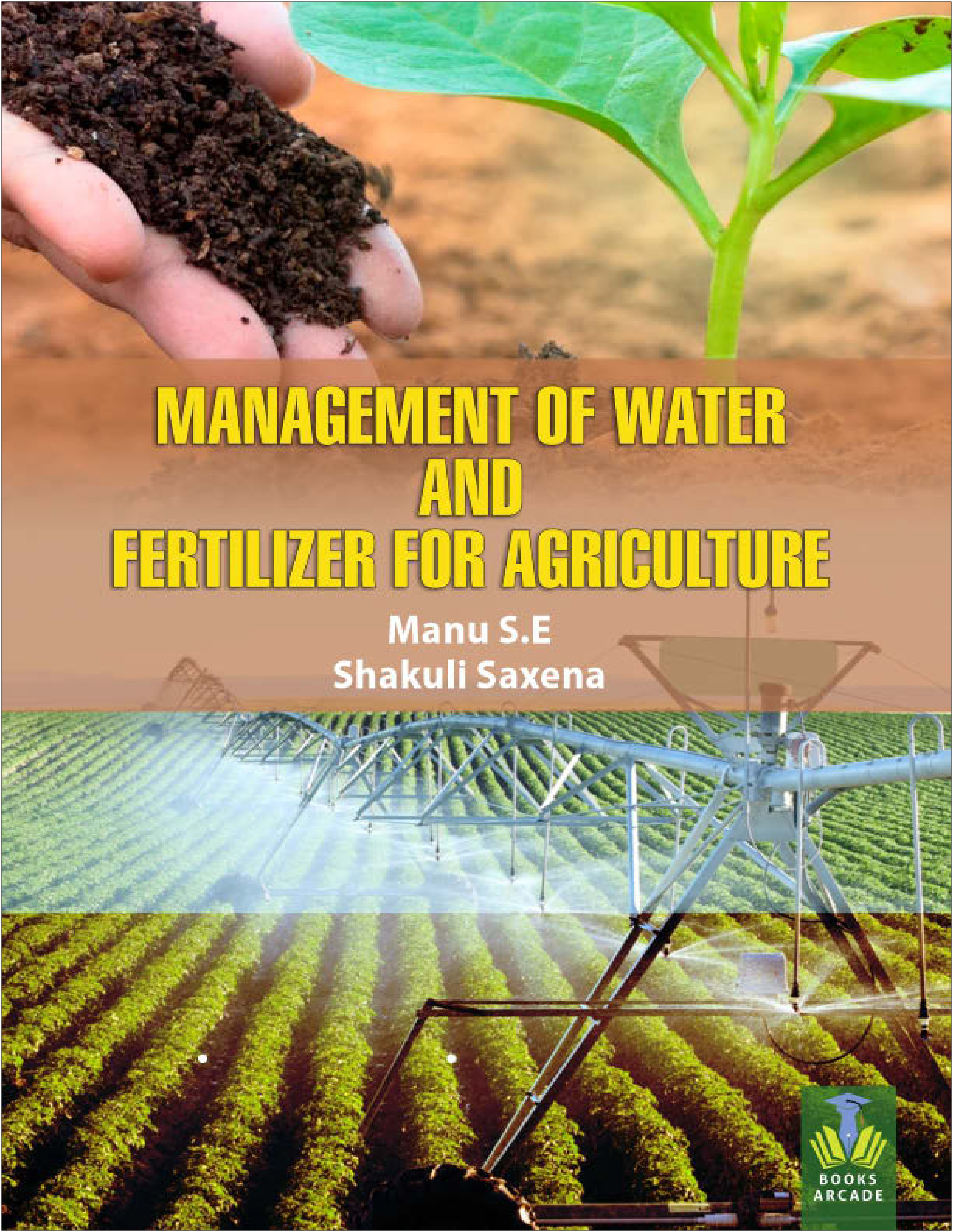

MANAGEMENT OF WATER AND FERTILIZER FOR AGRICULTURE

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CONTENTS

CHAPTER 1

MANAGING WATER AND NUTRIENTS TO MAINTAIN ECOSYSTEM FUNCTIONS WHILE ENSURING GLOBAL FOOD SECURITY

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ABSTRACT:

During the last 50 years, the cultivated area of the planet has increased by 12%. The world's irrigated acreage has doubled over this time, making up most of the net growth in cultivated land, while fertilizer consumption has grown globally by more than five times. A result of the rapid rise in irrigation and fertilizer use, as well as the introduction of better seeds and best management methods that significantly increased crop yields, agricultural output has increased by 2.5 to 3 times since the 1960s. Although 2 liters of water are often enough for daily drinking requirements, it typically requires 3,000 liters to create an individual's daily dietary needs. 70% of the water drained from aquifers, streams, and lakes is used for agriculture. Over 50% of the world's drinking water and 43% of all agricultural irrigation comes from groundwater. 20% of all farmed area is used for irrigation agriculture, yet it produces 40% of all food produced globally.

KEYWORDS:

Agriculture, Fertilizer, Food Security, Management, Nutrients.

INTRODUCTION

Millions of impoverished smallholder farmers still struggle to have access to water for productive agricultural usage, particularly in sub-Saharan Africa, where just 3.2% of the region's total arable land is fitted with irrigation systems. In many areas, informal irrigation that is driven by farmers is more common than institutional irrigation. The need for fertilizer is expected to increase globally. By 2020, it is anticipated to reach 200 Mt. Gains in nutrient usage efficiency, which have been shown for three decades in industrialized nations and since 2008 in China, will have an impact on future development. In the years to come, other Asian nations could continue along the same path. On the other hand, there are still sizable regions where farmers mine the nutrient stores of their soil and apply minimal fertilizer. This is especially true in sub-Saharan Africa, where farmers are projected to have used barely 10% of the world's average amount of nutrients in 2013, or 11 kg/ha, although the area has had its fastest growth since 2008 [1].

In order to meet the task of assuring future food and nutrition security on a global scale, we must keep raising agricultural production. To do this, we must carefully increase the area planted while increasing agricultural production on already-cultivated land, protecting ecosystem services, and limiting additional land degradation. Although food insecurity is often driven by insufficient family income rather than an insufficient global food supply, we must guarantee that smallholder farmers have cheap access to the inputs required to effectively grow crops for subsistence and for sale in local markets. Whether we can expand and enhance agricultural output in a sustainable manner is the issue that has to be answered right now. The grounds for this worry include, among others, pressure on biodiversity and ecological services, land degradation, rising competition for water supplies, diminishing soil nutrient levels, declining soil growth rates, and climate change.

About 40 to 65% of the nitrogen fertilizer applied is believed to be used in the year of application, according to data from researcher-managed plots throughout the world reporting nitrogen, phosphorus, and potassium efficiency for important cereal crops. Given the complicated dynamics of P in soils, first-year usage efficiencies for K vary from 30 to 50% whereas those for P are lower. Yet sprayed P is accessible to crops for a very long time, often for a decade or more. Less encouraging are the typical numbers for N efficiency in farmer-managed fields. In rain-fed environments, as much as 70 to 80 percent of the extra N might be lost, and in irrigated areas, as much as 60 to 70 percent. Contrarily, farmers may attain N usage efficiency levels similar to those shown in research plots when adopting precision farming methods in temperate climates in the absence of other limiting variables [2].

The fact that many farmers lack the tools necessary to maximize fertilizer and water utilization is one of the main distinctions between researcher- and farmer-managed plots. Given the interdependence of the two inputs, this is crucial. If agricultural yields now fall well short of their potential. Significant increases in water usage efficiency may be produced by better soil and fertilizer management. Application of nutrients in accordance with plant demands, placement appropriately to maximum absorption, quantity at which to optimum development, and use of the most suitable source are among the best management strategies for increasing fertilizer usage efficiency. Programs for stewarding nutrients reflect these concepts.

DISCUSSION

Improving nutrition efficiency requires using the right kinds and amounts of nutrients from organic and mineral sources. In China, India, and North America, for instance, data gathered over many years and from several locations indicate that balanced fertilization with the right amounts of N, P, and K enhances first-year recoveries by an average of 54%, compared to average recoveries of 21% when just N is administered. Unfortunately, owing to a lack of understanding, resources, or logistical issues, many farmers do not use balanced fertilization. Nutrient usage efficiency improvements shouldn't be seen as only fertilizer management. For instance, water transport systems are often connected to the processes of nutrient buildup or depletion. The following factors influence how water and nutrients interact while managing soil fertility: Use of soil nutrients by plants will be constrained by water stress in the soil. Plants can only absorb nutrients from the soil when there is enough soil solution for mass flow and dispersion of nutrients to roots. The most significant element influencing the pace of several chemical and biological processes that affect nutrient availability is the water content of the soil [3].

The capacity of plants to use water effectively is restricted by low soil fertility. In the African Sahel, for instance, only 10 to 15 percent of the rain is utilised for plant development; the remainder is lost to run-off, evaporation, and drainage. Crops' inability to obtain water owing to a lack of nutrients for good root development is one factor in the poor water use. For instance, Zaongo et al. showed that applying N fertilizer enhanced the root density of irrigated sorghum by 52% when compared to applying merely water. Similar to this, Van Duivenbooden et al. provide a thorough list of alternatives to increase water usage effectiveness in the Sahel. Consequently, irrigation alone may not increase yields without taking into account the soil and its nutritional state, even in arid areas where water seems to be the limiting factor for plant development.

The production of the world's food depends heavily on water management, and water shortage has become a serious issue in many areas. The observations made by Rijsberman and Molden are as follows: There is widespread consensus that the main constraining issue for impoverished people's ability to produce food and maintain an economic existence in rural Asia and the majority of Africa will be the growing shortage of water. At the national level, South America has a reasonably high water supply and is not commonly seen as having a water shortage. Whilst there is a clear need for investments in the water industry when seen from the standpoint of "economic water scarcity," The majority of tiny islands in the Caribbean and Pacific have a limited supply of water and will continue to do so in the future [4]. There are two main strategies for increasing and maintaining production in water-scarce conditions: genetically changing plants to fit the environment via irrigation and water loss, and altering the soil environment through irrigation and water loss. Depending on the geography and the crop, each of these techniques have improved water usage efficiency to varied degrees. The Indo-Gangetic Plain and the deltaic regions of South and Southeast Asia are two important agricultural locations where irrigation has significantly increased crop yields and increased food supply. Nonetheless, both in these and other areas, there are still plenty of room for growth.

In the world, it is believed that 70% of the water extracted from rivers, lakes, and groundwater is utilized for agriculture. A large portion of the water is consumed, but a large portion also flows off into streams or percolates into aquifers. Other farmers may reuse some of the water from runoff and deep percolation, or it may create in-stream flow. Run-off and deep percolation may be significantly reduced with drip and sprinkler systems, and evaporation can also be decreased with drip irrigation. If they are accessible, such methods do not always reduce consumption per unit space, however. Instead, they may increase consumption rates by increasing uniformity in the distribution and decreasing moisture stress times. Due to these factors, current irrigation methods may not necessarily "save water" in the strictest sense, but they can lessen the amount of water lost to non-beneficial plants or evaporation from soil surfaces. Instead than being seen as strategies for water conservation, these techniques can be seen as ways to improve water management, including labor savings, while boosting agricultural productivity [5].

Nowadays, it is estimated that treated, untreated, or diluted wastewater is used to irrigate up to 20 Mha, or about 10% of the worlds permanently irrigated area. Most of the time, farmers have little choice since their water supplies are contaminated, but as more nations intend to utilize wastewater, this trend is being aided by current climate change projections. For instance, Israeli policy choices have made it possible for farmers to use treated wastewater as an adequate source of irrigation water. Due to increased competition for scarce water resources, the recovery and reuse of wastewater from municipal, industrial, and agricultural sources will rise in the future. Finding the optimum way to use both treated and untreated wastewaters while reducing risk to irrigators, farm families, and consumers is one objective of agricultural research. The recovery of nutrients from wastewater, which might happen on farms or during the water treatment process, also presents a difficulty. Plants use nutrients and water in tandem. A plant with sufficient nutrients can often handle water stress better. For instance, farmers increase productivity in rain-fed environments by using. The yield gain per applied unit of nutrient is used to measure agronomic efficiency. It directly connects to economic return and more accurately depicts the actual production effect of a fertilizer applied. Only once study plots with no fertilizer input have been introduced on the farm are these yields known, which is necessary for the computation of AE. Because of the lingering effects of the application on subsequent crops, the NUE of the applied fertilizer is often underestimated if it is computed using data from yearly trials rather than long-term experiments. Long-term experiments are necessary to estimate the fertilizer's long-term impact to crop output.

The simplest kind of nutrient recovery efficiency is partial nutrient balance, which is often stated as nutrient output per unit of nutrient intake. It is also stated as "output minus input."

Crop producers, as well as governments at the regional or national levels, may measure or estimate PNB. A PNB near to 1 is often taken to indicate that soil fertility will be maintained at a constant level. However, using a PNB of 1 as an indicator of soil fertility sustainability can be misleading because the balance calculation is only a partial balance and nutrient removal by processes, such as erosion and leaching, are typically not included. This is especially true in areas with very low native soil fertility, low inputs, and low production, like sub-Saharan Africa. Moreover, the balance computations seldom take into account all nutritional inputs, which is why the phrase has the modifier "partial".

In addition to fertilizer, other nutrient sources include biosolids, irrigation water, the atmosphere, recoverable manure nutrients, biological N fixation, and biosolids. Achievable values, however, are cropping system and soil specific. Levels significantly below 1, where fertilizer inputs much outweigh nutrient removal, could signal unnecessary nutrient losses and therefore the need for increased NUE. A PNB larger than 1 indicates "soil mining" of nutrients, when more nutrients are extracted with the harvested crop than are added by fertilizer and/or manure. If the available nutrient concentrations in the soil are known to be greater than required, this circumstance can be desirable. A PNB >1 must be viewed as unsustainable in situations when soil nutrient content is at or below acceptable levels, nevertheless. Due to cash flow and market circumstances, particularly for P and K, PNB might see significant variations over the short term and on individual farms. Hence, a longer-term evaluation of PNB over a number of years is more beneficial [6].

One of the more complicated NUE expressions is apparent recovery efficiency, which is often described as the difference in nutrient absorption in the plant's aboveground sections between treated and unfertilized crops in relation to the amount of fertilizer provided. Scientists researching the crop's nutrition response often choose it as their preferred NUE expression. In addition to requiring measurement of nutrient concentrations in the crop, it is similar to AE in that it can only be assessed after a plot devoid of nutrients has been utilized on the site. Moreover, like AE, it often understates long-term NUE when derived from yearly response data.

The yield in proportion to overall nutrient intake is referred to as internal utilization efficiency. It changes depending on management, habitat, and genotype. A very high IE indicates nutritional insufficiency. Poor IE indicates subpar internal nutrition conversion brought on by additional stressors. The increase in yield in response to the increase in crop nutrient absorption in the plant's above-ground portions is referred to as physiological efficiency. Similar to AE and RE, it requires a plot where the targeted nutrient is not applied. It is mostly tested and utilized in research, and it necessitates measuring the amounts of nutrients in the crop.

Application and benchmarks for NUE

When analyzing any management approach, it is usually beneficial to include more than one NUE term since this enables a better understanding and measurement of the crop response to the given nutrient. The various indications have to be utilized all at once. The lowest fertilizer rates being assessed, rates linked to high PNB, often produce the greatest AE. Increased PFP and P removal after crop harvest will result from genetic alterations, such as the recently identified Phosphorus Starvation Tolerance gene that enables rice to access more soil P. Farmers would benefit greatly from such a breakthrough immediately and it may enable the system to function at a lower level of soil P. Nonetheless, soil P depletion does happen if P usage is lower than the improved removal threshold.

For system sustainability, an acceptable PNB must be reached even with such genetic modifications. A thorough examination of nutrient management should take into account additional NUE terms, grain yield, fertilizer rates, and native soil fertility even if individual NUE terms may be used to characterize the effectiveness of fertilizer applications. For instance, in conditions of limited soil P availability, AE for P might be very high with low P rates; yet, PNB for P under these circumstances could be much higher than 1, depleting the already minimal soil P supplies as seen in Figure 8. A low P rate with a high AE for P in this situation would not be seen as a best management practice, although being preferable than making no P application at all [7].

This chapter will provide examples of the significant diversity in the key NUE metrics and trends as well as the key influences on them. By choosing relevant NUE metrics for the scale of interest, collecting data for those measures, and then establishing standards for assessing the obtained data, improvements in nutrient stewardship may be supported. The ideal place to create benchmarks is locally, with complete understanding of the methodology used to generate NUE measurements and the appropriate cropping system, soil, climate, and management context. The purpose of this chapter is to provide broad rules for understanding NUE metrics, however. Such generic criteria for the most used NUE measurements for N, P, and K for cereal crops. Where feasible, levels based on local research and experience should take the place of these standards.

NUE on Various Scales

The NUE terms in Table 1 may be calculated at scales ranging from the whole world to specific fields' tiny subareas. Scalability is a desirable quality for performance indicators because it makes connections between smaller-scale consequences and local management strategies more obvious. Yet, as the size grows, the estimation's accuracy and dependability for particular locations decline. In any event, the accuracy of the data utilized to calculate these estimations is crucial. Simpler indicators, like the PFP scale, are easier to use than more complicated ones, like RE and PE. These are few instances of NUE words used at various scales. The geographical variations in PNB within a single nation provide as an example of how this complicated combination of variables affects NUE. For instance, [8] PNB changes in a reasonably predictable manner for US watershed zones. As they take into account both N fixation and applied manure nutrients. In the southeast of the United States, which is characterized by soils with a coarse texture and little organic matter and limited water-holding and cation-exchange capabilities, PNB levels for N, P, and K are often low. However, a large portion of this area grows high-value crops, many of which are inefficient fertilizer consumers. The western side of the nation, where native soil K levels are typically high and lead to an uncommon reaction to K fertilization, is at the opposite extreme, with extraordinarily high PNB levels. When analyzing NUE statistics at regional sizes, such considerations need to be taken into account.

Field or farm scale

The PFP and PNB may be computed for any farm that maintains track of inputs and outputs and provide helpful information to producers. Figure 2 displays the kind of information that is often accessible at a farm size by displaying trends in fertilizer usage per hectare and per ton of grain for a farm in Brazil. In this instance, crop production increases together with higher fertilizer usage per ha led to a rise in PFP. When applied in tandem with higher nutrient rates, changes to a cropping system's agronomic practices may have a significant impact on NUE and lead to increases in fertilizer rates, crop yields, and NUE all at once. PFP and PNB indicators do not take into account the natural nutrient sources in the soil, and as a result, they do not accurately indicate how effective fertilizer-derived nutrients are. The AE, RE, and PE indices are better at estimating the short-term NUE of applied nutrients, however these indices call for data that are not often accessible at the farm size [9].

