although population growth remained rapid. Overall, this led to a decrease in the amount of food grains available per person in the last decade of the 20th century. If food were divided equally according to needs, even at the current level of production, there would be enough to satisfy the country's population's protein and energy demands. However, as we can see, there is a national abundance of food while there is also widespread famine. The diminishing land to man ratio, shrinking farm holding sizes, deteriorating soil health, and resulting decline in total factor productivity are the main concerns to food security and livelihood in India[9], [10].

The performance of a production system and the sustainability of its development pattern are assessed using the total factor productivity as a key metric. As was already said, throughout the 1970s and 1980s, agricultural productivity grew astronomically as a result of the adoption of green revolution technologies. However, the process of agricultural expansion has recently begun to show indications of weariness. Despite the fact that input costs have been rising steadily, there hasn't been a recent increase in agricultural output, which suggests a decline in TFP. The yearly growth rates of productivity for all main crops have been trending downward, which is also symptomatic of decreased TFP in Indian agriculture. Future chances for food security in the nation are doomed if this tendency is permitted to continue. Emerging deficiencies of micro and secondary nutrients; soil degradation due to acidification, aluminum toxicity, soil salinization and alkalization, soil erosion, and soil pollution; wide nutrient gap between nutrient demand and supply; nutrient leaching and fixation of nutrient; and decline in soil organic matter are some of the factors that contribute to decreased total factor productivity.

Agriculture's Constraints

Due to rising industrial and drinking water consumption, which significantly affects this sector's share of the available water resources, water scarcity is the industry's top worry. A network of canals from rivers, ground water, well-based systems, tanks, and other rain water collecting items are included in the irrigation infrastructure of the nation. 39 Mha of India's 143 Mha of arable land is irrigated by ground water, while 22 Mha is irrigated by canals. However, the monsoon continues to be a factor in around two-thirds of India's agricultural regions. The land that is irrigated is made up of 69% food crops and 31% non-food crops. A wise use of water will be crucial to meeting the demands of a burgeoning population. Rainfed agriculture has the capacity to feed the expanding population via wise and effective water usage. Therefore, in order to maximize agricultural profitability and produce more per unit of water, it is crucial to learn effective water management practices.In many areas of the nation, soil fertility is declining owing to factors including crop waste removal or burning, less manuring, intense cropping, uneven and excessive fertilizer and pesticide use, and subplowed soil compaction. Major risks to the nation's agriculture include desertification and soil degradation caused by the indiscriminate and excessive use of pesticides, insecticides, and fertilizers over time. A significant contributor to water contamination is the improper use of agrochemicals. The degradation of soil fertility caused by excessive nitrogen loss by crops and insufficient nutrient replenishment is thought to be one of the biggest obstacles to achieving and maintaining better output. Widespread deficits of at least six minerals, including nitrogen, phos- phorus, potassium, sulphur, zinc, and boron, have been observed in Indian soils as a result of excessive nutrient mining. If plant nutrients are not provided in sufficient amounts and in a balanced ratio, there will be a far larger loss of native nutrients, and the soil may eventually lose its ability to produce high yields. There is sufficient evidence to show that integrated nutrient supply through joint use of fertilizers and other nutrient sources of organic and biological origin is the best nutrient management strategy. Crop nutrient demands cannot be entirely met through fertilizers due to an estimated annual gap of about 10 million tonnes between nutrient removal and supply through fertilizers. But for the last 50 years and for the foreseeable future, fertilizers have remained important nutritional supplements. As a result, fertilizer policy and nutrient management are inextricably intertwined, and any changes made to the latter are likely to have an impact on not just the rate and amount of fertilizer input but also the effectiveness of nutrient utilization and total economic returns.