But, if a producer is interested, a check plot or omission plot might be built on the farm. Traditionally, these techniques have only been used in research settings. There is value in establishing both annual check plots, where the response of a single crop to a nutrient application can be evaluated, and perennial check plots, where the same area remains devoid of fertilizer application over years and will reflect the long-term contribution of applied nutrients to productivity and soil quality.

As the inclusion of check plots might cost the producer in terms of lost production and loss of consistency in the quality of harvested product, it is advisable to conduct such on-farm research in cooperative groups. This restriction is crucial for check-plot formation in areas with serious flaws, like the SSA. Moreover, group findings from on-farm studies done across a producing region are more significant than isolated observations.

Plot-scale analysis

In order to calculate all the main NUE forms, research plots normally provide a complete complement of data on nitrogen absorption and elimination in crop harvest for plots with and without the use of fertilizers. Research papers often contain measurements of more than one NUE expression since each word tackles distinct issues and has many meanings. Table 4 and Table 5 provide summaries of NUE measurements from several field experiments of rice, wheat, and maize in China as well as from field trials of wheat in three different areas of China. The regional wheat statistics demonstrate the significant disparities in NUE that occur across areas within nations owing to variations in climatic conditions, soil characteristics, and cropping practices.

NUE estimates derived from experimental station research plots are often higher than those derived from farmers' use of the same techniques in producing fields. These discrepancies result from the size disparities between study plots and whole fields for management of fertilizer methods, plowing, sowing, insect control, irrigation, and harvest. The difference computations shown in Table 1 are often used to calculate RE in research plots.

An alternate approach for determining N includes utilizing the fertilizer's 15N isotope as a tracer to calculate how much of the administered fertilizer was absorbed by the crop. The two approaches are often connected, but since the 15N is cycled via microbially mediated soil processes, RE as calculated by the 15N method will typically be lower than the other estimations. When recovery is evaluated both in the soil and in the plant, especially over a longer period of time, tracers are more helpful. Ladha et al. compiled the findings of many experiments where 15N was 5.7 to 7.1%, omitting the first growing season, was reported as the range for the estimate of N recovery by five successive crops. Total RE varied from 35 to 60% throughout the first growing season. High-yield cereal systems often have greater AE than systems at lower yield levels, regardless of whether trials are conducted on experiment stations or on farmer fields. The increased nutritional needs of crops at high yield levels are expected to surpass the soils' capacity to deliver nutrients without the use of fertilizers to a larger degree than at lower yield levels, therefore this should not come as a surprise. This widens the gap between the yield of the crop fertilized with fertilizer and the yield of the crop fertilized without fertilizer. A crop with a quicker rate of nutrient uptake may also lessen the possibility of nutrient losses from the producing field [10].

NUE trends for N

Among areas and cropping systems, NUE exhibits significant heterogeneity, which also shows up in temporal patterns. Intensively farmed nations like the US, Germany, the UK, and Japan often exhibit rising NUE as a consequence of static or even falling N consumption and rising crop yields. Yet, the temporal patterns of cropping systems among these nations might differ substantially. To properly analyze NUE trends, it is essential to comprehend the context of the whole system. This is shown by contrasting PFP patterns for N for maize and wheat in the US. Between 1975 and 2005, maize PFP climbed by around 50%, but wheat PFP fell by 30% during same time period before rising by 30% from 2005 to 2010. The improvement in crop, soil, and nutrient management, which increased yields by over 80% over the course of this 30-year period, was primarily responsible for the rise in maize PFP. Overall, PFP has increased linearly over the last 25 years at a rate of 0.9 kg grain -1.

Why then did wheat output not follow a similar trajectory in the same nation when producers had equal access to technology and innovation? The disparity in cropping, tillage, and fertilizer application histories between the major maize and wheat areas is probably the cause. The region that produces the majority of the world's wheat has been transitioning from management systems where the main source of nitrogen was soil organic matter mineralization caused by tillage and fallow periods to less tilled, more intensive cropping systems that maintain or increase soil organic matter. Wheat production during this transition became increasingly reliant on fertilizer as a N supply due to the decrease in soil organic N mining, which decreased apparent PFP and PNB. When Illinois and Montana's PNB are compared, it is clear that Illinois has the ability to close the N balance difference whereas Montana has historically had unacceptably high N balances that have been dropping for the last 20 years. The same causes that have been driving up PFP for maize systems are likely to blame for the recent reversal of the PFP trend for wheat.

PFP frequently exhibits declining trends in nations where agriculture is generally intensifying because fertilizer N use rises more quickly than crop yields, even though yields are also rising. In Argentina, wheat and maize are examples of this. Such drops in PFP are often followed with more sustainable PNB relationships when less mining of soil nutrients is happening, as in the instance of wheat in the US mentioned above. Such movements may be deceiving if the frequency of legumes in the rotation varies over time, especially if biological N fixing is not taken into account by the N balances.

It takes a systematic method where all areas are calculated using a similar process across time to provide a picture of regional changes in NUE around the globe. Just mineral fertilizer usage was taken into account for nutrient inputs, leaving out nutrients found in animal dung, atmospheric deposition, biological N fixation, and municipal garbage. 38 fruits and vegetables, 9 cereals, 9 oil crops, 6 pulse crops, 5 root or tuber crops, and 5 other crops were among the crops taken from the FAO database. Forage crops, which comprised plants such silage maize, alfalfa, and other hay, were the main group that wasn't included. In areas with large confinement cattle operations, this category may be a substantial source of productivity and nutrient removal. Alfalfa and "other hay," for instance, in the US account for more than 15% of the nation's total P removal and more than 40% of the K removal. As both forage crops as output and manure as input are omitted from these NUE calculations, the error introduced should, in most situations, not be significant at this wide regional scale. Nonetheless, some of the nutrients present in forage crops will be returned to the fields as animal dung. As biological N fixing was not included while making the input estimate, neither was N removal by legumes for determining PNB. This can lead to skewed PNB estimates in places with more legumes in the rotation. Based on literature values or data from research trials, the nutritional content of harvested crops was determined.

Throughout the last 25 years, there has been a very little rise in the global PFP and PNB levels. Most of the time, regional temporal patterns in PFP for N are comparable to PNB, although there are noticeable differences between regional trends globally. The greatest PFP and PNB values were by far found in Africa and Latin America in 1985, albeit trending in different directions. According to PFP statistics, both of these places have very high production for each administered unit of nitrogen fertilizer. The high PNB values for Africa, however, indicate that the continent is growing increasingly reliant on non-fertilizer sources to counteract crop N loss, which is a risky and unsustainable condition. South America, on the other hand, has remained relatively high production per unit of nitrogen, while also achieving a more sustainable nutritional balance. PNB and PFP are generally rising higher for Africa, North America, Europe, and the EU-15, but moving lower for Latin America, India, and China. The PNB for Europe during the last ten years seems to have leveled out at approximately 70%, whereas the PNB for China, India, and Latin America has been dropping at roughly the same pace for the past 25 years[11].

NUE trends for P and K

For P and K, NUE relationships are dominated by the main impacts of soil characteristics and often considerable residual effects of prior management. Most of the advantage of P and K treatment on many soils comes in later years due to impacts on soil fertility, while the majority of the benefit and recovery of N addition occur within the year of application. These residual effects must be taken into account for an appropriate assessment of the present state and long-term trends of NUE for P and K. The best way to understand short-term AE, RE, and PFP for P and K is often in the context of the present soil fertility status and the corresponding PNB, which predicts the future soil fertility status if the current PNB doesn't change.

Argentinan wheat trials provide as an excellent example of the impact of soil P fertility on AE and RE. When soil fertility is much below essential levels, very high AE and RE are detected, and these values quickly fall as soil fertility improves. When rates of application are close to removal and soil fertility levels are kept close to the essential level, the intermediate AE and RE values are related to sustainability. When fertilizer P is given at prescribed amounts in Asia, first-year RE field studies show that P recoveries of 25% are usual there. The majority of these research were conducted under favourable climatic and management circumstances on soils with low P fixing capacity. Dobermann noted that while within-studies RE ranged greatly from zero to over 100% but that 50% of all data were between the 10 to 35% RE range, despite the fact that average RE values were comparable across research. Due to the soil fertility and impacts of fertilizer application rate outlined above, such fluctuation is to be anticipated. To assess the present state of P usage, its effect on temporal patterns of soil fertility, and to test the notion that P balance affects soil fertility, regional aggregate data may be employed. IPNI reviewed soil tests performed for the crops in North America between 2005 and 2010 by both commercial and public soil-testing facilities. The PNB for this same 5-year period is plotted against the change in median soil P levels for the 12 Corn Belt states in Figure 10. PNB values above 0.94 were the result.

For P, the same strategy employed for N was used in order to provide a global picture of regional patterns in NUE. Similar to N, P has had a growth in PFP and PNB globally over the last 25 years, with PFP in the most recent 5-year period surpassing 195 kg output per kilogram P and PNB approaching 70%. In terms of both PFP and PNB, Africa has distinguished itself significantly from all other areas on a global scale. PNB levels for P in Africa, India, and China were roughly comparable in the years 1983–1987 at around 90% each, but they proceeded in opposing directions during the subsequent 25 years, with PNB in Africa tripling to over 180% and falling to about 50% in China and India. Although the values in China and India suggest that soil P levels should be rising, the PNB value for Africa suggests that excessive soil P mining is taking place. There is no proof that the usage of the local rock phosphate changed much, but these numbers do not account for this. Notwithstanding the dearth of trustworthy data on the use of rock phosphate as a direct application fertilizer in Africa, a number of sources claim that use levels have remained very low. Even in the nations with the greatest application rates, average application rates per country are less than 0.5 kg ha-1, demonstrating a negligible contribution of P from rock phosphate sources.

PNB and PFP are generally growing up in P for Africa, North America, Europe, and the EU15, but they are trending down in P for Latin America, India, and China, much as they did in P for N. While comparing the absolute values of the expressions, it is important to keep in mind that certain places are affected far more than others by the lack of manure inputs in these NUE estimations. The reliability of differences in temporal patterns is probably higher. Compared to N or P, information on K utilization efficiency is relatively scarce. This is partially attributable to K's ecologically friendly traits, in which economic or agronomic concerns dominate interest in efficiency. Less funding is provided as a consequence for research and instruction on effective usage. With the exception of certain highly fixing clay soils, K is typically thought to have a better first-year recovery efficiency than P. According to reports, applied K recovered between 20 and 60% of its cost in the first year. Prior to 1998, Dobermann reviewed typical recovery efficiencies from field experiments in Asia, finding that they ranged from 38 to 51%. According to Jin, typical AE values for field experiments on cereal crops in China from 2002 to 2006 were from 8 to 12, while RE for K was in the 25 to 32% range. The RE values for K were somewhat higher in a more recent series of field experiments on winter wheat in North-Central China, in the 34 to 44% range, but the AE values were once again in the 8 to 10 range [12].

The decreased AE was probably caused by K treatment rates that were higher than what was ideal for each site-soil year's K supply. For cereals grown on soils with low levels of accessible K reserves, Dobermann stated that AE values for K of 10–20 were reasonable aims. The same technique used for N and P in building a picture of regional changes in NUE throughout the globe was utilized for K. In the same way that N and P have climbed over the last 25 years, the world's PFP and PNB for K have also increased, with PFP in the most recent 5-year period surpassing 145 kg of output kg-1 K and PNB approaching 140%. Throughout the course of these 5 years, non-forage crops removed 40% more K than was used as commercial fertilizer globally. China had the highest shift in PNB throughout the region over the 25-year period, going from removing more than 5 times as much K as was being applied to a PNB nearing 100% when K removal and fertilizer were both used. Although South America, India, and China are heading lower, as was the case for N and P, PNB and PFP for Africa, North America, Europe, and the EU-15 are generally rising higher in K. While comparing the absolute values of the expressions, it is important to keep in mind that certain places are affected substantially more than others by the lack of fodder crop production and K removal in these NUE estimations. The reliability of differences in temporal patterns is probably higher.

NUE, water, and looking forward

Plant water status is one of several managerial and environmental elements that combine to affect NUE. Similar to this, plant nutritional status may significantly affect how efficiently water is used. This book's remaining chapters will examine how these two crucial crop growth factors interact. Although in arid environments it can be important to balance pre-anthesis and post-anthesis growth to ensure enough water remains to fill grain, WUE can be improved through nutrient management. Nitrogen availability influences aboveground biomass, plant residue generation, and nutrient dynamics in soil, canopy cover to minimize soil evaporation, and crop growth and WUE. Many crops have exhibited improved WUE when enough nutrients are supplied.

The link between NUE measurements and WUE throughout a range of N levels is well shown by data from a lysimeter experiment on spring wheat that was carried out in Canada. The research, which comprised treatments that were both rainfed and irrigated, demonstrates the significant influence water status may have on yield response to N and the ensuing AE and PNB. A water shortage significantly decreased AE and PNB at all N levels, as shown by the bottom graph in the figure, although the efficiency decline was noticeably larger at the lower N levels. Figure 15's top graph demonstrates how WUE improves when N levels rise for both the dryland and irrigated treatments. The irrigated treatment's lower apparent optimal N level for yield and WUE is due to increased NUE under irrigation, as illustrated in the bottom graph.

The goal of nutrient utilization is to improve the overall performance of cropping systems, and we reiterate this concept as we finish this chapter. The statistics in Figure 15 show that even while NUE typically declined as N rates rose, the performance of the system as a whole was enhanced by increasing WUE and yield at the same time until an ideal N rate was reached. For either water or crop nutrients to be used efficiently or effectively, they must both be controlled at the best levels for the particular system.

Sustainable intensification's basic goal is to continuously enhance system performance. These improvements are the result of management adjustments made by certain farmers for particular fields. While many of the nutrient management technology and techniques that might increase production and efficiency are now available and are discussed elsewhere in this book, many of them go unused. In the future, it will be necessary to develop regionally relevant NUE indices that farmers can easily detect and that are particular for nutrients, soils, and cropping methods. These recommendations would assist farmers in determining what to assess, where change is most required, and maybe the simplest to implement. The definition of the need of and effects of management changes on system performance would be aided by guidelines.

The yield gain per applied unit of nutrient is used to measure agronomic efficiency. It directly connects to economic return and more accurately depicts the actual production effect of a fertilizer applied. Only once study plots with no fertilizer input have been introduced on the farm are these yields known, which is necessary for the computation of AE. Because of the lingering effects of the application on subsequent crops, the NUE of the applied fertilizer is often underestimated if it is computed using data from yearly trials rather than long-term experiments. Long-term experiments are necessary to estimate the fertilizer's long-term impact to crop output.

The simplest kind of nutrient recovery efficiency is partial nutrient balance, which is often stated as nutrient output per unit of nutrient intake. It is also stated as "output minus input." Crop producers, as well as governments at the regional or national levels, may measure or estimate PNB. A PNB near to 1 is often taken to indicate that soil fertility will be maintained at a constant level. However, using a PNB of 1 as an indicator of soil fertility sustainability can be misleading because the balance calculation is only a partial balance and nutrient removal by processes, such as erosion and leaching, are typically not included. This is especially true in areas with very low native soil fertility, low inputs, and low production, like sub-Saharan Africa. Moreover, the balance computations seldom take into account all nutritional inputs, which is why the phrase has the modifier "partial". In addition to fertilizer, other nutrient sources include biosolids, irrigation water, the atmosphere, recoverable manure nutrients, biological N fixation, and biosolids. Achievable values, however, are cropping system and soil specific. Levels significantly below 1, where fertilizer inputs much outweigh nutrient removal, could signal unnecessary nutrient losses and therefore the need for increased NUE. A PNB larger than 1 indicates "soil mining" of nutrients, when more nutrients are extracted with the harvested crop than are added by fertilizer and/or manure. If the available nutrient concentrations in the soil are known to be greater than required, this circumstance can be desirable. A PNB >1 must be viewed as unsustainable in situations when soil nutrient content is at or below acceptable levels, nevertheless. Due to cash flow and market circumstances, particularly for P and K, PNB might see significant variations over the short term and on individual farms. Hence, a longer-term evaluation of PNB over a number of years is more beneficial.

One of the more complicated NUE expressions is apparent recovery efficiency, which is often described as the difference in nutrient absorption in the plant's aboveground sections between treated and unfertilized crops in relation to the amount of fertilizer provided. Scientists researching the crop's nutrition response often choose it as their preferred NUE expression. In addition to requiring measurement of nutrient concentrations in the crop, it is similar to AE in that it can only be assessed after a plot devoid of nutrients has been utilized on the site. Moreover, like AE, it often understates long-term NUE when derived from yearly response data.

CONCLUSION

The yield in proportion to overall nutrient intake is referred to as internal utilization efficiency. It changes depending on management, habitat, and genotype. A very high IE indicates nutritional insufficiency. Poor IE indicates subpar internal nutrition conversion brought on by additional stressors. The increase in yield in response to the increase in crop nutrient absorption in the plant's above-ground portions is referred to as physiological efficiency. Similar to AE and RE, it requires a plot where the targeted nutrient is not applied. It is mostly tested and utilized in research, and it necessitates measuring the amounts of nutrients in the crop.

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CHAPTER 2
APPLICATION AND BENCHMARKS FOR NUE

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ABSTRACT:

When analyzing any management approach, it is usually beneficial to include more than one NUE term since this enables a better understanding and measurement of the crop response to the given nutrient. The various indications have to be utilized all at once. The lowest fertilizer rates being assessed, rates linked to high PNB, often produce the greatest AE. Increased PFP and P removal after crop harvest will result from genetic alterations, such as the recently identified Phosphorus Starvation Tolerance gene that enables rice to access more soil P. Farmers would benefit greatly from such a breakthrough immediately and it may enable the system to function at a lower level of soil P. Nonetheless, soil P depletion does happen if P usage is lower than the improved removal threshold. For system sustainability, an acceptable PNB must be reached even with such genetic modifications.

KEYWORDS:

Agriculture, Fertilizer, Food Security, Management, Nutrients.