Farmers Must Double Their Income

The primary issues facing India's 138 million farmers today are, on the one hand, a decline in agricultural revenue and, on the other, an increase in input costs. According to recent research by the National Institute of Agricultural Economics and Policy Research, less than $15,000 is the yearly per capita income for almost 70% of the nation's farmers. Birthal et al.'s additional analysis of the issue revealed that although they are geographically dispersed, they are mostly concentrated in the states of Uttar Pradesh, Bihar, West Bengal, Odisha, Rajasthan, and Madhya Pradesh, Assam, Jharkhand, and Maharashtra. The majority of these states lack the infrastructure needed to increase agricultural revenue. Additionally, almost 70% of farmers are marginal, and 77% of them earn the pitiful sum of $6,067 per person annually. Therefore, it is crucial to reduce the income disparity between the agricultural and non-agricultural sectors in order to improve the farming community's standard of living, prevent farmers from leaving the industry, maintain their interest in farming, and assure sustainable production for global food security. As a result, policymakers' attention has been focused specifically on the plight of small and marginal farmers. The Honourable Prime Minister called for tripling farmers' incomes by 2018, correctly identifying this as a national goal. To achieve this aim, practically all of the factors that have a favorable influence on farmers' earnings would need to expand much more quickly. In order to maintain and accelerate agricultural development in the nation, the NITI Aayog has highlighted crucial areas and recommendations in its action plan for 2017–18. The problem, however, is how to boost food production over the next 20 years without endangering the already severely depleted land and water resources. Additionally, to convert increased production development into a level of revenue sufficient to support a farm family. It has become abundantly evident that a simple increase in agricultural output is insufficient in the absence of a fair return for the farmers.

Alternatives for Increasing Farmers' Income

The task of increasing income, especially for a large percentage of small and marginal farmers, would require technologies by which they can save money on inputs and have more income by higher productivity and by using fewer resources. Given the current challenges of factor productivity growth decline, depleting natural resources, increasing cost of inputs, higher incidence of diseases and pests, higher cost of inputs, less profit to farmers, and above all the negative impact of climate change, Therefore, it is obvious that the plan to double revenue would demand for sustainable intensification, diversity, better resource use efficiency, and resilience in farming that is financially profitable. In this sense, it is important to take seriously the multifaceted method listed below:

Farming diversification

Agri-allied industries including animal husbandry, forestry, and fisheries may help diversify agricultural livelihoods, which will improve livelihood options, boost resilience, and significantly increase labor force participation in this industry.

Decreased Post-Harvest Losses

By building storage, cold chain, and market infrastructure, wastes of high-value goods like fruits, vegetables, seafood, etc. may be minimized. This can be done by increasing investment in warehouses and food processing.

Policy Assistance and Market Connectivity for farmers

This may be accomplished by boosting financial assistance, reforming the market, providing insurance, establishing a minimum support price for agricultural products other than just food grains, and connecting farmers to the market.

Techniques for Increasing Productivity and Efficiency

The restoration of soil productivity must be combined with other policies that influence how people utilize the land, especially those that deal with water and fertilizer usage. The only way to double farm revenue would be via an integrated strategy that increased income while cutting production costs. In recent years, there has been a lot of study on managing the soil to increase factor productivity and net returns. For greater net returns from agricultural systems, site-specific and integrated management techniques were stressed in the majority of the publications. Recycling agricultural wastes reduces input costs, improves soil quality, and increases profit. In recent years, it has been discovered that soil management methods that include sensor-based input management, conservation agriculture, the application of bio-inoculants, and nanotechnologies are more successful at increasing farm income.

The full review of water management in agriculture found that upgrading rainfed farming might increase productivity by two to four times.

The lack of appropriate financial incentives for farmers to use yield-enhancing crops or cropping practices is one of the primary causes of yield disparities. Lack of access to information, extension services, and technical skills are further causes. Significant barriers to the adoption of new technology at the farm level may also be created by inadequate infrastructure, poor institutions, and discouraging agricultural policies. Another issue is the loss of fertile soil; every year, 6000 to 12000 Mt of topsoil, which contains close to 5.6 to 8.4 Mt of nutrients, is washed away mostly as a result of poor management of soil and water resources.

The emphasis on using main nutrients has resulted in widespread deficits of secondary and micronutrients like S, Zn, and B. Other micronutrient deficiencies, such as those in iron, copper, manganese, and molybdenum, are also on the increase. In this scenario, the nation produced a respectable amount of food, but farming as a whole became unprofitable over time owing to declining crop yield and soil health, increasing production costs, and depleting natural resources.

a. Close the Yield Gap

The net irrigated area in India is now at 65.3 Mha, while the gross cropped area is 195 Mha with a cropping intensity of 135%. The cropped area in India has remained stable at around 143 Mha over the previous several decades. Since there is no longer room for horizontal development, the only viable option is vertical expansion via greater productivity, for which there is plenty room. Some states' productivity is lower than the national average, whilst others may increase production even more due to their abundant resources and access to cutting-edge technology. The current yield gaps can also be closed by adopting good agronomic practices that are based on resource conservation, efficient nutrient and water use, large-scale adoption of biotechnology, including the use of genetically modified food crops, and increasing seed replacement rates/the area under seeds of improved varieties and especially hybrids.

b. Innovation Scaling

Taking into consideration the anticipated effects on production and productivity, there are several significant advances that presently need to be scaled up as a matter of priority. Some of them are: (i) hybrid rice, where the current area coverage is only about 2.0 m ha, but there is potential to cover at least 10.0 Mha in the following ten years; (ii) single cross maize hybrids, where the current area covered by these hybrids is less than 60%, but there is potential to double the production of maize in the following ten years provided that >90% of the maize area is brought under promising single cross hybrids. In addition to this conservation agriculture innovations also have a huge potential in rainfed farming, which currently accounts for about 55% of the total 141.0 Mha cultivable area in India, protected cultivation (currently only covering about 50,000 ha in India, compared to >2.0 Mha in China), and micro-irrigation (currently only covering about 8.6 m ha of the total irrigated area of 64.7 Mha, but with the potential to double by 2018).

c.Controlling soil-related limitations to increase crop production

The efficiency with which crops utilise their inputs is influenced by soil-related restrictions, which also has an impact on agricultural production's economics. For instance, liming acid soils with calcite, dolomite, or paper mill sludge increases the effectiveness of phosphorus utilization. Similar to this, adding gypsum to alkali and saline-alkali soils improves the efficiency of nutrient utilisation. Similar to this, removing physical restrictions such sub-soil compaction via the use of proper tillage techniques increases the effectiveness of nutrient utilization. To increase food production, a soil environment free of constraints is crucial.

CONCLUSION

Initiatives to improve capacity within ATIRI boost regional institutions and extension services in addition to providing people with the skills and knowledge necessary to embrace new technology. This encourages resilience and self-reliance in agricultural communities. Additionally, by placing a strong emphasis on information sharing, ATIRI makes sure that farmers have access to timely, pertinent, and context-specific agricultural information. This is crucial because information enables farmers to make educated choices and overcome new obstacles in the face of shifting market dynamics and changing climatic trends. ATIRI supports larger rural development objectives as well as food security by developing agricultural resilience, enhancing livelihoods, and encouraging sustainable practices. It may boost agricultural communities' overall socioeconomic well-being, promote economic development, and lessen poverty. Stakeholder participation, strong communication channels, and ongoing assessment are necessary to optimize the effect of ATIRI. The program should also be in line with national agricultural policy and incorporated into larger agricultural development objectives. The ATIRI acts as a light of development, ensuring that innovations reach people who need them most at a time of fast technology breakthroughs and changing agricultural landscapes. We can strive towards a future where agricultural communities flourish, food security is ensured, and sustainable practices are the norm by investing in the efficient spread of agricultural technology and knowledge.

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CHAPTER 13

EXPLORING THE VARIOUS STRATEGIES AND PRACTICES FOR SOIL CONSTRAINTS AND THEIR ALLEVIATION

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

ABSTRACT:

Soil constraints pose significant challenges to agriculture and environmental sustainability. This abstract provides an overview of soil constraints and their alleviation, emphasizing their impact on crop productivity, land degradation, and water quality. It explores various strategies and practices for mitigating soil constraints, including soil amendment, crop rotation, and conservation tillage. The abstract also highlights the importance of tailored solutions, interdisciplinary approaches, and sustainable land management to address the diverse array of soil constraints. In conclusion, it underscores the urgency of taking proactive measures to alleviate soil constraints to ensure global food security and ecosystem healthsoil constraints represent a critical nexus between agricultural productivity and environmental stewardship. This review has illuminated the multifaceted challenges posed by soil constraints, from diminished crop yields and land degradation to impaired water quality and ecosystem disruption.Mitigating soil constraints demands a nuanced and context-specific approach. Soil amendment through the application of organic matter, lime, or gypsum can address issues related to soil acidity, salinity, or compaction. Crop rotation and diversification strategies help break pest and disease cycles while improving soil fertility. Conservation tillage practices reduce erosion and enhance soil structure.

KEYWORDS:

Erosion Control, Environmental Factors, Soil Characteristics, Soil Erosion, Soil Management.