INTRODUCTION

A thorough examination of nutrient management should take into account additional NUE terms, grain yield, fertilizer rates, and native soil fertility even if individual NUE terms may be used to characterize the effectiveness of fertilizer applications. For instance, in conditions of limited soil P availability, AE for P might be very high with low P rates; yet, PNB for P under these circumstances could be much higher than 1, depleting the already minimal soil P supplies as seen in Figure 8. A low P rate with a high AE for P in this situation would not be seen as a best management practice, although being preferable than making no P application at all. This chapter will provide examples of the significant diversity in the key NUE metrics and trends as well as the key influences on them. By choosing relevant NUE metrics for the scale of interest, collecting data for those measures, and then establishing standards for assessing the obtained data, improvements in nutrient stewardship may be supported. The ideal place to create benchmarks is locally, with complete understanding of the methodology used to generate NUE measurements and the appropriate cropping system, soil, climate, and management context. The purpose of this chapter is to provide broad rules for understanding NUE metrics, however. Such generic criteria for the most used NUE measurements for N, P, and K for cereal crops. Where feasible, levels based on local research and experience should take the place of these standards [1].

NUE on various scales

The NUE terms in may be calculated at scales ranging from the whole world to specific fields' tiny subareas. Scalability is a desirable quality for performance indicators because it makes connections between smaller-scale consequences and local management strategies more obvious. Yet, as the size grows, the estimation's accuracy and dependability for particular locations decline.

In any event, the accuracy of the data utilized to calculate these estimations is crucial. Simpler indicators, like the PFP scale, are easier to use than more complicated ones, like RE and PE. These are few instances of NUE words used at various scales. Differences across the various locations in Table 3 at this extremely coarse scale may be caused by a variety of variables, such as crop rotation, soil characteristics, climate, governmental policies, and managerial intensity.

The geographical variations in PNB within a single nation provide as an example of how this complicated combination of variables affects NUE. For instance, PNB changes in a reasonably predictable manner for US watershed zones. As they take into account both N fixation and applied manure nutrients, the PNB values in Figure 1 are less "partial" than those in Table 3. In the southeast of the United States, which is characterized by soils with a coarse texture and little organic matter and limited water-holding and cation-exchange capabilities, PNB levels for N, P, and K are often low. However, a large portion of this area grows high-value crops, many of which are inefficient fertilizer consumers. The western side of the nation, where native soil K levels are typically high and lead to an uncommon reaction to K fertilization, is at the opposite extreme, with extraordinarily high PNB levels. When analyzing NUE statistics at regional sizes, such considerations need to be taken into account [2].

Field or Farm Scale

The PFP and PNB may be computed for any farm that maintains track of inputs and outputs and provide helpful information to producers. Figure 2 displays the kind of information that is often accessible at a farm size by displaying trends in fertilizer usage per hectare and per ton of grain for a farm in Brazil. In this instance, crop production increases together with higher fertilizer usage per ha led to a rise in PFP. When applied in tandem with higher nutrient rates, changes to a cropping system's agronomic practices may have a significant impact on NUE and lead to increases in fertilizer rates, crop yields, and NUE all at once. PFP and PNB indicators do not take into account the natural nutrient sources in the soil, and as a result, they do not accurately indicate how effective fertilizer-derived nutrients are. The AE, RE, and PE indices are better at estimating the short-term NUE of applied nutrients, however these indices call for data that are not often accessible at the farm size.

But, if a producer is interested, a check plot or omission plot might be built on the farm. Traditionally, these techniques have only been used in research settings. There is value in establishing both annual check plots, where the response of a single crop to a nutrient application can be evaluated, and perennial check plots, where the same area remains devoid of fertilizer application over years and will reflect the long-term contribution of applied nutrients to productivity and soil quality. As the inclusion of check plots might cost the producer in terms of lost production and loss of consistency in the quality of harvested product, it is advisable to conduct such on-farm research in cooperative groups. This restriction is crucial for check-plot formation in areas with serious flaws, like the SSA. Moreover, group findings from on-farm studies done across a producing region are more significant than isolated observations [3].

Plot-scale analysis

In order to calculate all the main NUE forms, research plots normally provide a complete complement of data on nitrogen absorption and elimination in crop harvest for plots with and without the use of fertilizers. Research papers often contain measurements of more than one NUE expression since each word tackles distinct issues and has many meanings. NUE measurements from several field experiments of rice, wheat, and maize in China as well as from field trials of wheat in three different areas of China. The regional wheat statistics demonstrate the significant disparities in NUE that occur across areas within nations owing to variations in climatic conditions, soil characteristics, and cropping practices.

NUE estimates derived from experimental station research plots are often higher than those derived from farmers' use of the same techniques in producing fields. These discrepancies result from the size disparities between study plots and whole fields for management of fertilizer methods, plowing, sowing, insect control, irrigation, and harvest. The difference computations shown in Table 1 are often used to calculate RE in research plots. An alternate approach for determining N includes utilizing the fertilizer's 15N isotope as a tracer to calculate how much of the administered fertilizer was absorbed by the crop. The two approaches are often connected, but since the 15N is cycled via microbially mediated soil processes, RE as calculated by the 15N method will typically be lower than the other estimations. When recovery is evaluated both in the soil and in the plant, especially over a longer period of time, tracers are more helpful. Ladha et al. compiled the findings of many experiments where 15N was 5.7 to 7.1%, omitting the first growing season, was reported as the range for the estimate of N recovery by five successive crops. Total RE varied from 35 to 60% throughout the first growing season [4].

DISCUSSION

Status of developments in NUE for N

Status of NUE for N at this time

Ladha et al. reviewed 93 published papers that used research plots to evaluate NUE in-depth. The central tendency for the NUE expressions for maize, wheat, and rice is estimated in this review. PFP and AE values were usually greater for maize and rice than for wheat, at least in part because wheat grain has a higher N content. With a 10th percentile value of 0.2 and a 90th percentile value of 0.9, RE values varied greatly between areas and crops. A large portion of the value range was ascribed to differences in soil, climate, and management circumstances across trials. As was previously indicated, measured NUE from production fields is often lower than from research plots. The average RE for fertilizer N applied by rice farmers in the key rice-producing areas of four Asian nations, for instance, was 0.31 as opposed to 0.40 for field-specific management and 0.50-0.80 in well-managed field tests, the RE for N in cereals under present agricultural techniques ranges from 0.17 to 0.33, in study plots from 0.25-0.49, and at the highest, from 0.55-0.96. In India, RE averaged 0.18 across 23 farms for wheat produced in unfavorable weather, but 0.49 across 21 farms in favorable weather [5].

High-yield cereal systems often have greater AE than systems at lower yield levels, regardless of whether trials are conducted on experiment stations or on farmer fields. The increased nutritional needs of crops at high yield levels are expected to surpass the soils' capacity to deliver nutrients without the use of fertilizers to a larger degree than at lower yield levels, therefore this should not come as a surprise. This widens the gap between the yield of the crop fertilized with fertilizer and the yield of the crop fertilized without fertilizer. A crop with a quicker rate of nutrient uptake may also lessen the possibility of nutrient losses from the producing field.

NUE trends for N

Among areas and cropping systems, NUE exhibits significant heterogeneity, which also shows up in temporal patterns. Intensively farmed nations like the US, Germany, the UK, and Japan often exhibit rising NUE as a consequence of static or even falling N consumption and rising crop yields. Yet, the temporal patterns of cropping systems among these nations might differ substantially. To properly analyze NUE trends, it is essential to comprehend the context of the whole system. This is shown by contrasting PFP patterns for N for maize and wheat in the US. Between 1975 and 2005, maize PFP climbed by around 50%, but wheat PFP fell by 30% during same time period before rising by 30% from 2005 to 2010. The improvement in crop, soil, and nutrient management, which increased yields by over 80% over the course of this 30-year period, was primarily responsible for the rise in maize PFP. Overall, PFP has increased linearly over the last 25 years at a rate of 0.9 kg grain -1.

Why then did wheat output not follow a similar trajectory in the same nation when producers had equal access to technology and innovation? The disparity in cropping, tillage, and fertilizer application histories between the major maize and wheat areas is probably the cause. The region that produces the majority of the world's wheat has been transitioning from management systems where the main source of nitrogen was soil organic matter mineralization caused by tillage and fallow periods to less tilled, more intensive cropping systems that maintain or increase soil organic matter. Wheat production during this transition became increasingly reliant on fertilizer as a N supply due to the decrease in soil organic N mining, which decreased apparent PFP and PNB. When Illinois and Montana's PNB are compared, it is clear that Illinois has the ability to close the N balance difference whereas Montana has historically had unacceptably high N balances that have been dropping for the last 20 years. The same causes that have been driving up PFP for maize systems are likely to blame for the recent reversal of the PFP trend for wheat [6].

PFP often exhibits declining trends in nations where agriculture is generally intensifying because fertilizer N consumption rises more quickly than crop yields, even while yields are also rising. In Argentina, wheat and maize are examples of this. Such drops in PFP are often followed with more sustainable PNB relationships when less mining of soil nutrients is happening, as in the instance of wheat in the US mentioned above. Such movements may be deceiving if the frequency of legumes in the rotation varies over time, especially if biological N fixing is not taken into account by the N balances.

It takes a systematic method where all areas are calculated using a similar process across time to provide a picture of regional changes in NUE around the globe. Just mineral fertilizer usage was taken into account for nutrient inputs, leaving out nutrients found in animal dung, atmospheric deposition, biological N fixation, and municipal garbage. Forage crops, which comprised plants such silage maize, alfalfa, and other hay, were the main group that wasn't included. In areas with large confinement cattle operations, this category may be a substantial source of productivity and nutrient removal.

Alfalfa and "other hay," for instance, in the US account for more than 15% of the nation's total P removal and more than 40% of the K removal. As both forage crops as output and manure as input are omitted from these NUE calculations, the error introduced should, in most situations, not be significant at this wide regional scale. Nonetheless, some of the nutrients present in forage crops will be returned to the fields as animal dung. As biological N fixing was not included while making the input estimate, neither was N removal by legumes for determining PNB. This can lead to skewed PNB estimates in places with more legumes in the rotation. Based on literature values or data from research trials, the nutritional content of harvested crops was determined [7].

Throughout the last 25 years, there has been a very little rise in the global PFP and PNB levels. Most of the time, regional temporal patterns in PFP for N are comparable to PNB, although there are noticeable differences between regional trends globally. The greatest PFP and PNB values were by far found in Africa and Latin America in 1985, albeit trending in different directions. According to PFP statistics, both of these places have very high production for each administered unit of nitrogen fertilizer. The high PNB values for Africa, however, indicate that the continent is growing increasingly reliant on non-fertilizer sources to counteract crop N loss, which is a risky and unsustainable condition. South America, on the other hand, has remained relatively high production per unit of nitrogen, while also achieving a more sustainable nutritional balance.

PNB and PFP are generally rising higher for Africa, North America, Europe, and the EU-15, but moving lower for Latin America, India, and China. The PNB for Europe during the last ten years seems to have leveled out at approximately 70%, whereas the PNB for China, India, and Latin America has been dropping at roughly the same pace for the past 25 years.

NUE trends for P and K

For P and K, NUE relationships are dominated by the main impacts of soil characteristics and often considerable residual effects of prior management. Most of the advantage of P and K treatment on many soils comes in later years due to impacts on soil fertility, while the majority of the benefit and recovery of N addition occur within the year of application. These residual effects must be taken into account for an appropriate assessment of the present state and long-term trends of NUE for P and K. The best way to understand short-term AE, RE, and PFP for P and K is often in the context of the present soil fertility status and the corresponding PNB, which predicts the future soil fertility status if the current PNB doesn't change. Argentinan wheat trials provide as an excellent example of the impact of soil P fertility on AE and RE. When soil fertility is much below essential levels, very high AE and RE are detected, and these values quickly fall as soil fertility improves. When rates of application are close to removal and soil fertility levels are kept close to the essential level, the intermediate AE and RE values are related to sustainability [8].

When fertilizer P is given at prescribed amounts in Asia, first-year RE field studies show that P recoveries of 25% are usual there. The majority of these research were conducted under favourable climatic and management circumstances on soils with low P fixing capacity. Dobermann noted that while within-studies RE ranged greatly from zero to over 100% but that 50% of all data were between the 10 to 35% RE range, despite the fact that average RE values were comparable across research. Due to the soil fertility and impacts of fertilizer application rate outlined above, such fluctuation is to be anticipated. To assess the present state of P usage, its effect on temporal patterns of soil fertility, and to test the notion that P balance affects soil fertility, regional aggregate data may be employed. IPNI reviewed soil tests performed for the crops in North America between 2005 and 2010 by both commercial and public soil-testing facilities. The PNB for this same 5-year period is displayed against the change in median soil P levels for the 12 Corn Belt states in Figure 10. PNB values over 0.94 were the outcome.

For P, the same strategy employed for N was used in order to provide a global picture of regional patterns in NUE. Similar to N, P has had a growth in PFP and PNB globally over the last 25 years, with PFP in the most recent 5-year period surpassing 195 kg output per kilogram P and PNB approaching 70%. In terms of both PFP and PNB, Africa has distinguished itself significantly from all other areas on a global scale. PNB levels for P in Africa, India, and China were roughly comparable in the years 1983–1987 at around 90% each, [9] but they proceeded in opposing directions during the subsequent 25 years, with PNB in Africa tripling to over 180% and falling to about 50% in China and India. Although the values in China and India suggest that soil P levels should be rising, the PNB value for Africa suggests that excessive soil P mining is taking place. There is no proof that the usage of the local rock phosphate changed much, but these numbers do not account for this. Notwithstanding the dearth of trustworthy data on the use of rock phosphate as a direct application fertilizer in Africa, a number of sources claim that use levels have remained very low. Even in the nations with the greatest application rates, average application rates per country are less than 0.5 kg ha-1, demonstrating a negligible contribution of P from rock phosphate sources.

PNB and PFP are generally growing up in P for Africa, North America, Europe, and the EU15, but they are trending down in P for Latin America, India, and China, much as they did in P for

N. While comparing the absolute values of the expressions, it is important to keep in mind that certain places are affected far more than others by the lack of manure inputs in these NUE estimations. The reliability of differences in temporal patterns is probably higher. Compared to N or P, information on K utilization efficiency is relatively scarce. This is partially attributable to K's ecologically friendly traits, in which economic or agronomic concerns dominate interest in efficiency. Less funding is provided as a consequence for research and instruction on effective usage. With the exception of certain highly fixing clay soils, K is typically thought to have a better first-year recovery efficiency than P. According to reports, applied K recovered between 20 and 60% of its cost in the first year. Prior to 1998, Dobermann reviewed typical recovery efficiencies from field experiments in Asia, finding that they ranged from 38 to 51%. According to Jin, typical AE values for field experiments on cereal crops in China from 2002 to 2006 were from 8 to 12, while RE for K was in the 25 to 32% range. The RE values for K were somewhat higher in a more recent series of field experiments on winter wheat in North-Central China, in the 34 to 44% range, but the AE values were once again in the 8 to 10 range [10].

The decreased AE was probably caused by K treatment rates that were higher than what was ideal for each site-soil year's K supply. For cereals grown on soils with low levels of accessible K reserves, Dobermann stated that AE values for K of 10–20 were reasonable aims. K was developed using the same method used for N and P to paint a picture of regional trends in NUE around the globe. In the same way that N and P have climbed over the last 25 years, the world's PFP and PNB for K have also increased, with PFP in the most recent 5-year period surpassing 145 kg of output kg-1 K and PNB approaching 140%. Throughout the course of these 5 years, non-forage crops removed 40% more K than was used as commercial fertilizer globally. China had the highest shift in PNB throughout the region over the 25-year period, going from removing more than 5 times as much K as was being applied to a PNB nearing 100% when K removal and fertilizer were both used.

Equal K applications. PFP and PNB for Africa both grew significantly over the course of the 25 years, with a PNB in the years 2003–2007 showing that crops eliminated more than six times the amount of K that was applied as fertilizer. Although South America, India, and China are heading lower, as was the case for N and P, PNB and PFP for Africa, North America, Europe, and the EU-15 are generally rising higher in K. While comparing the absolute values of the expressions, it is important to keep in mind that certain places are affected substantially more than others by the lack of fodder crop production and K removal in these NUE estimations. The reliability of differences in temporal patterns is probably higher [11].

NUE, water, and Looking Forward

Plant water status is one of several managerial and environmental elements that combine to affect NUE. Similar to this, plant nutritional status may significantly affect how efficiently water is used. This book's remaining chapters will examine how these two crucial crop growth factors interact. While in dry settings it might be vital to balance preanthesis and postanthesis growth to ensure enough water remains to fill grain, WUE can be enhanced by nutrition management. Nitrogen availability influences aboveground biomass, plant residue generation, and nutrient dynamics in soil, canopy cover to minimize soil evaporation, and crop growth and WUE. Many crops have exhibited improved WUE when enough nutrients are supplied.

The link between NUE measurements and WUE throughout a range of N levels is well shown by data from a lysimeter experiment on spring wheat that was carried out in Canada. The research, which comprised treatments that were both rainfed and irrigated, demonstrates the significant influence water status may have on yield response to N and the ensuing AE and

PNB. A water shortage significantly decreased AE and PNB at all N levels, as shown by the bottom graph in the figure, although the efficiency decline was noticeably larger at the lower N levels. Figure 15's top graph demonstrates how WUE improves when N levels rise for both the dryland and irrigated treatments. The irrigated treatment's lower apparent optimal N level for yield and WUE is due to increased NUE under irrigation, as illustrated in the bottom graph [12].

CONCLUSION

The goal of nutrient utilization is to improve the overall performance of cropping systems, and we reiterate this concept as we finish this chapter. The statistics in Figure 15 show that even while NUE typically declined as N rates rose, the performance of the system as a whole was enhanced by increasing WUE and yield at the same time until an ideal N rate was reached. For either water or crop nutrients to be used efficiently or effectively, they must both be controlled at the best levels for the particular system. Sustainable intensification's basic goal is to continuously enhance system performance. These improvements are the result of management adjustments made by certain farmers for particular fields. While many of the nutrient management technology and techniques that might increase production and efficiency are now available and are discussed elsewhere in this book, many of them go unused. In the future, it will be necessary to develop regionally relevant NUE indices that farmers can easily detect and that are particular for nutrients, soils, and cropping methods. These recommendations would assist farmers in determining what to assess, where change is most required, and maybe the simplest to implement.

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CHAPTER 3

AGRICULTURE'S WATER USAGE EFFICIENCY: MEASUREMENT, SITUATION AND TRENDS

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ABSTRACT

The greatest user of water is agriculture, and if trends in food consumption and present production techniques continue, total evapotranspiration from agricultural land worldwide might treble in the next 50 years. It is urgently necessary to increase water production, or more appropriately, water usage efficiency. The discussion has a particular emphasis on better understanding and using the relationships between water and nutrients to increase water production at all levels. Moving from a crop-plant to a field, farm, system, basin, region, and national level increases the complexity of measurement and improvement measures for physical or economic water production. In both large-scale commercial systems in developed countries and small-scale systems in developing countries, the key to optimizing trade-offs between yield, profit, and environmental protection is to achieve synchrony between nutrient supply and crop demand without excess or deficiency under different moisture regimes. To find the water-saving potential, proper water accounting methods must be implemented. The only way to produce all the food that will be required with the water now available is to boost water productivity as strain on the land and water resources grows.