1. INTRODUCTION

One of the most important variables limiting agricultural productivity is soil acidity. In India, soil acidity has an impact on around one-third of the farmed area. Pulses, oilseeds, and coarse cereals are mostly produced on acidic soils, especially on acidic upland. The following discusses in depth the main soil restrictions and strategies for their relief that are available to increase agricultural yield in India:

A) Chemical restrictions on soil

Salinity, sodicity, acidity, and nutrient toxicity, especially with regard to iron and aluminum, are the main chemical restrictions on soilsalty ground: Saline soils are characterized by greater levels of salt that is soluble in water, which has an impact on crop development. These soils may be restored by the application of fertilizers, as well as by reducing the water depth through subsurface drainage and leaching of soluble salts. Salinity issues are reduced by applying farm yard manure at a rate of 5 t ha-1 10-15 days before to planting after reclamation[1], [2].

Saline Soils

Sodic soils have an excess of sodium in the complex, an exchangeable sodium percentage that is more than 15, and a pH that is higher than 8.5. These soils may be salvaged by When the soil is at its ideal moisture level, till it and then add gypsum as needed. Create a drainage system and impound water to remove the soluble salts. In alkali soils, nitrogen is the main nutrient that must be limited. In the first years of restoration, P and K fertilizer is not necessary.

Sour Soils

Acidic soils often have low pH levels. Acidity is caused by the predominance of H+ and Al3+ and results in a lack of P, K, Ca, Mg, Mo, and B. Crop output is decreased by soil acidity due to its detrimental effects on the plant system and declining soil health. You may improve acid soils by doing the following:It is advised to apply lime evenly via broadcast and incorporation in accordance with the lime requirement test. Dolomite, basic slag, flue dust, wood ash, and pulp mill lime are some substitute amendments that may be used in place of lime[3], [4].

B) Physical limitations of soil

Due to unfavorable soil physical characteristics, India's millions of hectares of land, in both rainfed and irrigated ecologies, provide extremely poor agricultural yields and low nutrient efficiency. Under these circumstances, increasing crop output and optimizing fertilizer utilization requires improving soil health. Low water retention and high permeability, slow permeability, surface and subsurface mechanical impedance, and shallow depth of the soils are the major soil physical constraints found in various regions of the country. These factors either limit crop growth or decrease the effectiveness of basic inputs like water and fertilizer.

Inflexible soil

A significant obstacle to crop productivity is the red "chalka" soils' rapid and permanent hardening after drying. The negative impact is reduced by adding slowly decaying wastes like rice husk, coir pith, powdered groundnut shell, etc. and then applying the proper amount of tillage. For key crops, the effectiveness of several amendments at various rates was assessed. The most effective amendments were determined to be: FYM at 10 t ha-1, coir pith at 20 t ha-1, powdered groundnut shell at 5 t ha-1, gypsum at 4 t ha-1, and rice husk at 5 t ha-1.

Abrasive Pan Soils

Due to the mobility of clay and iron hydroxides and their settlement at shallow depths, which inhibits root development, hard pan develops in red soil regions at a depth of 15 cm. The high bulk density of the sub-soil hard pans reduces infiltration, water storage capacity, accessible water, and circulation of air and nutrients, all of which have a negative impact on crop yields. Reclamation of these soils may be accomplished by: Shattering the hard pan to a depth of 45 cm once every three years by chiseling the soils with a chisel plough at intervals of 0.5 m first in one direction and then in the direction opposite the previous one. Chisel ploughing once every three years at a depth of 40 to 50 cm with a 50 cm interval enhances root proliferation and soil moisture retention, increasing crop production, especially cotton yield, in clay loam rainfed soils where hard pan forms.In addition to having a longer residual impact, applying FYM or composted coir pith at a rate of 12.5 t ha-1 might increase yield. The soil retains more moisture as a result of the broken hard pan and the incorporation of manures. The rooting volume above the compacted layer will grow with the construction of ridges[5], [6].

Soft rice soils

They are distinguished by the topsoil's low bulk density, which causes farm animals and laborers to sink and results in inadequate anchoring for rice seedlings. When the soil is semidry, 400 kg stone rollers or oil drums with sand inside may be passed over the soil eight times, and lime addition at a rate of 2 t ha-1 can be made once every three years.

Crinkly Soils

When raindrops strike soils with a weakly aggregated soil structure, the soil aggregates are readily disrupted, causing a clay crust to develop at the soil surface. The clay pan hinders seedling emergence and halts the free flow of gases between the soil and atmosphere.By harrowing or cultivator plowing, the surface crust may be readily broken. By enhancing aggregate stability with the application of lime or gypsum at 2 t ha-1 and FYM at 12.5 t ha-1, surface crust development may be avoided. agricultural leftovers being kept as a protective covering on the surface. Following sowing, apply FYM @ 3 t ha-1 or chopped wheat straw to the sown rows.

This keeps the soil water level in the crusted top soil higher and avoids aggregate breakdown and soil dispersion. very permeable soil High permeability is seen in light-textured laterite and fluffy soils, which results in water and nutrient losses. Application of tank silt, black soil, FYM, composted coir pith, or press mud at a rate of 25 t ha-1 year may be used to reclaim these soils. During the summer, deep plowing the field using a disc or mound board plough will increase the soil's ability to retain water.

Soils with a Heavy Clay Texture

Due to the clay component that clay soils include, they have low permeability and nitrogen fixation. Such soils may be recovered by adding 100 t ha-1 of river sand. Additionally, deep plowing the land using a disc or mould board plough throughout the summer will improve infiltration and percolation.

Sluggish Black Soils

Madhya Pradesh, Maharashtra, as well as portions of Rajasthan, Uttar Pradesh, Bihar, and Tamil Nadu, are home to the slowly permeable soils. Due to water stagnation caused by the very low permeability, the root zone experiences oxygen stress. The root development is hampered in this zone by the buildup of carbon dioxide and other byproducts brought on by the prevalent anaerobic conditions. These black clay soils can only be tilled or farmed within a narrow range of soil moisture because they are sticky while wet and extremely hard when dry.

DISCUSSION

Black soils in high rainfall locations get a variety of tillage and land form treatments, such as ridges and furrows, broad bed and furrows, raised and sunken beds of various widths, to prevent water logging during the rainy season. During the summer, deep plowing the land using a disc or mould board plough improves infiltration and percolation. The physical characteristics and internal drainage of the soil will be improved by the application of FYM, composted coir pith, or pressmud at a rate of 25 t ha-1 yr-1. Shallow soils: Insufficient soil volume prevents roots from growing and prevents the crop from receiving the necessary quantity of water and nutrients. Root development was shown to be facilitated by the construction of a 10 cm high ridge on shallow soils with a depth range of 15 to 35 cm. Clay or rice husk addition enhances the physical state and crop development even more. Farmers in Andhra Pradesh must deal with the dual issues of erosion and shallow depth. Runoff and soil loss were both decreased by 88 and 92 percent, respectively, by the contour's formation of ridges and furrows together with khus barriers spaced at intervals of 1 m vertically. Additionally, this promotes optimal moisture retention for increased crop yields[7], [8].

d. Increasing the Efficiency of Nutrient Use

The greater usage of chemical fertilizers has been attributed to improved yield in irrigated regions. The average amount of nutrients used in India now is around 105 kg ha-1, and the country uses about 32 Mt of chemical fertilizer, of which about 25 Mt is nitrogenous fertilizer. However, the efficiency of nutrient usage is not more than 30%. Consequently, one of the biggest challenges is improving fertilizer use efficiency, which calls for the adoption of creative solutions like the use of seed-cum-fertilizer drills, the adoption of efficient soil testing/soil health cards and decision support systems for soil/plant test-based nutrient use, the use of neem coated urea for slow release and better uptake, the use of custom fertilizers, fertigation, etc. Urea was first coated with neem oil in 2010 to the level of 20% of total output, and subsequently up to 35% in 2011. The use of neem oil coating will be required starting in 2015 for all domestic urea manufacturing. This policy change is anticipated to have a significant beneficial impact on nitrogen management since neem oil coating has been shown to increase nitrogen usage effectiveness. Additionally, neem coating would guard against urea being accidentally used for commercial or non-agricultural reasons. Other significant policies that have a direct or indirect impact on nutrient management in the nation include the New Urea Policy-2015, the New Investment Policy-2012, the promotion of water-soluble fertilizers and tailored fertilizers, and coating/fortification with secondary and micronutrients.

The most effective and synergistic combination of other inputs, such as water, tillage, and mulches, may boost the use of nutrients. These inputs alter the soil's physical, chemical, and biological environment, which affects agricultural plants' ability to recover nutrients. In the soil plant system, water plays a crucial role in the transformation, transport, and absorption of nutrients. For their influence on crop development and productivity, water and nutrients interact synergistically. Wheat production and the effectiveness of water and nutrient usage by wheat were shown to significantly and favorably interact with applied N and water supply. In sandy loam soil, N usage efficiency rose up to 300 mm of water supply with 80 kg N ha-1. Interestingly, when water supply was raised from 50 mm to 125 mm, it did not rise. However, when water supply was increased further to 300 mm, it rose significantly. This suggested that the proportion between these two inputs had an impact on the effectiveness of input usage[9], [10].