KEYWORDS:

Agriculture, Fertilizer, Food Security, Management, Nutrients.

INTRODUCTION

The necessity to leave adequate water in rivers and lakes to support ecosystems and fulfill the rising needs of cities and industry, as well as to increase agricultural water productivity, is a vital response to the developing water shortage. Amount of carbon absorbed and crop yield per unit of transpiration were the original definitions of water use efficiency used by crop physiologists. Later definitions changed to include biomass or marketable yield per unit of evapotranspiration. Water use efficiency is defined as "the ratio of irrigation water transpired by the crops of an irrigation farm or endeavor during their growth period to the water diverted from a river or other natural source into the farm or project canal or canals during the same period of time" by irrigation scientists and engineers to describe how effectively water is delivered to crops and to indicate the amount of water wasted at plot, farm, command, or system level. By incorporating the ideas of regularity, appropriateness, and sagacity of irrigation, this strategy was further enhanced.

Even some academics have noted that the often stated link between water and agricultural output is an indicator rather than an efficiency. Nevertheless, this idea of water usage efficiency only offers a partial picture since it does not explain the overall benefits generated or the fact that water lost to irrigation is often utilized again by other users. The advantages and disadvantages of using water for agriculture in terrestrial and aquatic environments are now included in the current emphasis on water production. The ratio of net advantages from crop, forestry, fisheries, livestock, and mixed agricultural systems to the quantity of water consumed to create those benefits is known as agricultural water productivity. In its widest meaning, it encapsulates the goals of increasing food production, revenue generation, quality of life, and ecological advantages while reducing the social and environmental costs per unit of water utilized. Economic water productivity is defined as the value derived per unit of water used, and it has also been used to relate water use in agriculture to nutrition, jobs, welfare, and the environment [1]. Physical water productivity is defined as the ratio of agricultural output to the amount of water consumed. The notion of "water-use efficiency" and "water productivity" as applied at plant, field, farm, region/sub-basin, basin, and national level using conventional and remote sensing based estimates are explained in depth in this chapter. Moreover, techniques for increasing water production in irrigated paddy fields, water-scarce circumstances, and huge river basins are reviewed.

If water is limited and one wants to fully use other agricultural inputs, such as fertilizers, premium seeds, tillage and land formation, as well as labor, energy, and equipment, increasing water productivity is especially suited. Additionally, there are pressures to reallocate water from agriculture to cities and industries, as well as other reasons, such as ensuring water is available for environmental uses and climate change adaptation, meeting the rising food demands and altering dietary patterns of a growing, wealthier, and more urbanized population, and assisting poor farmers in growing their businesses.

A productive use of water results in greater nutrition and food for families, more income, and useful work. Aiming for high water productivity may cut crop cultivation costs and water extraction energy needs. This lessens the need for more land, and water supplies in systems that are supplied by rain and irrigation. Average annual agricultural evapotranspiration may treble in the next 50 years if there are no increases in water productivity. A strategic response to the developing water shortage, the optimization of other agricultural inputs, and increased farm incomes and livelihoods thus includes a better knowledge, measurement, and improvement of water productivity [2].

Measuring Water Production and Usage Efficiency

The ratio of total biomass or grain yield to water supply, evapotranspiration, or transpiration on a daily or monthly basis is how crop scientists quantify and assess water usage efficiency. If water use efficiency does not change significantly throughout the season, yield can be thought of as a linear function of transpiration since biomass yield versus evapotranspiration relations have intercepts on the evapotranspiration axis, which are taken to represent direct evaporation from the soil. Since the intercept has a constant value and the yield against evapotranspiration relationship is linear, water usage efficiency would rise as evapotranspiration rose due to the higher transpiration/evapotranspiration ratio. For this reason, up to a certain point, an increase in agricultural water supply also results in an improvement in water usage efficiency. The availability of applied nutrients has been shown to boost the effectiveness of fertilizer application, and water and nutrients interact to affect yield and yield components.

Water accounting, which accounts for losses that happen as water moves from the reservoir, conveyed and delivered at the farm gate, applied to the farm, stored in the soil, and ultimately consumed by the crops for crop production, is the basis for the irrigation system's perspective on water use efficiency. The ability to quantify water transportation efficiency, application efficiency, water input efficiency, irrigation water use efficiency, and crop water use efficiency depends on the region of interest. The irrigation efficiency often relates the output, or the quantity of water retained in the root zone, to an input, such as some measure of water provided, as opposed to crop water usage efficiency, which compares the output to crop evapotranspiration. The word "water production" was created in an effort to resolve the concept's inherent limits and generalized complexity. The idea of water productivity as a reliable indicator of agricultural systems' capacity to transform water into food. The output of a particular system in proportion to the water it uses is how much water it produces, and this may be quantified for the whole system or specific components of it, specified in time and location.

DISCUSSION

Agricultural benefit Water use

When crop output is expressed in kg ha-1 and water usage is calculated as mm of water applied or received as rainfall, converted to m3 ha-1, it is common to depict water productivity in units of kg m-3. Other representations include food or its monetary worth. Plot, field, sub-basin, and basin are used to describe agricultural systems, as well as the crops and cropping practices used at each component level. When comparable comparisons are done at the individual agricultural system components, water productivity numbers make more sense. The cycle of agricultural output that powers the system determines the time span over which water productivity is assessed. Typically, this would take into account both productive and unproductive water consumption throughout the course of at least one full crop cycle spread over the whole year. In order to evaluate the average, minimum, or maximum water production within each season, assessment may be spread out across a number of years. Cropping methods provide additional advantages to yield, such as feed, legumes, or soil nutrition, which may have a big impact on water productivity in the coming years. Also, the trends in the weather, the spread of illness and pest infestation, the state of the markets, etc. may cause an estimating mistake at the time of assessment that may or may not be indicative of the typical condition [3].

Setting the limits of the system for which WP is to be evaluated is the first step. The definition of the production system and the geographic region for which water consumption may be described decide this. The most straightforward method for measuring partial water potential is at the field or plot level for a single crop. Nevertheless, when representing a big hydrologic system, certain estimate mistakes may occur. This will be covered in a different section. The definition of a given production system may be overrepresented or underrepresented inside regions with a high or low storage capacity in rain-fed areas and areas with shallow groundwater levels, respectively. WP will vary geographically due to variable soil water storage capabilities. Agriculture's biomass, or output, may be represented in a variety of ways, including yield, or the food and energy equivalent, revenue, or other accepted indicators of well-being obtained from the agricultural system. This may be stated as follows: Calculate the yield and agricultural water usage across an interest region to estimate the WP of a primary crop. Random surveys and secondary agricultural production statistics may be used to estimate crop production data over wide regions.

Gross margin for a single product during a single crop rotation phase serves as the economic yardstick for productivity at the field size. A composite metric can be necessary for regions with several production systems and for cross-system comparability. The Standardized Gross Value of Production was created in order to balance out regional pricing variations throughout the globe. In order to determine SGVP, equivalent yield is computed using local crop prices in comparison to the local price of the main locally produced, globally traded base crop. The corresponding output is then valued at market pricing as the next phase. Economists often utilize long-term averages of World Bank prices to do this in order to correct for biases brought on by annual price changes. For instance, if a commodity's local price is double the local price of wheat, then 2 t ha-1 of a pulse crop's output yield is comparable to 4 t ha-1 of wheat. The "wheat equivalent" of all harvested crops is then combined, and the "gross value of output" is determined by multiplying this amount of wheat by the average global wheat market price.

The full scope of economic benefits from agricultural production, however, goes far beyond the straightforward measurement of local production, to include indirect and broader impacts, which may include higher employment rates and wages, improved markets for inputs and the outputs, and a general improvement of the economy and well-being. There are many different farm/nonfarm multipliers throughout the economy.

According to estimates, the multiplier in India might be as low as 1.2 for regional programs and as high as 3 for the whole nation. In industrialized economies, multipliers are often bigger; one estimate puts Australia's multiplier at 6. According to Hussain et al., the most important metric is marginal value, which depicts the extra value produced when more water is supplied or lost when it is not. The enhancement of environmental benefits and services, changes in the Human Development Index or the Basic-Needs Index, and other non-economic advantages of production may all be quantified.

Calculating the amount of water used: the determinant

Water used or depleted for crop production is not the same as water input to a field or an agricultural system. We might calculate water consumption efficiency as output for each irrigation supply unit, however. Instead of using the quantity of irrigation water used or the amount of rainfall received, the amount of water directly used by the agricultural system is used to assess water production. This difference becomes more crucial as we go from the field to the farm to the basin because water that is introduced into the system but not used is accessible downstream and is thus disregarded in calculations. This may be calculated at a specific scale using a straightforward water balance equation or by adhering to the water accounting framework.

The amount of water that evapotranspiration consumes

Due to fluctuations in the amount of water diverted, the link between water diversion and depletion is complicated. Moving out to a greater size causes the variances to average out. Starting interventions in places with the lowest water production is a good idea. It is relatively difficult to establish water balances for each farm and crop at the greater size of an administrative unit, the sub-basin, and the basin.

Moreover, at the field or system sizes, a portion of the provided water is often reused there as well as in other parts of the basin. The value of production per unit of crop consumptive water consumption is believed to be a superior measure of water productivity in order to circumvent these difficulties in capturing the reuse and benefits beyond the regions of interest. Consumptive water usage suggests possible evapotranspiration in irrigated regions. While it is the minimum of effective rainfall and ETp in rain-fed environments.

The following methods may be used to estimate agricultural yields and consumptive water usage, depending on the information, expertise, and resources that are available and the goal of the study either the more current methods involving remote sensing imaging and crop modeling or the statistical data on crop yields, historical values of crop coefficients, and potential evapotranspiration [4].

The value of agricultural production may be estimated using long-term subnational data on detailed land use, crop output, amount of irrigated and rain-fed areas of various crops, and combined total production. The main crops' crop coefficients and climate data may be used to calculate consumptive water usage. Amarasinghe et al. have provided a detailed description of the procedure. The following are the significant governing equations:

Combining data from crop censuses with remote sensing

The implementation and comprehension of the water productivity framework and the design of the interventions are often hampered by a lack of data necessary for monitoring the productivity of land and water resources, particularly across huge irrigation systems and river basins. It would be very beneficial to integrate satellite observations for climate data with auxiliary in-situ data into a geographic information system. Measurements from remote sensing are transformed into crop yield and real evapotranspiration. The leading crops are mapped using census data, land use-land cover maps, and existing maps. With the Normalized Difference Vegetation method, the yields are extrapolated to the pixel level from national data.

Satellite data index. Based on land-based satellite data, a simplified surface energy balance model is used to map crop evapotranspiration surface temperature and weather station information. By dividing crop yield by ETa for each pixel, the WP of the dominating crops and the overall agricultural production are plotted. Large sub-basins in Pakistan, the Indo-Gangetic basin, the Karkheh basin in Iran, the Nile basin, and numerous others have all been thoroughly mapped using these techniques.

These WP maps clearly show the spatial variance. Regardless of administrative borders, we can pinpoint "hot areas" and "bright spots" with high and poor performance, respectively. By connecting them to groundwater level, terrain, rainfall distribution, and other geographical data, it is possible to identify causative correlations that may be used to support better intervention planning.

Increasing the Water Productivity of Agriculture

A worldwide approach for raising agricultural output has included irrigation, fertilizers, and better seeds as crucial elements. Increasing irrigation water usage efficiency has been a focus of better agricultural water management over the last several decades, but more recently, more emphasis has been focused on producing more with relatively less water—increasing water productivity. By enhancing biological, economic, and environmental output per unit of water utilized in both irrigated and rain-fed agricultural systems, there is a need to identify novel approaches to boost water productivity. By extracting more productive transpiration from rain and irrigation withdrawals, growing more and higher-value crops per unit of transpiration, lowering evaporation, and managing agricultural water delivery and drainage better, physical productivity increases may be accomplished. Such possibilities exist at the biological, environmental, and managerial levels and are quite varied.

Water efficiency at the Plant Level

Physiological mechanisms are necessary for both real crop output and actual evapotranspiration. For carbon intake and vapour exhalation, stomata must open. There is a recognized linear link between plant biomass and transpiration for a particular crop variety and climate. Depending on the ratio of biomass to transpiration, different plant species need more water. Wheat and barley, which are C3 crops, need less water than maize and sugarcane, which are C4 crops. The CAM crops, such cactus and pineapple, need the least amount of water. The development of cultivars with a greater harvest index, which results in more profitable product per unit of transpiration, has proven to be one of the most effective tactics used by plant breeders. During the last 40 years, this plant-breeding approach has most likely increased the potential for increases in water productivity than any other agronomic technique. Wheat and maize harvest indices increased from around [5]. 0.35 before to the 1960s and 0.5 after that. This took place in Asia and abroad throughout the Green Revolution period. The subsequent growth in the harvest index has, however, seemed to have peaked, and the pace of increase has decreased. To achieve the next breakthrough, new developments in plant biotechnology are necessary, such as the creation of salt- and flood-tolerant rice for coastal areas and drought-tolerant rice variants for dry regions. One such effective example is the introduction of the submersion-tolerant Scuba gene into rice. The almost linear connection between crop output and transpiration has profound effects on water requirements. A nearly proportional increase in transpired water is necessary to boost food production in productive regions. Increases in food production have had negative effects on the environment, including a sharp decrease in water levels in the Indus basin and other highly productive regions, according to Molden et al. More water will need to be flowed in order to feed more people. A different course of action may be to pay more attention to low-productivity regions in Africa and South Americas, where sparing use of water and fertilizer may have significant positive effects.

The availability of water, its utilization, and the delivery of nutrients to plants all have an impact on how quickly plants develop and produce yields. According to common reports, applying fertilizers increases the effectiveness of water usage by increasing yield more than evapotranspiration. Raising soil nutrient levels may improve the efficiency of evapotranspiration and transpirational water usage. Aesthetically pleasing soils encourage quick ground cover growth, which reduces evaporation and improves evapo-transpirational water usage efficiency, as well as rapid leaf area expansion, which increases transpiration. Increased soil nutrient levels seem to have cumulative impacts on water usage effectiveness, and raising or optimizing yields via proper fertilizer application would boost agricultural plants' transpiration efficiency. Plants that have utilized fertilizers properly may also be more resistant to drought. Up to a certain point, increasing water supply also results in higher water usage efficiency. By improving the availability of applied nutrients, water supply has been shown to boost the effectiveness of fertilizer application. In reality, it has been shown that water and nutrients interact in terms of yield [6].

Typically have greater impacts than the combination of their separate effects. Gajri et al. very persuasively demonstrate that N treatment and early-post seeding irrigation in wheat increase profile water usage by increasing depth and density of roots as well as leaf area index and leaf area duration in thoroughly wetted coarse-textured soils with little organic matter. Better roots boost the plant's ability to collect water by expanding its water storage, but broader canopy with a longer lifespan raises the plant's need for water. Increasing canopy also results in an increase in the evapotranspiration's transpiration component. Hence, nitrogen application boosts water consumption efficiency in addition to evapotranspiration and transpiration/evapotranspiration ratios. Important management implications result from a significant interaction between N and water for yield, the dependency of water use efficiency on nitrogen rate, and the relationship between nitrogen use efficiency and water availability. When pre-sowing irrigation alone or pre-sowing irrigation with phosphorus application were applied to the wheat crop, respectively, as compared to control, water usage efficiency was also 119% and 150% greater. Farmers often have more control over fertilizer rates, thus they must be appropriately regulated in connection to the water resources available.

Many research found a correlation between soil nitrogen content and effective water utilization. Similar to this, adding phosphorus fertilizers boosts plant water availability by increasing root density and rooting depth. Phosphorus improves water usage efficiency and aids in crops performing at their best under moisture-restricted situations when it is used in a balanced soil fertility program. The transfer of water to other sections of the plant and the intake of water by the plant roots are greatly influenced by potassium. Potassium fertilizers have a direct role in the plant's water management since they minimize transpiration water loss. The use of potassium improves the water usage efficiency for the development of total dry matter in sandy soils. Rockstrom and Baron came to the additional conclusion that crop transpiration and yield connection demonstrate non-linearity under on-farm and low-yield situations based on the outcomes of a number of on-farm experiments in the savannahs prone to water constraint. On-farm yields may more than double with integrated soil and water management if dry period mitigation and enhanced soil fertility are prioritized. Most of the time, using enough fertilizers to boost yields will enhance water usage efficiency.

Usually, non-water elements such soil fertility and crop water productivity restrict yield and crop water productivity in instances when it is less than 40–50% of the potential. Yet, when yield levels are over 40–50% of their potential, yield increases are accompanied with a nearly equal rise in evapotranspiration; hence, as yields climb, incremental increases in water productivity decrease. For instance, increasing yields from 1 to 2 t ha-1 with relatively little quantities of water and fertilizer would result in far bigger improvements in water productivity than doubling yields from 4 to 8 t ha-1. So, before hitting the top limit, it seems that there is a lot of room for increasing production relative to evapotranspiration. The management approaches that create this heterogeneity are significant because they provide the prospect of potential improvements in the proportion between evapotranspiration and marketable yield. To guarantee sustained productivity in the intensive cropping system for the high productivity fields, balanced fertilizer usage should be promoted. This is because an absence of it might result in a rapid fall in yields and water use efficiency over time. The capacity of the soil to store water is increased by the addition of organic components, which enhances the plants' access to water [7].

Water production in times of Water Scarcity

In huge portions of Asia and Africa, severe water shortages and declining environmental quality are endangering the viability of agriculture. Better cultivars and agronomy are both required to boost agricultural output per unit of water. The difficulty is in controlling the crop or enhancing its genetic composition. Passioura discovered after analyzing a large dataset that the maximum water productivity for well-maintained water-limited cereal crops in the field is generally 20 kg ha-1 mm-1. If production is noticeably lower than this, it is probable that significant stressors other than water, such as malnutrition and illnesses, may manifest. Regrettably, there are no genetic changes that are expected to significantly increase water production. The focus is on little, timely watering and managing soil nutrients, both of which have been demonstrated to boost water usage efficiency by 10–25%. In rain-fed agriculture, soil fertility is often the limiting factor for higher yields. Due to inadequate rainfall penetration and plant water intake from weak roots, soil degradation via nutrient depletion and loss of organic matter results in substantial yield decrease that is tightly tied to water determinants.