Utilizing both resources more effectively is achieved by using pressure irrigation in combination with application irrigation and nutrients. This will boost WUE and NUE while saving water and reducing nutrient leaching losses. The crop output and quality will improve as a result. There is a 35 and 22% reduction in water and nutrient use, respectively. Crops typically experience water and temperature stress in dry and semi-arid conditions in well-drained soils. In these regions, it has been discovered that post-sowing residue mulching increases the efficiency of nitrogen utilization by altering the hydro-thermal regime, which improved N mineralization and encouraged root development. On a sandy loam soil, straw mulching of maize improved the dry forage production by 13%. It was brought on by a 43 and 13% increase in N and P absorption, respectively.

e. Boosting Agricultural output and Maintaining Soil Health

Nutrient management solutions that are balanced and integrated for a sustainable food supply and way of life. In order to properly maintain the balance between soil nutrient reserves with real plant nutrient absorption and nutrient export or removal from the farm, knowledge gaps in IPNS management between scientists and farmers continue to be a significant problem. Long-term use of high analysis fertilizers in intensive agricultural systems resulted in soil health degradation primarily due to over-mining of vital plant nutrients, necessitating a review of the production system in terms of soil health in order to maintain productivity and financial returns. It has been shown that in intensive systems, nutrient utilization efficiency is constantly declining despite technological developments. Organic matter recycling and sui rotations were used to maintain soil fertility and nitrogen availability until the 19th-century discovery of chemical fertilizers. Effective nutrient management techniques have been created, however most of the time farmers do not adhere to the recommendations, mostly due to a lack of knowledge on the application of nutrients based on soil tests. The emergence and spread of multi-nutrient deficiencies in soil seems to be a direct result of unevenly applying inorganic fertilizers in intensive cropping systems. Soil health and sustainability management via the application of balanced nutrients combined from both inorganic and organic sources must be taken into account in order to buck the trend of declining yields and financial losses. It will increase the sustainability and health of the soil, as well as the effectiveness with which inputs are used and the profitability of the system. In order to manage soil health and sustainability, manures, crop residues, biofertilizers, etc. may need to be combined with inorganic fertilizers. Utilizing biofertilizers, FYM, or green manures in place of inorganic fertilizers not only increases soil health and production but also lowers the cost of nutrients. Furthermore, by reducing the cost of nutrients and boosting production in sustainable ways, combining the soil health card program with INM has the potential to raise the farmer's revenue.

In major cropping systems like rice-rice, rice-wheat, maize-wheat, sorghum-wheat, pearl millet-wheat, and rice-maize, it is possible to substitute a portion of the fertilizer N needs of the kharif crop by FYM without negatively impacting the system's overall productivity, according to long-term studies being conducted under all Indian Coordinated Research Projects. With integrated usage of 100% NPK and FYM, Ranchi's maize-wheat cropping system had the greatest sustainable yield index after 27 years. Due to their restricted availability and low P content, organic manures by themselves cannot provide enough P for optimal crop development. However, it is known that organic manures increase P availability and reduce P adsorption/fixation in P-fixing soils. By competing with P for the same sorption sites, organic anions created during the breakdown of organic inputs might increase the amount of P available in the soil and enhance crop utilization. Itfound that a soybean-wheat system using fertilizer P and manure recovered more apparent P on Vertisol.

Biofertilizers in intensive systems with INM

According to a study by AICRP on LTFE, the INM module in soybeans has led to a 20–25% increase in seed yield compared to farmers' practices. It is grown on 903 thousand hectares in the districts of Bhopal, Sehore, Vidisha, Rajgarh, and Raisan, and as a result, these districts will get an extra Rs. 586 crores in revenue, helping nearly 13 lakh agricultural holdings. Similar to how the IPNS module in wheat has the potential to enhance farmers' income by Rs. 444 crores in certain areas. Numerous studies have shown that using biofertilizers continuously improves soil sustainability, quality, and cost of nutrient input, which increases farmer revenue. As a cost-effective and sustainable alternative to chemical fertilizers for sustainable agriculture, the use of biofertilizers is one of the key elements of INM. Biofertilizers are made by using a variety of microorganisms and their interactions with agricultural plants. A variety of microorganisms, including those that solubilize phosphate and potassium, Rhizobium, Azotobacter, Azospirillum, Cyanobacteria, Azolla, and others, are utilized as biofertilizers in agriculture. Rhizobacteria that promote plant development and bacteria that dissolve silicates are both available as biofertilizers. To efficiently employ and spread the usage of biofertilizers, there are a number of limitations.

The usage of biofertilizers is crop- and location-specific, in contrast to mineral fertilizers. Due to local soil microbial competition, inadequate aeration, high temperatures, soil moisture, acidity, salinity, and alkalinity, as well as the presence of hazardous substances, etc., a strain that works well in one site may not work as well in another. Microorganisms have a short shelf life, and unlike mineral fertilizers, biofertilizers need careful handling and storage. They also lack the proper carrier material to restore and last in real-world field conditions.These factors need to be given serious consideration in order to get beyond the aforementioned obstacles and turn biofertilizers into a useful addition to mineral fertilizers.

Precision and Site-Specific Nutrient Management

Half of the world's current crop productivity is said to be attributed to the usage of commercial fertilizers. Crop production would have to expand on about the same or less land area, with less water, fertilizers, fossil fuel, labor, and as climate change for sustainable availability to food for a growing population in the next decades. In order to meet the rising demand for agricultural production without jeopardizing the natural resources on which agriculture relies, resources, especially nutrients, must be handled carefully. The need for precise techniques is being driven by factors such as rising input costs, labor shortages, smallholder farming's economic implications, and public awareness of the environmental impact of intensive agriculture.

The site-specific nutrient management technique was created as a result of the notion of balanced fertilization being used in a way that takes site-specific information into account. It takes into account the intrinsic geographical variability present in fields used for crop production and makes sure that all necessary nutrients are administered at rates and ratios that are appropriate for the crop's nutritional requirements. The SSNM technique has been used to a variety of crops and agro-ecologies due to the universality of its guiding principles.

Fertilizer Based on a Soil Test

The projected yield responses from fertilizer recommendations based on qualitative or semi-quantitative methodologies or procedures are not obtained. The All India Coordinated Research Project Soil Test Crop Response has established an improved technique of fertilizer prescription for varied soil test results for various crops under various agro-ecological subregions. The targeted yield strategy has been utilized in soil test crop response research to establish a link between crop yield and soil test estimations and fertilizer inputs. When farmers applied fertilizer nutrient dosages based on soil tests, significant agronomic and financial gains were realized. In order to account for the nutritional contributions of organics, soil, and fertilizers, calibrations are also being created under integrated supply of organics and fertilizers. Additionally, a method for fertilizing crops based on the results of the first soil tests for the whole cropping system is being developed.

In order to help users utilize fertilizers professionally based on the results of soil tests, ready reckoners in the form of fertilizer prescription equations have been created. These ready reckoners have been proven by several multi-location/verification follow-up experiments as well as frontline demonstrations. Higher response ratios and benefit: cost ratios were seen across a broad variety of agro-ecological zones in several FLD experiments using rates of fertilizer application based on soil test results. Economic examination of 66 crop yield goal combinations under STCR revealed that in 65% of trials, STCR alone may increase the BCR to more than 2. STCR may be utilized as a supplemental technique in the remaining 35% of trials to raise BCR over 2. Therefore, the STCR-based strategy to nutrient delivery has shown a clear benefit over the generally suggested dosage of fertilizer treatment.

Farming Systems Approach

Improved water, nutrient, and energy use efficiencies are possible with micro-watershed-based agricultural diversification through farming systems approach, which includes crop and animal husbandry, horticulture, beekeeping, pisciculture, etc. This will enable integrated nutrient management to become a reality. The main objective of the agricultural systems approach is to boost and stabilize farm revenue and productivity. Diverse businesses provide chances for recycling, which reduces pollution since one business' trash might become an input for another. The advantages of multi-enterprise agricultural systems include risk minimization, job creation, and sustained/increased family income. It is necessary to design and disseminate appropriate and situation-specific agricultural diversification strategies in order to maintain livelihoods in rural regions, especially for small and marginal farmers. Diverse regions are working to create farm diversification models that include a smart mix of businesses that might, from a particular plot of farmland, provide appealing revenue in addition to supplying for family needs.