Studies have also demonstrated that, up to a point, water supply and nitrogen may be replaced for one another to increase crop yields. Soil nutrient mining is especially serious in sub-Saharan Africa. Farmers in sub-Saharan Africa are depleting soil nutrients by engaging in intensive agriculture. During the last 30 years, Saharan Africa has lost nitrogen, phosphorus, and potassium at rates of 22, 2.5, 15 kg ha-1, and accordingly. This represents an annual fertilizer loss of US$ 4 billion. The outcome is meager harvests. Similar to this, participatory watershed management studies in more than 300 communities in India revealed that agricultural methods have significantly reduced soils of secondary nutrients like sulphur as well as micronutrients like zinc and boron. When both micronutrients and sufficient nitrogen and phosphorus were sprayed to a variety of rain-fed crops in farmers' fields, a significant boost in crop yields of 70-120% was attained. Investments in soil fertility thus immediately enhanced water management. The addition of boron, zinc, and sulphur boosted the productivity of rainwater by 70% to 100% for maize, peanut, mung bean, castor, and sorghum. Rainwater output was 1.50 to 1.75 times greater even in terms of financial rewards.

As compared to well controlled experimental locations, farmer fields have a lower water usage efficiency, which suggests that more work needs to be done to get farmers to use water-saving methods. Water-saving irrigation techniques, such as deficit irrigation, low pressure irrigation, subsurface drips, drip irrigation beneath plastic covers, furrow irrigation, rainwater harvesting, and conservation agriculture, would be very useful in such situations. Agriculture that conserves water comprises agricultural methods that can fully use irrigation systems and natural rainfall. It is preferable to optimize yield per unit of water rather than yield per unit of land if water is more constraining than land. In the areas of West Asia, North Africa, and northern China, limited or deficit irrigation is becoming a common practice. In rain-fed locations, supplemental irrigation, which combines dryland farming with restricted irrigation, is the best option for increasing crop yields. According to findings from a large-scale research conducted in India, supplementary irrigation water has the greatest marginal productivity. With better management, a single supplemental irrigation may enhance overall output by an average of 50%. Even at the national level, supplementary irrigation and water collection are economically feasible. When farmers have supplementary irrigation available to them, droughts have relatively little of an effect on their output. The crop uses more water when plant nutrients are more readily available, although the additional water usage is often minimal. A famous illustration is given by Carlson et al., who demonstrated that N fertilizers essentially quadrupled maize yields while only causing a 10% change in transpiration [8].

By switching to a more efficient irrigation system, the efficiency of on-farm water consumption may be increased even further. With correctly managed water conditions, the harvest index and water usage efficiency reach their maximum levels. In areas with limited water resources, micro irrigation has expanded quickly in recent years and has been used for a range of high-value crops. Traditional border or furrow irrigation techniques in northwest China need an annual average water demand of roughly 7,320 m3 ha-1, compared to just 3,250 m3 ha-1 for areas under micro irrigation. Subsurface drip irrigation for annual and perennial crops has likewise advanced from being a unique technique used by researchers to a widely established practice. A considerable rise in production and water usage efficiency has been seen in a variety of crops, according to Water Management Research Laboratory analyses of data collected over a 15-year period. When crops were cultivated in places with high water tables, the use of high-frequency irrigation decreased deep percolation and increased usage of water from shallow groundwater. Wheat yields in the Middle East were twice as high when subsurface irrigation was used instead of furrow irrigation. The efficiency of water usage varied from

N release from the soil was likewise much larger under subsurface irrigation than under furrow irrigation, ranging from 1.64 to 3.34 for subsoil irrigation and from 0.46 to 1.2 kg grain m-3 for furrow irrigation. Without sufficient water, nitrogen usage efficiency is still poor, which causes significant nitrogen losses. Lower water production and increased NO3-N leaching are consequences of having too much water. Low water productivity is caused by a shortage of N, yet too much of it reduces nitrogen usage efficiency and increases losses. While greater NO3-N leaching is a natural consequence of higher WP, its negative effects may be significantly minimized by controlling the amount and timing of nitrogen fertilizer and water application. Higher water productivity and decreased NO3-N leaching result from improved inorganic nitrogen and water management. Using fertilizers with a regulated or gradual release might further reduce the leaching of NO3-N.

Under paddy fields, Water Productivity

Lowland rice is grown by ivated irrigation on submerged soil. While planting transplanted rice, fields are flooded before to planting and puddled to decrease percolation. The daily losses are then made up by repeated watering. Moreover, rice may be planted directly by broadcasting pre-germinated seed on a moist soil surface, or by dry seeding following typical soil tillage and flooding after the seedlings have taken root. In terms of water usage efficiency, Bhuyian et al. demonstrated that wet-seeded rice cultivation, which uses less water, is superior to the conventional transplanted rice. Recent advances include the use of aerobic rice, the system of rice intensification technology, and drip irrigation and microsprinkler irrigation of rice fields.

Depending on the soil, climate, and hydrologic conditions, the total water intake for producing rice ranges from 700 to 5,300 mm, with 1,000 to 2,000 mm being a common amount for many lowland locations. The water productivity of lowland rice is substantially lower than that of wheat and maize, ranging from 0.2 to 1.2 kg m-3. Reduced large-scale wasteful water outflows during crop growth and enhanced rainwater use may both increase rice's water productivity. The floodwater depth may be reduced, the soil can be maintained near saturation, or alternating soaking and drying regimes can be used instead of maintaining a constant 5–10 cm of water in the rice field. By more efficiently using rainfall, dry-seeded rice technology presents a considerable possibility for irrigation water conservation. According to studies, keeping a field bund of 22 cm in height around rice fields has enabled paddy fields capture more than 95% of seasonal rainfall, reducing the requirement for irrigation. In comparison to wet-seeded and transplanted rice, dry-seeded rice dramatically boosted water production when it came to irrigation. Growing rice like an irrigated upland crop, like wheat or maize, is a novel way to reduce the amount of water required for the crop. The water savings potential of aerobic rice is significant, particularly in soils with high percolation rates when stress-tolerant cultivars are used. On a regional scale, postponing the transplanting of the rice to escape the oppressively hot summer season may save significant quantities of irrigation water. The government passed a law requiring all farmers to postpone paddy transplanting until June 15 in an effort to at least somewhat compensate for the rapidly declining water levels in the Indian Punjab. According to studies, this law really saved 2.18 billion m3 of water in real world savings.

Studies have also shown that the application of N to rice considerably boosted water productivity, which in turn increased grain production by increasing biomass and grain number. To increase water productivity in irrigation systems with a shallow water table, effective N management is just as crucial as water-saving irrigation. Fischer predicted that the increase in productivity would need over 300% more nitrogen than is now applied in irrigated areas, assuming the technologies that impact how well nutrients are used by the rice crop do not change. In both large-scale systems in developed countries and small-scale systems in developing countries, the key to optimizing trade-offs between yield, profit, and environmental protection is to achieve synchrony between N supply and crop demand without excess or deficiency under different moisture regimes. So, nitrogen fertilizer losses in water-intensive paddy fields are an indicator of an imbalance between the supply and demand for nitrogen rather than the primary factor influencing nitrogen efficiency. This presents a tremendous opportunity for better management of nitrogen and water resources [9].

River basins and big systems' Water Production

Water productivity concerns are more complicated at bigger regional or river basin sizes with more users and greater user engagement. Reducing non-productive water flow reduction and strengthening irrigation management Some of the techniques to increase water productivity at the basin level include facilities, reallocating, and co-managing water among users by allocating water to high-value uses and the outflows for the environment and downstream. The main ways to produce "new water" are to convert the consumptive fraction of current agricultural allocations to other uses, build desalination plants, and build more places to store excess floodwater. The widespread use of water-saving techniques, such as deficit irrigation, precision irrigation systems, improved soil moisture monitoring and management, and urban indoor and outdoor efficiency initiatives, has a significant potential to reduce water use across many basins. To find the chances for water savings, we need to have the right water accounting systems in place. Since each basin is unique, the combination of supply- and demand-side solutions will change depending on what is hydrologically, economically, socially, and politically feasible.

Recent assessments of water productivity in ten significant river basins in Asia, Africa, and South America, which represent a variety of agro-climatic and socioeconomic conditions, revealed that there was very high inter-basin and intra-basin variability, primarily due to a lack of inputs and subpar water and crop management. In the Asian basins, intensive farming results in substantially higher agricultural production and water productivity. In African basins, water productivity is much lower since most agriculture is subsistence-based. The principal crops' yields differ across and within basins. The yields of all three crops in the Yellow River basin are comparatively high. While the Indus-Ganges basins practice the most intense farming, both rice and wheat, which are the main sources of food and revenue, are often produced at very low yields.

All of the basins have significant intra-basin variability. In the Limpopo, the average yield of maize is 3.6 t ha-1. Whereas the enormous regions of subsistence farms, which are threatened by recurrent droughts and soil nutrient depletion, generate less than 2 t ha-1, the irrigated commercial farms with appropriate inputs of fertilizers and crop management produce as much as 9 t ha-1. The "bright spots" in the Indus-Ganges basin, the Indian states of Punjab and Haryana, produce more than twice as much as they would elsewhere. Similar to how crop management, fertilizer usage, and other inputs may be connected to variations in water productivity across various basins. The Yellow River has the best water production for maize, followed by the Mekong, while Limpopo has the lowest. More opportunities to narrow the performance gap between the top and bottom performers are suggested by increased regional variance in water production. Assessing the potential for improvement and identifying priority actions in underperforming regions would both benefit from an understanding of the causes of these discrepancies at the regional or water-basin scale [10].

Causes of Water Productivity Fluctuation

In addition to biophysical factors, the degree of socioeconomic development has a considerable influence on agriculture at the broad scale of a nation or river basin. The prevalence of poverty is often greater the more the agricultural sector contributes to the gross domestic product. As a result, farmers are less able to increase agricultural inputs, raise water productivity, and manage droughts and floods. The majority of the agriculture in the African basins is rain-fed, with subpar infrastructure, minimal fertilizer and irrigation inputs, and therefore low crop yields and low agricultural water productivity. For all locations, water stress is a deciding issue. In the majority of places, particularly in basins with a severe water shortage, water is an issue for agricultural production. Due to competition demand from other industries, water scarcity has been worse over time and will likely keep getting worse. Farmlands are susceptible to droughts and sometimes even floods since there are insufficient diversion and storage systems.

Better seed types, fertilizers, herbicides, and energy for tillage and other activities are key inputs for huge regions of poor productivity. Degradation of the land is often another important issue. To get around these restrictions and ensure increases in yield and water productivity, integrated management of soil, water, plants, and pests is necessary. The ecology is deteriorating and climate change are now posing additional dangers. Agriculture is nearly guaranteed to have a detrimental influence on the environment as it becomes more intensive. The need for environmental flows from the rivers is often disregarded in confined basins where there is a competitive demand for water. In the 1990s, the Yellow River stopped flowing toward the ocean. The Indus is another enclosed basin where groundwater and surface water are overused, resulting in considerable groundwater table decreases that pose a danger to intensive agriculture systems' viability. Water quality often becomes a big problem due to the limited amount of water still present in rivers and aquifers. According to a study conducted on the Yellow River in 2007, 34% of the river system had water quality levels below level V, which are deemed unsuitable for all forms of economic activity, including agriculture. Arsenic pollution of groundwater poses a serious danger in the lower reaches of the Ganges basin and is associated with excessive groundwater use. Water quality in regions with heavy irrigation is seriously threatened by nonpoint source contamination from agriculture, which is often coupled by excessive fertilizer inputs. Water resources and, as a result, water production are threatened by the drastically deteriorating water quality. Similar to this, agriculture, particularly rain-fed agriculture, will be increasingly sensitive to severe climate events brought on by climate change, such as shorter and more intense rainy seasons and longer and more intense dry seasons, which will affect agricultural water production. However more accurate evaluations of the effect of climate change on agricultural water yield are particularly required [11].

Increasing regional water productivity or basin water productivity

Growing the right crops in areas with high water productivity due to climate and management techniques and exporting them to areas with lower water productivity may result in significant increases in water productivity. Comparing the "bright areas" and "hot spots" on basin-level water productivity maps is a good way to find the yield gaps that are readily apparent. Remote sensing data on crop water production at the pixel level provide precise descriptions of the magnitude and fluctuation. The next phase is to evaluate the biophysical potential using regional analysis based on soil and solar radiation, and to investigate the use of water and fertilizer in combination with crop-genetic advancements. This strategy continues to be the key one for achieving the global objective of increased productivity and food security. Improved water management is a key component of the solutions for increased productivity. Poor farmers might increase their output if they have access to dependable, affordable irrigation coupled with the essential supplies [12].

CONCLUSION

The initial definition of "water-use efficiency" has significantly improved over the last 50 years to include "agricultural production" or "value per drop of water". It refers, in the widest sense, to the net socio-economic and environmental advantages brought about by the use of water in agriculture. A reliable indicator of an agricultural system's capacity to transform water into food is the more widely used notion of "water productivity" and its assessment at different scales. When water is in short supply in comparison to other production-related resources, increasing water productivity is especially crucial. Although water productivity rises as water availability increases up to by improving the availability of applied nutrients, water supply eventually increases the efficiency of fertilizer usage.

When the realm of interest expands beyond the crop-plant level to include fields, farms, systems, basins, regions, and the national level, the complexity of measures of physical or economic water productivity rises. Understanding that the water input to a field or agricultural system is different from the water utilized or depleted for crop production is crucial. This is because the water added to the system but not used is accessible downstream and is thus not included in the estimate. Together with more traditional approaches, the integration of crop modeling and remote-sensing satellite data has made it possible to more thoroughly map the differences in basin- or regional-level water productivity and pinpoint prospective hotspots for effective interventions.

The most effective method for increasing land and water productivity was to develop crop varieties with higher harvest indices during the Green Revolution period, but subsequent advances have slowed down. Now that food production has increased further, water use has increased almost proportionately as well, overusing water supplies in the productive regions. Instead, in the large low-productivity rain-fed regions, dry season mitigation and soil fertility management may be able to more than quadruple on-farm yields. Better roots brought on by fertilizer boosts a plant's ability to collect water by expanding its water storage and canopy along with longer-lasting increases in the plant's need for water. Fertilizer rates, which farmers have more control over, must be appropriately adjusted in proportion to the water resources available. Even under water-scarce situations, very low water production levels may be a sign that other significant pressures, such as inadequate nutrition and illnesses, are at play. Increased yields are often constrained by soil fertility in big rain-fed regions of sub-Saharan Africa. Optimizing trade-offs between yield, profit, and environmental protection in both large-scale systems in rich nations and small-scale systems in developing countries requires synchronizing nutrient supply and crop demand without excess or deficiency under different moisture regimes.

The problems with water production are more complicated at big river basin sizes because there are many different users and uses that interact with one another. Reallocating and co-managing the resources among the high-value applications while preserving a healthy environment are two options for increasing water production. To find the water-saving potential, proper water accounting methods must be implemented. Growing the right crops in areas with high water productivity due to climate and management techniques and exporting them to areas with lower water productivity may result in significant increases in water productivity. There is now a lot of room to improve economic water productivity by raising the value produced by water usage and lowering related expenses. Nevertheless, a number of important factors such as urbanization, diet and population changes, and fluctuating input and commodity prices will need quick system responses in order to capitalize on possible increases in water productivity.

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CHAPTER 4
WORLDWIDE APPROACH FOR SUSTAINABLE FERTILIZER MANAGEMENT

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ABSTRACT:

Including farmers and other stakeholders, nutrient stewardship is the efficient and effective use of plant nutrients to generate economic, social, and environmental advantages. In order to support sustainable agricultural intensification, nutrient stewardship strives to increase farmers' ability and help them and their advisors continually produce more food, feed, fiber, and energy with less nutrient losses. Concepts like balanced fertilization, site-specific nutrient management, enhanced placement, timing of treatments to match with plant nutrient demands, slow- and controlled-release and stabilized fertilizers, etc. are all included in the idea of nutrient stewardship. A crucial component of nutrient management is having access to information, the necessary fertilizers, and associated services.

KEYWORDS:

Agriculture, Fertilizer, Food Security, Management, Nutrients.

INTRODUCTION

The idea, the underlying scientific theories, and the application of 4R Nutrient Stewardship are all described in this chapter. As maize is a commonly produced crop worldwide and N is often the nutrient of greatest importance for good management in relation to agronomic, economic, social, and environmental factors, management of N on maize is utilized as the main example throughout the chapter. These concepts may be modified to apply to various crops and nutrients. A global framework for sustainable fertilizer management was developed and is now being used in many regions of the world thanks to the collaborative efforts of the International Plant Nutrition Institute, The Fertilizer Institute, the Canadian Fertilizer Institute, and the International Fertilizer Industry Association. In order to increase sustainability, "4R Nutrient Stewardship" offers a framework for utilizing the appropriate nutrient source, administered at the right rate, at the right time, and in the right location. It provides a comprehensive view of adaptive management of the life cycles of nutrients while taking into account the effectiveness of nutrient management strategies on the economic, social, and environmental fronts. The 4R framework takes into account the needs of all parties involved, including farmers, input providers, consumers of food, feed, fiber, and energy, as well as people who are concerned about the environment and the associated environmental services. Worldwide, it is being utilized to provide managerial advice, research, and educational initiatives [1].

The idea behind 4R nutrient stewardship

Four crucial aspects of nutrient management are the focus of 4R Nutrient Stewardship:

1. Select plant-available nutrient forms that provide a balanced supply of all necessary nutrients and release timing that is synchronized with crop needs.
2. Apply all limiting nutrients at the correct rate to satisfy plant needs in relation to production and quality objectives.

3. Application of nutrients should be timed to account for interactions between crop absorption, soil supply, environmental concerns, and logistical considerations for field operations.
4. The proper placement of nutrients should take into account root-soil dynamics, geographical heterogeneity within the field, and the potential to reduce nutrient losses from the field.

Moreover, 4R Nutrient Stewardship takes the site-specific economic, environmental, and social objectives into account when evaluating the agronomic elements of nutrient management. Using BMPs that maximize the efficiency and efficacy of fertilizer usage is necessary for 4R Nutrient Stewardship. In order to maximize productivity and reduce nitrogen losses from fields, fertilizer BMPs aim to balance nutrient delivery with crop demand. The ideal BMPs for a particular farm will take into account the local soil and climate conditions, crop type, management method, and other site-specific considerations. BMP selection varies by region. The expectations of all stakeholders may be - and are - brought together for consideration via the use of 4R Nutrient Stewardship [2].

Using scientific approaches to Manage Nutrients

4R a solid grasp of nutrient dynamics is the cornerstone of nutrient stewardship. These are some instances of how choosing source, rate, timing, and location combinations for nutrient treatments may be influenced by scientific concepts of soil fertility and plant nutrition.

Correct Source

The ideal source for a nutrient management system must provide a balanced supply of all necessary nutrient components in forms that plants may use throughout the growth season. The correct source must also take into account factors such as susceptibility to nutrient loss, possible nutritional sensitivity of crops, potential nutrient interactions or compatibility concerns, and danger from any non-nutrient components present in the source material. The correct source may change depending on the crop, the environment, the field's soil characteristics, the items that are available, economic factors, and application technique possibilities.

Supply possibilities for nitrogen include, among others, anhydrous ammonia, urea, urea ammonium nitrate solution, calcium ammonium nitrate, and ammonium nitrate. Diammonium phosphate, monoammonium phosphate, triple superphosphate, and single superphosphate are the most popular sources of phosphorus. Ammonium polyphosphate is a typical fluid form. The most prevalent form of potassium is potassium chloride, although it may also be found as potassium sulfate and potassium nitrate. Farmers have access to a variety of sulfur, magnesium, and calcium sources. Trace elements come in a broad spectrum of sulfates, oxides, and chelates, with varying levels of solubility and plant availability [3].

Moreover, a number of treatments and additives are sold to alter the nutrients' availability. These include items that physically enclose fertilizer components in a protective covering, break down gradually to release nutrients that plants may use, or chemically alter the pace at which the nutrients from the fertilizer materials are released. For slow- or controlled-release fertilizer ingredients, many choices are available. For instance, the NPK granule in Figure 2 has a polymer coating. Water may gently seep into the granule via this covering and breakdown the nutrients. The nutrients then gradually pass through the coating and into the soil solution, where the plant roots may get them. To control the rate of release of the nutrients as desired, the coating's type and thickness may be changed. The farmer's capacity to control the time and rate of nutrient delivery is greatly improved even if this formulation raises the cost of the fertilizer. The crop's nutrient availability can be better managed thanks to the regulated nutrient release, which also reduces environmental losses.

Such systems were formerly mostly utilized for high-value crops and grass, but in recent years, the development of lower-cost materials has allowed for new uses in commodity field crops. Because to their ability to replace split applications, controlled-release solutions are continuing to become more and more popular. This helps to alleviate manpower shortages, reduce environmental losses, and increase fertilizer usage efficiency.

While some are available for P, controlled-release solutions are often utilized to manage N release. Moreover, there are a variety of controlled-release micronutrient solutions whose coatings work to retain the nutrients in plant-available form by limiting interactions with soil minerals or organic matter or to avoid leaching from the soil. The ideal rate balances the plant's nutritional needs with the nutrients that are available to it from all sources. The first step in supplying the proper rate is to understand the nutritional requirements of the crop during the different development phases. To prevent fertilizer surplus or shortage, the application rate should be chosen to balance nutrient supply with crop demand during the growth season. A rate that is too low will limit crop output and quality, while a rate that is too high would harm crops and have a detrimental influence on the environment. Application of nutrients either in excess or insufficiently will reduce economic profitability [4].

Applying enough N to make sure it wasn't restricting was a popular technique for commercial farmers in the United States in the 1970s. In comparison to the cost of maize, the price of N was modest, and possible environmental effects were not given much thought. While treatment rates were set at 21 to 27 kg N t-1 of anticipated output, crop removal was only marginally greater than the existing range of 11 to 13 kilogram N per metric t of production. In comparison to the expense of applying too little N, the cost of applying too much N was comparatively modest. Recent price changes have made excessive application unprofitable. Crop nutrient usage has also been enhanced by improved management and superior genetics. Optimal N rates for maize are often lower now than they were before, showing improved N usage efficiency. Between 15 and 17 kg N t-1 are now applied on average for maize in the United States, demonstrating a significant increase in N usage efficiency over the previous decades.

A number of techniques may be used to establish the optimal rate for a crop. Start with rate studies from regions with comparable climatic conditions and soil types. Since they correlate findings with the farmer's own management, on-farm rate testing are particularly beneficial. Farmers and their advisors can design a rate program that is best suited to each field and management level by using contemporary rate controllers and yield monitors in conjunction with soil tests, plant analysis, crop sensors, and field scouting. The rate program can then be implemented on a site-specific, variable-rate basis to match the variability within each field. Such on-farm testing is crucial for assisting farmers in making educated choices about their fertilizer investment. Low-tech solutions, such as the International Rice Research Institute's leaf color chart for rice or tiny test zones within a field, may also be used to improve and site-specific N management. The main component of the comparisons is the measurement of crop yields in proportion to the nutrients applied.

The critical value is the point at which further yield response to extra nutrient delivery is not anticipated, and the optimal rate will feed nutrients slightly above that value. The expense of giving nutrients at a rate just slightly over the necessary level is often more than the economic loss of doing so. Greater concentrations of particular nutrients may cause opulent consumption and, in severe situations, crop poisoning. Since fertilizers are expensive, toxic application rates from fertilizers are often not monitored. Because of the additional fertilizer expenditures, possible production losses, and greater danger of nutrient losses to the environment, these higher levels should be avoided. All nitrogen sources, including soil supplies, manure and other organic sources, crop residues, biological N fixation, irrigation water, and air deposition, should be considered when determining the appropriate rate. Regarding rate, there are significant interactions to take into account. The appropriate rate of N, for instance, may rely on the quantity of P, K, or sulfur available since the best response from N relies on other nutrients not being limited. Studies of rate comparison have a significant role in choosing the appropriate rate. Rate studies should ideally be carried out on a farm while taking into account other management elements, such as fertilizer location, that may affect nutrient losses and, therefore, the rate of nutrient needed. Variable-rate fertilizer application may be used to regulate the spatial variation in nutrient demands within a field utilizing precision farming technologies. On a site-specific basis within the field, it is possible to adapt variable-rate treatment to different crop demands by taking into account variability in nutrient needs based on soil testing and yield potential variables.

Over the growing season, crop nutrient absorption rates alter as the crop progresses from emergence to vegetative development, through reproductive phases, and finally to maturity. A sufficient amount of nutrients that are accessible to plants must be present where the crop may get them in order to fulfill crop demand during the growing season. Nevertheless, if the nutrient is present in the soil for a long period before the crop absorbs it, it can travel beyond the rooting zone or change into forms that are inaccessible. Application of nutrients at the proper time will maximize nutrient retention and boost crop output. Split-application of N for maize is a nice illustration of fertilizer application timing dependent on crop development stage and nutrient demands. In the United States, spreading out the administration of N to maize across two or three distinct occasions often utilizing various application techniques and fertilizer sources is becoming a more and more common practice.

For instance, if past crop residues had high carbon to nitrogen ratios, a little quantity of nitrogen may be surface sprayed as urea or UAN solution in the autumn to encourage soil microorganisms and aid in the breakdown of such residues. After a supplementary side-dress or top-dress treatment to fine-tune the total N program based on in-season monitoring or specified total N rate plans, a second, pre-plant application employing banded anhydrous ammonia or UAN solution may then deliver the majority of the N demand. A few weeks after emergence, saving some N for a final application enables a more informed final decision on the total application rate based on a more precise yield goal, lowers the possibility of environmental losses, and makes use of precision technologies for varying the final application within fields. If more N is needed, some farmers may apply urea as a last top-dress application of nitrogen even later in the growing season using high-clearance machinery. In West Europe, where the growing season is lengthy and there is a high risk of nitrogen loss, farmers often apply three or four applications of nitrogen to winter wheat in order to match the dynamics of nitrogen absorption by wheat [5].

Application timing must also take into account the weather, other time-sensitive procedures, physical and logistical restrictions of fertilizer application, and synchronization with crop height. The crop should get enough readily accessible N from the nitrogen management strategy to satisfy its demands during each stage of development. Figures 4a and 4b show the phases of maize development as well as how much nitrogen the crop-in-growth needs for various plant sections. During early development, maize requires a little quantity of nitrogen, a big amount in the middle of the growing season, and less during later grain fill. It is crucial to have the majority of the overall N need satisfied and taken up into the maize plant at that point because as grain fill progresses after pollination, the roots become energy-starved and less able to take up N. Remobilizing N from lower leaves and other sources provides a large portion of the N required for the growing grain.

Yet, maintaining the health of the lower stalk and leaves to boost the availability of carbohydrates to the roots is one of the strategies to promote N absorption by the maize crop and improve N usage efficiency. After pollination, modern maize hybrids absorb more nitrogen from the soil than older hybrids. For plants to reach their maximum production potential, appropriate N supply in the latter stages of the growth season might be crucial. Several studies have shown that using a nitrification inhibitor and delaying the delivery of nitrogen may improve N uptake, yield, and nitrogen usage efficiency.

The timing of processes impacting nutrient losses from the soil must also be taken into account when applying nutrients. For nutrients that are mobile in the soil, like N, timing is more crucial than for elements that the soil retains, like P and K. There are many loss mechanisms in the case of N. In general, wetter circumstances result in more leaching and denitrification losses. Every crop that uses nitrogen should have it applied as soon as feasible before the point of fast crop absorption in order to meet the crop's growth demands while reducing potential environmental losses of nitrogen. When it comes to P and K, the majority of the nutrients will be maintained in the soil even during periods of severe rainfall that cause runoff, and the time of administration has no effect on crop absorption. Yet, if P surface treatments take place only a few days or weeks before a runoff event, they may have a significant impact on water quality. Applying N and P at the right time depends on the soil type, slope, and meteorological conditions in order to minimize environmental effects [6].

Crop susceptibility to certain nutrient deficits, which is often tied to soil conditions, is another factor for timing. If soils become waterlogged or if excessive precipitation or irrigation encourages the loss of mobile nutrients below the rooting zone, transient trace element shortages may develop. Specific timing of fertilizer treatment or unique application techniques may be necessary for crops that are susceptible to certain micronutrient deficits in order to avoid or remedy deficiencies. While soil studies for micronutrients are sometimes unreliable, plant analysis is frequently the best method for fine-tuning micronutrient rates. The proper placement of nutrients both vertically and horizontally ensures that plant roots can always take up enough of each nutrient throughout the growth season. Fertilizer may be positioned in relation to the expanding roots using placement techniques. Precision farming technology has recently made it feasible to fine-tune fertilizer administration by changing the pace of treatment throughout the field to account for soil test level fluctuation.

There are various alternatives for positioning in relation to the seed row and developing plant roots:

- Band application or surface broadcast.
- Fertilizer used in the beginning.
- A concentrated nutrition supply is provided lower in the root zone via deeper banding.
- Strip-till systems, which retain a mostly tilled surface residue environment to aid in reducing erosion and preserving soil moisture, concentrate nutrients in a band below the surface.

The qualities of the fertilizer substance being administered also determine the best location. For instance, anhydrous ammonia has to be injected deeply enough into the soil to encapsulate the gas and stop it from escaping into the atmosphere. The effects of putting various fertilizer sources in different places are shown in Figure 5. There is a chance that fertilizer applied to the soil's surface will be lost to surface drainage. Other materials, like urea or UAN solution, may be given topically, but if they aren't incorporated into the soil, they can result in significant losses via volatilization if there isn't enough rain or irrigation within a few days to get the fertilizer into the soil. A urease inhibitor may successfully employ surface treatments in zero or reduced tillage systems by reducing volatilization losses in urea and UAN solutions. Stabilized, slow- and controlled-release fertilizer products provide growers greater placement choices since they prevent nutrients applied to the soil's surface from evaporating for a few days to many months. Movable nutrients, like N or S, may travel via the water in the soil to the roots for absorption. Comparatively, less mobile nutrients like P and K will often only travel a short distance through soil profiles. Thus, roots must come into touch with the fertilizer reaction zone at the place of application for crops to acquire these nutrients. Particularly, placement in or close to the seed-row may promote early-season development by increasing crops' availability to the nutrient and creating a "starter" effect. In order to handle the geographic heterogeneity in nutrient requirements within the field, placement may also be employed. With the help of precision farming tools, fertilizers can be applied to individual fields on a site-specific basis, using variable rate application to match fertilizer applied to different crop nutrient needs identified by soil tests, yield maps, and other techniques for evaluating variability in yield potential [7].

The use of fertilizer has an impact on both the present crop and those to come. Figure 6 shows the long-term impact of various fertilizer distribution strategies for immobile or slowly mobile nutrients, such as P and K. As a consequence of repeated broadcast application, nutrients are uniformly distributed horizontally and are concentrated close to the soil surface. The vertical distribution depends on the depth of incorporation.

The nutrients progressively penetrate deeper into the root zone as they go down the soil profile. When a band is applied repeatedly in the same spot with controlled guidance, it forms a fixed band that tends to grow in size over time while remaining relatively stationary, creating zones of high and low concentration. Without controlled direction, band application produces a number of randomly positioned bands that, over time, resemble the impact of broadcast application.

It is sometimes possible to increase the absorption of nitrogen from fertilizer early in the growing season by concentrating the N close to the crop roots. Nevertheless, since N is mobile in soil solution and maize crop roots are widely dispersed, precise N placement is probably not crucial beyond the first several weeks of development. For crops that have a location is particularly important because of the restricted roots system. Susceptibility to N loss via runoff and volatilization may be influenced by placement.

The possibility for these losses may be considerably reduced by simply integrating the N into the soil by shallow injection or tillage, which will also increase the crop's ability to use it effectively. Similar to this, by delaying the conversion of ammonia to nitrate, placing an ammonia source or one that produces ammonia in a band may lessen the likelihood of loss due to denitrification or leaching. When fertilizer will stay in the soil for a lengthy period of time prior to crop uptake, such as with autumn application for a spring-seeded crop or with early spring application for a long-season crop, banding ammonium or ammonium-producing sources will be very crucial. Another area of economic and environmental concern is erosion losses. The movement of nutrients with soil ppapers and organic matter during soil erosion results in a loss of income for the farmer as well as a possible environmental issue. In order to reduce erosion losses and maintain the nutrients in the field for the crops, choices for 4R nutrient delivery must be aligned with tillage and crop residue management techniques.

Implementing good management of nutrients

Integrating crop management objectives with environmental goals

Sustainability objectives must be expressed in terms that crop system managers can understand since nutrients are handled as one of several sets of inputs within cropping systems. Cropping systems are operated practically for a variety of goals. Fertilizer best management practices should be chosen to accommodate farmers' agronomic and financial demands, while simultaneously minimizing nutrient losses that threaten the ecosystem and ecological services that other stakeholders want to be safeguarded. The BMPs that serve numerous stakeholder goals are the right ones. It may be challenging to explicitly link some crop management techniques to the social, environmental, and economic pillars of sustainability at the field level.

As a result, it is helpful to think of cropping system goals as the means of tying practices to sustainability. The system's aims change by location, industry, and often through time. They also rely on the contributions of many stakeholders, including farmers, consumers, rural inhabitants, and other people. Productivity, profitability, agricultural system durability, and environmental health are four frequent practical management goals at the field or farm level.

These practices also have an impact on the notion of soil health in general, which is linked to the agricultural system's long-term resilience and durability. The entire management strategy should take into account factors such as nutrient availability, water-holding capacity, structure, biological activity, and other factors to maintain and promote soil health. A bigger, interconnected set of nutrient, crop, soil, water, and farm management practices includes fertilizer BMPs. In order to fully meet the spectrum of farm-level management goals, a fertilizer management strategy must work in harmony with the other agronomic methods. These many goals must be taken into account during the construction, assessment, and improvement of fertilizer BMPs at the farm level, as well as during the choice of indicators that indicate their combined effect at various sizes, from the field to the global level. The following definitions and metrics apply to the previously specified set of agricultural system management goals at the field or farm level [8]:

Productivity

The main indicator of productivity in cropping systems is the yield per unit of farmland, per unit of time, and per unit of total inputs. The productivity metric includes the yield's quality. Via volume and value, respectively, both may have an impact on profitability. Consideration of productivity should be made in light of all the resources used. To effectively assess production, many efficiencies may and should be measured.

Profitability

The gap between the value and the cost of manufacturing determines profitability. Net profit per farmland area per hour is the main indicator. A management practice's effect on profitability is influenced by its economic efficiency, which is the rise in yield value relative to the practice's cost.

The farming system's resilience

Durability is the cropping system's capacity to sustain resource quality throughout time. In order for agricultural production systems to maintain or improve outputs over time without needing more inputs, a durable production system is one in which the quality and efficiency of the resources employed do not degrade with time. If improved crop production and photosynthesis result in a greater return of agricultural wastes to the soil, system durability may rise with effective management methods, especially on degraded soils. The organic matter content of the soil may rise with more residue return, improving soil health and production.

Health in the environment

By material losses to the air and water, crop production systems have a variety of repercussions on the nearby ecosystems. Local, national, continental, or global levels may be affected by these effects. Practices created to maximize resource usage efficiency may restrict or mitigate some impacts. Not all impacts are, however, subject to the same amount of control. Just a tiny portion of certain significant input losses, such those of P or nitrous oxide, have an impact on the ecosystem. Others, such ammonia volatilization or dinitrogen emission from denitrification, may cause significant losses, although they are mostly under control by taking profitability into account [9].

Adaptive leadership

In order to create a comprehensive production system, nutrient management practices especially N management are combined with other crop management techniques. Using the finest research currently available for optimizing the components of the system, including their interactions, is crucial when choosing fertilizer BMPs for a specific area. Stewardship of nutrients necessitates ongoing adjustment to the changing agricultural system in which it is used. To adapt to changing circumstances in the production system, an adaptive management method is needed for the development and deployment of fertilizer BMPs. Adaptive management is a continuous loop that reacts to the knowledge obtained through putting techniques into use and assessing them. The decision-making process is guided by the farmer's experience and information from academic institutions and business sources. Site factors and stakeholder inputs provide more data that should be taken into account.

The choice of which inputs and techniques are implemented or changed in the production system is ultimately made by the farmer. In the end, he or she is also accountable for the positive and negative effects on the economy, the environment, and regulations. Study of the results of these actions offers insight to modify management choices for further action. Decisions on nutrient supply, rate, timing, and placement are interrelated, and management goals will change depending on the environment, the goals of the farmer, and stakeholder feedback on the relative importance of the various system performance indicators. What is considered "correct" in terms of source, pace, time, and location will be greatly influenced by how important these goals are in relation to one another. To ensuring that the methods selected have the maximum probability of achieving the management goals, sound science is important.