f. Water and soil conservation

Due to extreme heat, soil erosive soil loss, and severe drought stress, crop yields in rainfed agriculture are poor. India's principal grain, oilseed, and pulse crops were found to have a total output loss owing to water erosion of 16%, which is estimated to be 13.4 Mt in actual physical terms and Rs. 11,130 crores in actual economic terms. The average output loss in India's six zones ranged from 10% to 24% on average. State-level output losses varied from 1.4% in the alluvial Indo-Gangetic Plains states of Punjab and Haryana to 41% in Nagaland, a state in the erosive northeastern Himalayas. Cereals made up 66% of the overall output loss among the main crop groupings, followed by oilseeds and pulses. The monetary losses, which totaled 45% for grains, 33% for oilseeds, and 22% for pulses, followed a similar pattern. Out of all the crops, rice was the most negatively impacted in terms of both output and monetary losses. Since the losses add up over time, it is essential to implement the proper soil and water conservation measures for rainfed regions' rehabilitation in order to avoid drastic drops in their production levels, which may worsen as a result of population pressures. In the parched plains of peninsular India, water collection and storage are important choices. According to many studies, improving water penetration and reducing evaporation losses by techniques in the root zone may boost crop output by 33 to 173 percent. Additionally, in these drought-prone areas, water collecting for additional irrigation might be crucial. When used at a crucial point in crop development, one such supplementary irrigation may boost agronomic output by 23 to 250 percent. Installation of check dams, percolation tanks, recharge tube-wells, and rainfall conservation all contribute to increasing recharge. Modern advances are required to increase water usage efficiency, including remote sensing, field water management, crop planning, and modeling to plan watershed management. When combined with better cultivars and INM approaches, the efficacy of these soil-water management techniques may be increased.

g. Utilizing conservation agriculture to enhance soil health

Three main factorssoil erosion, a reduction in soil organic matter, and salinization—are largely responsible for the unsustainable nature of agricultural systems. All three are correlated with soil health. These issues are primarily brought on by tillage-induced declines in soil organic matter, soil structural deterioration, water and wind erosion, decreased rates of water infiltration, surface sealing and crusting, soil compaction, insufficient or non-return of organic materials, and monocropping, in addition to other related factors like water, labor, and energy shortages and emerging difficulties of climatic change-induced weather variability. The unsustainable components of current agricultural systems, such as intense tillage, removal and burning of all crop residues/non-return of organic material to the soils, and monoculture, must be eliminated right now. Conservation agriculture may be achieved by taking a simple step to remove the unsustainable elements of traditional tillage-based agriculture. A resource-saving and production-optimizing agricultural system, the CA is based on three fundamental, interconnected principles. It aims to achieve sustainable intensification while increasing economic profits, improving natural resources and the effectiveness of external production inputs with environmental stewardship. With locally developed and modified approaches, the CA principles are generally relevant to all agricultural landscapes and land uses. The CA systems may be used in the majority of habitats and ecologies with site-specific modifications and enhancements. In nearly 2 Mha of irrigated intense and rainfed extended production ecologies in India, CA based management approaches have been used, and they have benefited farmers, small business owners, and policy makers. To assist the collection, volume reduction, transportation, and application of residues as well as the seeding of subsequent crops under a layer of residues on the soil surface, suitable farm equipment must be developed. In order to properly manage straw, it is necessary to modify combine harvesters to collect and remove crop residues from the field, develop twin cutter bar type harvesters for harvesting the top portion of the crop for grain recovery, and create lower cutter bars for straw harvesting at the appropriate height. Another need for the effective use of CA technology in farmers' fields is the development of straw spreaders for the consistent dispersion of the crop leftovers.

CONCLUSION

One-size-fits-all solutions often fall short, the key to successful soil restriction reduction rests in the combination of multiple methodologies. Agronomically competent sustainable land management is essential for tackling soil limitations on all fronts. For the purpose of locating and putting into practice specific solutions to soil restrictions, interdisciplinary cooperation between scientists, politicians, farmers, and environmentalists is essential. To keep abreast of new soil-related concerns, investment in research, technological development, and information sharing is equally important.

Proactive steps to ease soil restrictions are essential as the globe confronts increasing challenges from population expansion, climate change, and resource shortages. The protection of natural resources, the preservation of the environment, and the assurance of global food security all rely on our capacity to properly handle these limitations. We can build a resilient and productive agricultural landscape while maintaining the health of our ecosystems for future generations by emphasizing sustainable land management and adopting creative solutions.

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