It is crucial to take each practice's supply, pace, timing, and location of nutrients into account. Each of the 4Rs in respect to each practice often has a number of choices. Compares five distinct possibilities for P application using the maize-soybean cycle in the Lake Erie watershed in North America as an example. Techniques, demonstrating how the 4Rs may be combined, along with the respective benefits and restrictions of each combination. These comparative analyses provide the knowledge required to put 4R Nutrient Stewardship into practice. The 4R framework is concerned with specific strategies and how they work together to control nutrients in a cropping system.

Performance indicators that may be used to track advancements in sustainability improvement indicate the influence of these practices on the cropping system's economic, environmental, and social implications. Figure 8 shows the relationships between several potential performance indicators and the social, environmental, and economic aspects of sustainable production [10].

When used in conjunction with other agronomic and conservation practices, as part of an integrated system of crop management, the chosen fertilizer BMPs are most successful. Nutrient losses and decreased profitability from poorly managed fertilizer applications have the potential to harm both the water and the air. The same impacts might result from improper crop planting or tillage management. While making management modifications, it is crucial to take into account the whole system due to the complex interplay of many components. The performance indicators connected to sustainable fertilizer BMPs, the measures that were utilized to calculate them, and the sustainability objectives that were connected to each indicator. The interests of different stakeholders must be taken into account when ranking these and other sustainability indicators in terms of significance. The farmer, as was previously said, is the ultimate decision-maker and is responsible for the system's outcomes [11], [12].

CONCLUSION

Applying the correct source of nutrients at the right rate, at the right time, and in the right location is the goal of 4R Nutrient Stewardship. "Right" is described as a combination that enhances the cropping system's overall sustainability while taking economic, environmental, and social considerations into account. Science-based criteria educate and direct the selection of the ideal source, rate, location, and timing. Implementation requires a lot of expertise and is site- and crop-specific. The 4Rs have an impact on how well cropping systems operate when they work in harmony with other soil and crop management techniques. Its performance takes into account how effectively nutrients, water, and all other production inputs are used. A cycle of adaptive management makes sure that the cropping system's performance is always being improved by the management approaches you choose. The results in terms of an increase in the cropping system's performance should be shown and communicated using indicators that represent the economic, social, and environmental goals of various stakeholders.

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CHAPTER 5

USING GENETICALLY IMPROVED WATER AND NITROGEN SOURCES TO BOOST CROP YIELDS

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ABSTRACT:

Improvements in water and nitrogen usage "efficiencies" are often cited as significant cropping system goals for genetic modification. Efficiency may be examined in a variety of ways, but in contemporary agriculture, the most important correlation is the yield generated per unit of resource input. This study makes an effort to understand the intricate web of interrelated elements that govern the ratios and to pinpoint opportunities for agricultural plants' genetic modification to raise yields while reducing water or nitrogen input. In terms of the water usage ratio, it is almost difficult to reduce transpiration without negatively impacting photosynthetic, carbon inputs, and eventually yield due to the fundamental relationship between CO2 exchange and water vapor loss via stomata.

KEYWORDS:

Agriculture, Fertilizer, Food Security, Management, Nutrients.

INTRODUCTION

It has been discovered that stomata's reactions to significant vapor-pressure deficits vary genetically. In addition to improving the ratios of mass buildup to plant water loss, selection and refining of this characteristic may result in reduced transpiration rates at increased vapor-pressure deficits with little adverse effects on photosynthesis. Using plants that can be seeded in large densities and produce leaf canopies quickly may help reduce water loss by shading the soil. These characteristics would help to reduce soil evaporation and, under conditions of heavy off-season rainfall, would permit plant growth at times when there was more water available.

Crop plants' uptake of nitrogen and meristematic activity and growth are tightly correlated. While effective N absorption and conversions into proteins and nucleic acids are made possible by a high degree of control at the molecular level, there are limited prospects for improvement. Increasing the percentage of applied N fertilizers absorbed by the crop is a crucial characteristic for increasing the N usage ratio. Genetically altering individual genes will not effectively increase nitrate absorption because of the complexity of the feedback mechanisms regulating N transport in roots and the integration of feedback loops with plant-wide processes. Changes may be made practicable if done at the process level via plant breeding that keeps track of the effectiveness of the whole plant. The capacity for increased N storage resulting from parallel alterations may influence increased N intake. N that has been stored must exist in molecular forms that do not cause feedback reactions. Enhancing early plant development to better match growth with fertilizer applications, increasing root densities deeper in the soil horizon, and maintaining root growth and N absorption longer in the reproductive phase are further approaches for boosting N uptake [1].

Increasing production is the main objective of agricultural plant genetic modification. Higher yields were often achieved in the past by giving an abundance of resources to reduce barriers to yield potential. The use of input resources must now be optimized due to rising economic and environmental consequences. The two key resources in question are nitrogen fertilizer and water. How can water and nitrogen consumption by agricultural plants be improved while still increasing production and financial return is a crucial topic confronting all of agriculture? In cases when inputs of water or nitrogen are limited, the goal of this chapter is to investigate physiological changes in agricultural plants that may sustain or boost crop yields. While "water use efficiency" and "nitrogen use efficiency" have been employed with many different meanings, the real objective must be to increase output while reducing water or nitrogen inputs. Such a "resource usage ratio" prioritizes yield, the economic outcome that farmers ultimately need.

The fact that neither the numerator nor the denominator for each ratio is a straightforward genetic attribute presents a significant obstacle in the effort to genetically enhance the water or nitrogen usage ratio. There is regulation at the process level. It is doubtful that water and nitrogen utilization ratios may be altered through straightforward genetic modification due to the involvement of a variety of physiological systems. Every genetic alteration must also be adaptable to a variety of environmental settings since the regulating plant systems are greatly impacted by the environment. Higher plants' physiological systems that regulate their consumption of water and nitrogen are closely linked to how the whole plant works. Over millions of years, plants have developed in situations where water and nitrogen are often scarce. It should come as no surprise that the mechanisms governing the extraction of the two resources from the soil are carefully calibrated to assure both survival and competition. Also, as a consequence of natural selection, the governing mechanisms are a part of intricate networks of redundant components and feedback loops. Finding physiological flaws in contemporary germplasm that can be fixed to increase water and nitrogen utilization ratios is in fact a difficult task [2].

The management of water and nitrogen consumption ratios in agricultural plants is covered in this chapter, and we make an effort to pinpoint tactics that might be used to boost overall plant development and production. The debate supports claims that regulating systems are too intricate and intricately woven into plant activity for individual gene targeting and conventional molecular modifications to be successful. To a certain extent, several enhancements of using plant breeding and manipulations at the entire plant level, it is possible to get insight into the mechanisms governing the utilization of nitrogen and water.

Usage of Water

Stomata opening to enable carbon dioxide to seep into leaves for photosynthesis results in water loss from leaves. Higher plants go through this physical process, and there is no genetic way to stop the inevitable loss of water while acquiring carbon. The water usage ratio at the leaf level is defined by the progression of equations that follows. The gradient of CO2 from the atmosphere to the interior of the leaf and the gaseous conductance of CO2 into leaves are used to characterize carbon acquisition. Throughout a growing season, the value of Ca remains generally constant, but there is no denying that it is rising as a result of human-caused CO2 emissions into the atmosphere. The transport characteristics of CO2 and water vapor molecules in air determine the value of the ratio hc/hw. The ratio hc/hw is around 0.64 in the still air of the stomatal pore, which accounts for a large portion of the physical restriction on gas conductance.

The addition of the precursor phosphoenol pyruvate pathway to photosynthesis to produce a low Ci is an apparent strategy to boost A/TL for C3 species. This strategy, nevertheless, has been demonstrated to be exceedingly difficult to change in plants. Harold Brown and colleagues investigated C3 and C4 activity in interspecific hybrids and closely related Panicum species. The whole set of C4 morphological and biochemical features seems to be required to exhibit C4 activity, which was not the case in interspecific hybrids. Photosynthetic rates very slightly increased in transgenic rice plants that generated manyfold more of the crucial C4 enzyme phosphoenol pyruvate carboxylase in their leaves.

Vapor pressure deficit is a word used in biology that doesn't seem to be susceptible to genetic modification. Recent research suggests that limiting transpiration rates in hot weather might reduce the amount of energy that plants feel. This characteristic often manifests as noon reductions in stomatal conductance, which restricts the contribution of transpiration at this time to the overall day transpiration. As a consequence, a higher percentage of gas exchange takes place when it is not under high pressure, and everyday gas exchange has a lower effective rate. Consequently, a midday reduction in stomatal closure would be enhanced by plant traits, increasing A/TL. The issue, of course, is that midday drops in stomatal conductance lead to reduce A and, depending on how much it happens, might eventually lead to a drop in crop production [3].

By reducing the amount of fat or protein produced, especially in the seeds, the value of the mass conversion coefficient "b" for a certain genotype within a species might be increased. The challenge with this strategy is that a grain's economic worth is mostly determined by the fat and protein content of the seeds.

For instance, the amount of protein in wheat grain greatly influences its quality. Both the fat and protein composition of soybean seeds affect their value. It is improbable that the seeds' economic worth can be compromised in order to change the transpiration ratio. Again emphasizing the importance of in determining the transpiration ratio is the canopy transpiration use ratio as described in Eqn. As was previously said, high canopy transpiration usage ratios are a consequence of low effective environmental conditions or plant characteristics. Reduced stomatal conductance and reduced CO2 assimilation are probably the trade-offs necessary to obtain a lower effective while trying to control transpiration at high.

DISCUSSION

Improvement of transpiration water usage ratio via genetics

The study presented above does not suggest to a specific "attack point" for boosting the transpiration water usage ratio. If selection pressure has already been exerted in creating genotypes, the important factors of its component plant products are not likely to be subject to significant modification. Any species already exposed to breeding pressure for commercial output is likely to have rejected any individuals with poor photosynthetic activity, i.e. low, and unattractive grain composition.

A plant variable that may be improved is the upper limit for gas exchange that plants will tolerate. Some crop species, including soybean, peanut, and sorghum, have genotypes that restrict gas exchange under high temperatures. Water conservation is this trait's main advantage. Although reduced gas exchange at high temperatures will lead to a reduction in photosynthetic activity, the ability to store water for use later in the season often leads to an increase in yield, especially if drought conditions develop. Limiting transpiration rate to a maximum value under high led to a yield improvement in roughly 75% of the growing seasons in simulated tests of this characteristic for sorghum in Australia. Simulations showed a yield gain for soybeans in the US in 80 to 85% of the growing seasons [4]. The most straightforward way to increase the evapotranspiration water usage ratio, it turns out, is to reduce the amount of water that evaporates from the soil surface. This ratio is based on all the water that is accessible to the crop. In other words, any technique to reduce soil evaporation would result in a higher total water usage ratio from evapotranspiration. Plant genetic modifications that enable early planting under low and quick leaf canopy growth to shade the soil surface may help reduce E. Moreover, plants that retain high yields when planted in close-cropped rows or at high plant densities will cause the soil surface to shade early and produce less E.

Using Nitrogen

The crucial resource that often controls plant development rates and restricts agricultural yields is nitrogen. Crop yields may be increased and N losses and groundwater pollution may be prevented through plant modifications that boost plant growth per unit of applied N fertilizer. Improvements have been made via plant breeding as a result of years of work identifying and seeking to change the important N components of cropping systems. The question of "What more alterations may be performed in plants to advance the nitrogen usage ratio" might be asked since the advances have not been significant

The process of absorbing and assimilating nitrogen

There are several intricate steps involved in the whole plant route for digestion of N. Generally speaking, the process starts with absorption by the root system, is followed by transport via the root symplasm to the xylem, long-distance transport with the flow of water to mature leaves in the shoot, and assimilation into amino acids. The amino acids may either be converted to protein in the mature leaves or transferred by the phloem to the meristems where they are converted to proteins and nucleic acids, the basic building blocks regulating DNA replication and cell division. The main event in the growth process is, of course, cell division, or meristematic activity [5].

The link between nitrogen uptake from the soil and plant mass accumulation has been frequently shown over the years in models depicting complete plant growth responses. N uptake is the "pacemaker," as Clarkson noted, of the growth process. Plant manipulations that promote N acquisition from the soil are essential components of effective techniques for increasing the N usage ratio in crop systems. Theoretically, boosting root growth, the N absorption surface, and increasing uptake per unit of root might all lead to improvements in inorganic N uptake. All kinds of adjustments are intricate and need taking into account both temporal and geographical considerations. Prior to or during the first phases of plant growth, and most definitely during the initial stages of root system development, fertilizer is given to cropping systems. If there is a lot of rain shortly after planting, a lot of the nitrogen may be leached from the soil profile, making it inaccessible to the plant and polluting soil water sources. Hence, improvements in seedling and early vegetative development will be necessary, at least in part, to increase root competition for inorganic N. Indeed, the size of the root system is significant, but so is the natural activity of each individual root. For instance, finer later roots quickly carry absorbed N to the shoot, supplying the N supply that fuels the shoots' fast development.

Crop plants often develop root densities in the topsoil layers that are many times higher than the 1.0 to 1.5 cm cm-3 needed to access N in the soil solution after they have entered the vegetative growth phase. The high solubility of nitrate in the soil solution causes the need for a relatively low root length density threshold. The primary inorganic N molecule in agronomic systems is nitrate, which quickly diffuses to root surfaces through ion diffusion in the solution and mass flow to the roots when water is drawn from the soil. Although the high solubility of nitrate, root length densities at deeper depths in the soil horizon might often be substantially lower than the minimal threshold for N uptake. This is especially relevant when acid soil aluminum toxicity or a hard pan are limiting downward root growth [6]. It is fair to assume that root morphological growth places absorbing surfaces close to soil nitrate and that genetic alteration of absorption pathways might enhance nitrate uptake. Yet, is there proof that this strategy can work? Via the plasma membrane of root cells, most likely epidermal or outer cortical cells at the root periphery, N is taken up from the soil solution. In the roots, there are at least two mechanisms for nitrate absorption: a low-affinity system where nitrate uptake rises linearly with rising solution N concentrations, and a high-affinity pathway that saturates at external nitrate concentrations below 1,000 M. The routes' potential for absorption is often far greater than the quantity of N that roots actually absorb in situ. The plant tightly controls the actual uptake rates, and both the high-affinity and low-affinity routes are susceptible to feedback regulation.

For the absorption of nitrate and ammonium, feedback regulatory mechanisms are present. The feedback effects may come from signals connected to the ions themselves as well as from amino acid intermediates in the N assimilation route, according to evidence from a large number of transport studies. In response to internal or external influences that influence the development process and the "demand" for N above or below ground, feedback regulation is engaged or released to various degrees. Shoot-based stimuli may activate feedback mechanisms that regulate N intake by cycling amino acids from the shoot to the root.

A second transport phase, N loading into the xylem, affects feedback regulation of inorganic N absorption into the root. The bulk of the nitrate goes inside via a sequence of cortical cells to the stele after being absorbed by cells at the root periphery. Here, the ions cross another membrane and are loaded into mature xylem arteries. Years ago, several studies revealed that the control of xylem transport is distinct from root absorption. In rare cases, declines in uptake may be caused by control of transit into the xylem. Experiments with plants under phosphorus and sulfur stress provide an excellent illustration. Nitrate and amino acids start to build up in the root in the very early stages of phosphorus and sulfur shortages. Shortly after, nitrate absorption starts to drop. The response suggests that the ultra-sensitive xylem transport phase is the catalyst for engaging feedback effects on absorption since it happens before noticeable changes in energy or root development. The "coordinated control" of the nutrient transport systems is a key element in ensuring that the nutritional content of developing plants remains constant [7].

Events that take place during the twilight period of the diurnal cycle provide further proof of the significance of xylem transport control. Although though the rate of nitrate absorption by the root is somewhat slower when it is dark, a far higher percentage of ingested nitrate is maintained in the root. Inhibition of the xylem transport mechanism controls retention in the root, and the inhibition is unaffected by drops in water flow. The complex control of xylem N transport involves stomatal opening and closing as well as water movement through the plant. Separate circadian cycles that are maintained in synch by the periodicity of light in the aerial environment regulate coordination. As a consequence, nitrate supply to leaves is increased in the light, when biochemical circumstances are most conducive to absorption energetically.

Changing Nitrate Assimilations Biochemically

The physiology and biochemistry of N uptake by higher plants have been extensively studied in study. Increasing N consumption and plant development has been thought to involve a basic metabolic strategy at times. Yet, it is very debatable whether changes to the N absorption route will lead to faster development. Conceptually, the fact that enzymes that promote biochemical activity are reaction-specific and that assimilation systems normally prevent the unnecessary use of N as a consequence of millions of years of evolution present a dilemma. Crop plants' uptake of nitrate has 'feed forward' and 'feedback' control features when evaluated within a biochemical framework. The inducible uptake systems acting at root cell membranes are the first of the feed-forward components, which then progress to the partial or complete induction of a number of enzymes in the assimilation route. Similar to uptake, assimilation's following enzymatic components are subject to feedback control.

For the majority of agricultural plants, leaves serve as the principal location of nitrate reduction and subsequent absorption. Years ago, it was shown that nitrate transport to the shoot and leaf assimilation are closely related. The most important finding was that, despite rather steady leaf nitrate contents, nitrate supply stoppage caused a sharp reduction in nitrate reductase activity. This suggested nitrate reductase had a high turnover rate, the majority of the nitrate in leaf tissues was isolated, and nitrate reductase induction was dependent on fresh nitrate from the xylem.

The presence of unassimilated nitrate in plant tissues is one of the misleading characteristics of nitrate absorption in plants. One may get the conclusion that nitrate reductase restricts nitrate absorption if the situation were purely biological. However as shown by the studies of Shaner and Boyer, nitrate is compartmentalized, most likely in vacuoles. Hence, competition between nitrate binding by the nitrate reductase enzyme and tonoplast transporters is likely what causes buildup of unassimilated nitrate. Nitrate from the vacuole may become accessible for reduction, however it is very slowly released. According to the release profile, stored nitrate acts as a reserve pool that may support or "buffer" N-dependent plant functions at times when N is in short supply.

Similar to leaves, the root system couples nitrate absorption into root cells with reduction, and some of the nitrate entering into storage pools. At least in this instance, nitrate compartmentation in the root is linked to nitrate reductase localisation in outer, peripheral cells and nitrate buildup in cortical cells that are closer to the core of the root. A part of the incoming nitrate is decreased after absorption into cells at the root periphery, while the majority of the nitrate transits via the root cortex and stele to the xylem. Evidently, the symplastic process isolates nitrate. From the bulk cytosols, stopping the process of nitrate reductase induction and reduction in the process. Although nitrate absorption and compartmentation both take place, most species' roots primarily transfer nitrate to the shoot.

It is clear that N assimilation is a very effective, high throughput process when looking at entire plant nitrate assimilation events on daily time intervals. The fine-tuning of biochemical elements prevents the buildup of intermediates and speeds up the processes that lead to the creation of proteins and DNA. The bulk of nitrate is translocated, absorbed, and integrated into macromolecule end-products in leaves within hours after absorption, despite the translocation delay that results from nitrate retention in the root under darkness. In fact, 15N tests show that within 12–24 hours, 80–85% of the N ingested by plants is converted to protein.

The excessive accumulations of certain amino acids that can place under stressful situations shouldn't cause confusion. Proline, for instance, may sometimes build up in leaf tissues when there is a water stress. Arginine may also build up when there is a phosphorus shortage. Nonetheless, in both situations, accumulations are quantitatively insignificant when represented as a proportion of the N absorbed and do not significantly divert the N supply to meristems. Along with the numerous other pressures that obstruct plant development, the primary plant reaction to water and phosphorus constraints is to limit N absorption.

Increased expression of certain enzymes in the N synthesis pathways has almost never had an impact on plant performance as a whole. This idea may be shown using a variety of instances. The overexpression of nitrate reductase by molecular genetic modification is one of the more convincing instances. Growth was not boosted even though higher nitrate reductase expression resulted in lower tissue nitrate concentrations. These initiatives came after years of work utilizing plant breeding to boost nitrate reductase activity, which had the same outcome.

Growth and yield were not correlated with higher nitrate reductase activities. Overexpression of asparagine synthetase genes produced some encouraging results, although growth advantages were only seen at low solution N concentrations. This finding is not applicable to cropping conditions when crops must absorb high quantities of N to promote fast development and satisfy the requirements of the harvestable plant material. Similar to this, under conditions of low fertility, transgenic canola plants that had alanine aminotransferase overexpression and increased alanine buildup in roots generated more plant mass. There were no variations in plant mass or seed output under more pertinent circumstances of increased N supply. Another instance comes from research on transgenic wheat, where it was discovered that cytosolic glutamine synthetase levels were elevated during leaf senescence and that this seemed to boost grain output of certain plants in a greenhouse. Nevertheless, there has been little evidence to support either the hypothesised mechanism of greater mobilization of N from senescent leaves of the transgenic plant or the effect's occurrence in the field.

Changes to carbon storage and assimilation

Increasing photosynthesis and the overall quantity of C in the plant may also help to enhance the N usage ratio. Plant growth divided by the total quantity of N collected by the plant has traditionally been used to determine the N usage ratio at the plant level. As a result, the ratio G/Naccum seems to be positively associated with G, or the rate of CO2 uptake at the leaf level. Most of the nitrogen in leaves is in the photosynthetic enzyme ribulose 1,5-bisphosphate carboxylase/oxygenase at any one time throughout plant growth. For instance, the percentage of total leaf N in RuBisco is around 25% in wheat and rice whereas it is almost 50% in soybean. A nonlinear link between leaf N and leaf photosynthesis rate that seems to be well characterized for each crop species is one effect of the high levels of N in the photosynthetic apparatus. As leaf N rises, there is a decreasing return in increasing A, eventually nearing a maximum rate of A.

Improvement of nitrogen use ratio by genetics

Given the discussion above, we are unable to identify a gene, or even a set of genes, that might be used as prospective targets for genetic engineering to increase growth or yield in field settings. This puts us at conflict with the movement to increase N utilization via the use of molecular biology techniques. Many indications suggest that enhanced acquisition of N is required for raising the N usage ratio, however molecular investigations to discover and overexpress nitrate transporters in roots is not expected to be fruitful . In our opinion, genetically altering individual genes will not effectively increase nitrate absorption due to the complexity of the feedback system in roots and its interaction with processes in the whole plant. Simply said, there are just too many points of interaction with regulatory functions throughout the whole plant, and downstream impacts might invalidate ostensibly favorable changes and have detrimental implications on plant performance.

Techniques for genetic modification

We do believe that plant breeding may help achieve certain genetic advances. The benefit is choosing features that are incorporated into whole-plant responses. It is more likely for manipulation to be effective if changes are made at the process level and their effects on plant performance are continually assessed. Given the relationship between crop growth and its nitrogen driver, any improvements in crop growth and yield in the field environment, even those under unfavorable circumstances like drought, are likely to be followed by an increase in the absorption of applied fertilizer N. Increasing seedling vigor and development in the early vegetative phase is one aim that is very appealing. This will schedule the administration of N fertilizer to coincide with the growth of the roots and the plant's need for N. Enhancing early growth potential and making management changes to place fertilizer properly would increase absorption of applied N fertilizer and reduce environmental losses.

CONCLUSION

Genetic alterations that alter root architecture to promote development deeper into the soil might allow for improved recovery of nitrate migrating there. To overcome chemical or physical impediments in the soil horizon, deeper root development may then rely on genetic alterations. Only with more N storage that doesn't activate feedback effects may N acquisition rates rise beyond those necessary for growth. Increases in N-containing macromolecules like Rubisco are necessary for this. Instead, it could include creating or boosting levels of glycoproteins, similar to those seen in the leaf paraveinal cells of certain legumes. If attempts to improve storage rely on significant nitrate or amino acid accumulations, they are unlikely to be effective. Vacuolar storage capacity is limited, and feedback inhibition of transport pathways is a possibility. If N storage and/or Rubisco stability are improved, NHI increases may be effective. Increased functional N in leaves prolongs photosynthetic activity and balances senescence-causing activities such protein breakdown and N transfer to grains. The'stay green' feature, corresponding to the stabilization of N proteins and N containing macromolecules, would benefit from more upright leaves and improved light penetration into ever-diminishing leaf canopies. Increased glucose transport to the root system and an extension of the period of active root development and activity would also go hand in hand with prolonging photosynthesis further into grain filling. This might therefore boost the uptake of nitrate that is present in the soil at the end of the crop growth season. More N absorbed during grain fill would help balance out leaf degradation losses and, maybe, enable NHI to rise concurrently with NHI.

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CHAPTER 6

CROP PRODUCTION AND EFFECTIVE UTILIZATION OF NUTRIENTS AND WATER IN HUMID & SUB HUMID ENVIRONMENTS

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ABSTRACT:

As this chapter emphasizes, there is a critical need to increase the effectiveness of water and fertilizer usage by agriculture in humid and subhumid locations. According to recent studies, rain-fed production methods, which are the most prevalent in humid and subhumid regions, are responsible for 75% of agricultural water demand. In order to create the most effective cropping system overall, it is helpful to consider how to maximize the efficiency of water inputs, whether they come from irrigation or natural sources. The most effective cropping strategy, however, frequently maximizes crop yield per unit of land rather than necessarily per unit of water in humid and subhumid regions of the globe. To attain high yields, optimizing production requires the planned and effective use of fertilizers.

KEYWORDS:

Agriculture, Fertilizer, Food Security, Management, Nutrients.

INTRODUCTION

In these situations, strategies that reduce yield in favor of preventing complete loss due to drought are often not encouraged since it is difficult to forecast the severity and length of moisture stress, nor is the onset of drought. In contrast to irrigated production, there is tremendous room for improvement in the use of water in rain-fed systems. Fertilizer input to boost crop yield is one of the most crucial variables to obtaining greater water usage efficiency for many crops in humid and subhumid zones. We contend that there are numerous cropping systems around the world where it is possible to improve the management of fertilizers and, consequently, water use. Some of these opportunities include: 1) better coordination between crop demand and fertilizer supply; 2) increased use of banding nutrients to increase availability through positioning; 3) addressing spatial and temporal variability in nutrient needs; 4) more effective capture and use of rainfall; and 5) supplemental irrigation [1].

Categorization of the climate, plant growth, and water usage

There are various methods to categorize climate at increasingly precise scales thanks to modern huge climate datasets and strong geographic information system technologies. However Köppen or modified variants of it continue to be the most used system. It was clearly known by 1875 that climates could be categorized based on the kind of flora or physiological reaction they generated. The initial categorization developed by Köppen was based only on temperature and the duration that temperature was over a certain threshold. His approach understood that droughts often affected the plants in subtropical and temperate regions with hot summers. According to him, high temperatures in these belts generally occurred in the summer with limited cloud cover and rainfall, and only slightly harmed plants by increasing evaporation. As a result, there was a distinct divide between the northern woodland zone and the deserts or steppes in continental regions due to the strong relationship between heat and water scarcity. The monsoon regions of South and East Asia, the southernmost tip of North America, and

Brazil are just a few examples of the subtropical and hot summer climatic belts where heat and heavy humidity may coexist. The tropical belt was likewise defined for a significant portion of the year by this same mix of heat and excessive humidity. His second map of the planet showed temperature and precipitation, two climatic traits that are both simple to measure and for which there are extensive historical data. The primary climatic zones, according to Köppen, are: sub-arctic climate, tropical rain climate, dry climate, mild temperate climate, and snow climate. Hence, we have long known that crop development is influenced by temperature, water, rainfall, and humidity. An aridity index has served as the foundation for later empirical climatic categorization schemes like those proposed by Thornthwaite.

Non-irrigated agriculture has historically been the standard in humid and subhumid zones since these regions often get enough precipitation to sustain crop growth for the most of the year. Based on yearly precipitation and potential evapotranspiration, the United Nations Conference on Desertification established a simple yet effective approach that may be used to roughly define these zones. By dividing the yearly precipitation by the annual PET, this method delineates an area. These ratios have been used as a broad framework for categorizing various geographical areas, however it is important to keep in mind that Pr, soil water storage patterns, and growing season duration all vary significantly across sites belonging to the same PrPET-1 classification. Cropping technologies have been created to accommodate seasonal patterns of rainfall and steer clear of projected extended droughts. Precipitation is often low and sporadic in dry climate zones, and other environmental stressors, including high temperatures, are frequent. High radiation levels are another characteristic of these climates that persist throughout the growth season. In such areas, crop transpiration and free water are virtually always factors that influence production. The relationship between transpiration and production of individual leaves, individual plants cultivated in containers, and field crops was carefully examined and evaluated by de Wit in 1958. As seen by Equations 1 and 2, he was the first to recognize the significance of potential evapotranspiration in understanding yield and transpiration relations in dry zones and radiation in humid zones [2].

These findings imply that alternative agricultural production tactics may be necessary depending on the environment. Production in arid climates is restricted by T rather than net assimilation rate since Pr is often low in these environments. While irrigation might seem to enhance T and hence biomass production, WUE actually decreases since evaporation also rises, especially in poor fertility situations or in any other situation where direct soil evaporation predominates and the canopy is not completely closed. A limits output in humid and subhumid conditions, although T may easily reach its maximum since Pr is often greater than or equal to PET. As either the C3 or C4 photosynthetic processes cannot significantly raise A, boosting light harvesting would seem more sensible to explore in this scenario. Increasing the leaf area index, leaf area duration, leaf erectness, and canopy closure may all fit within this category. In the middle to end of the 20th century, different models, such as the Bierhuizen and Slatyer model, were created to explain the relationship between net photosynthesis and transpiration and T efficiency. According to the atmospheric CO2 concentration, the CO2 compensation point, and the border and stomatal resistances to CO2 diffusion, these authors estimated net photosynthesis per leaf area. The border and stomatal resistances to water vapor were reduced by air density and atmospheric pressure, and transpiration was linked to vapor pressure deficit.

Efficiency of fertilizer and water consumption in humid and subhumid zones as of right now. To accomplish sustainable agricultural output, it is vital to create smart resource management systems that optimize the effective use of water and nutrients. In many nations, a lack of water is a significant barrier to efficient crop nutrient absorption and utilization, while nutrients are often the biggest constraint on water productivity in humid regions. Statistics from Zimbabwe from 1979 to 1997 reveal a similar link between national GDP and rainfall variability, demonstrating a significant degree of reliance between the two elements and emphasizing the danger posed by changes in the world's climate. In fact, the various ways that water affects the conversion of nutrients from unavailable to available forms, the transportation of nutrients to the roots of plants, and nutrient loss processes through erosion and leaching with drainage account for the strong interaction between water and crop nutrient availability. The effectiveness of fertilizer usage by plants in subhumid locations is greatly influenced by rainfall, and fertilizer, particularly nitrogen response, is severely restricted during agricultural dry months. Hence, it is crucial to manage water restrictions in subhumid zones together with soil nutrient constraints. This is significant because expenditures in water management may not alone provide the returns necessary to justify the expense. In a recent research, Zougmore et al. shown that in order to provide the economic advantages required to make efforts in water harvesting profitable, investment in water management needs a concurrent investment in soil fertility management [3].

In humid areas, fertilizer availability typically restricts water usage efficiency. In these situations, limiting nitrogen losses via leaching and erosion may assist increase production per unit of fertilizer input. This is accomplished by managing drainage and runoff. According to Brouder and Volenec, management and crop improvement will be necessary to reduce any possible detrimental impacts of climate change on nutrient and water usage efficiency. These effects are likely to be plant- and site-specific. They predict that this trend will persist in regions and for crops where fertilizer and water usage efficiency are already well-managed. Climate change will make issues worse in places or systems where water and nutrients are not used well or efficiently. By the application of fertilizer best management techniques that boost crop output, there is a huge possibility to improve water consumption in rain-fed systems. We propose that potential to enhance fertilizer and water usage in many cropping systems exist via site-specific nutrient management and use of best management practices. Fertilization methods and enhanced banding of nutrients to handle geographical and temporal variations in nutrient demands, improve availability of nutrients via placement [4].

The most effective overall cropping system is often achieved by controlling crops to optimize the efficiency of water input, whether natural or irrigated. The most effective cropping strategy, however, frequently maximizes crop yield per unit of land rather than necessarily per unit of water in humid and subhumid climate zones. Although ET is below P throughout the most of the growing season in these places, water stress in fall-seeded crops is often uncommon. Water stress may happen at any point from emergence through maturity, with different severity, in spring and summer crops because it is often intermittent in time course and duration. In these conditions, strategies that reduce yield in favor of preventing complete loss due to drought are often not encouraged since it is difficult to forecast how severe and how long the moisture stress will last. In the humid and subhumid regions discussed in this chapter, there is a critical need to increase the effectiveness of water usage by agriculture. According to recent studies, the most prevalent production method in humid and subhumid zones, rain-fed production systems, are responsible for 75% of the roughly 7,100 km3 year-1 of water required by agriculture. Due to a lack of temporal synchronization between crop water demand and water supply, rain-fed systems often consume less water than full irrigation systems. Yet, owing to competition with human populations for freshwater resources, pollution of freshwater, and declining supplies of groundwater in certain areas, it is doubtful that the ability to grow or even sustain full irrigation capacity will improve. We must pay greater attention to agricultural water consumption in humid places due to the expected consequences of climate change, which include rainfall losses in many locations with marginal yields under rain-fed circumstances and of increasingly intense and varied climatic events globally. Thus, there is a need for methods and practices that boost the resilience and sustainability of food production in rainfall-based agriculture in addition to better efficiency in the use of water and plant nutrients.

DISCUSSION

Cropping Systems and Subhumid Zones

Depending on soil resources and moisture levels, subhumid zones have natural flora that varies from grasslands and shrubs to woods. Typically, inceptisols, mollisols, and alfisols make up soils. The annual mean rainfall in subhumid and wet subhumid zones is often sufficient for the development of seasonal annual crops. Water deficit may, and often does, emerge owing to variations in precipitation amount and timing. Deficit or restricted irrigation that is scheduled to deliver extra moisture when crops are most in need of it helps high-level agricultural productivity in these places. Depending on the season, this could happen during the dry season or when evapotranspiration is at its highest. When it rains, there will be precipitation. In the subhumid zone, a broad variety of crops are cultivated, including maize, wheat, rice, sorghum, peanuts, food legumes, and vegetables [5].

In the subhumid zone, intercropping different species is typical in subsistence farming methods. Compared to monocrop systems with little inputs, these systems utilise sunshine, nutrients, and water more effectively. Around 75% of the farmed land in Africa, according to Steiner, is covered by traditional intercropping techniques. Flexibility, profit, resource utilization, risk mitigation, soil conservation and maintenance, weed control, and nutritional benefits are the key motivations for farmers to intercrop. Intercropping methods also enable farmers to maintain soil fertility in minimal input systems, offer food and potential revenue throughout time, and optimize returns from scarce resources. These systems may include up to six species, although they often cultivate two to three crops that are complementary in terms of growth pattern, maturity, and nutrition.

The transition to monocrop systems in commercial systems has been compelled by the abandonment of manual labor for weeding and planting. Decreased cropping system complexity has made it possible to effectively manage greater areas, provided that fertility is maintained and the appropriate rotations are used. Rotations of wheat and rice in India and maize and soybean in North and South America are examples of this system. Both commercial and subsistence agricultural practices in this zone are very concerned with soil loss. Storms with relatively high rainfall intensities can cause soils to erode and leach, which lowers productivity, particularly when crops are continuously harvested or fallow intervals are brief. Crop wastes are almost always utilized as animal feed in subsistence systems, where they are often significant. This makes it impossible to utilize leftovers as soil cover or to add organic material back to the soil unless manure is concentrated first and then spread on agricultural fields. More may be left on the soil for cover thanks to increased residue production, which is made possible by enhanced crop nutrition. Agricultural residue that has been added back to the soil may increase its resilience, tilth, and ability to store moisture. Through better yields, crop residue retention has also proved useful in commercial agricultural systems. In these no-tillage production techniques, increased water infiltration and water-holding capacity are additional benefits. In subhumid regions like the mid-Atlantic USA, northwest India, and southern Brazil, this increase in soil water often results in better summer crop yields and/or greater profitability

Cropping systems and humid climates

Warm to hot summers and chilly winters are characteristics of humid continental climatic zones. These regions are more common in the northern than the southern hemisphere, and their precipitation is either more evenly distributed throughout the year or less in the winter. Rainfall patterns throughout the summer are often linked to thunderstorms. This zone includes the majority of North Korea, South Korea, Northeast China, and the Midwest of the United States. The most prevalent soil types are alfisols and mollisols. Hardwood woods and meadows often make up the native vegetation in this climatic zone. This climatic zone has a very high potential for agricultural output due to the presence of soils that retain moisture and nutrients as well as normally enough rainfall [6].

The majority of humid subtropical climatic zones are found on the southeast sides of continents, often between the latitudes of 25° and 40° north and south. Southeast China, Paraguay, Uruguay, the Southeast United States, Taiwan, Vietnam, South Korea, Malawi, Tanzania, and Zambia are just a few examples. Summers are humid and warm, with mild to warm winters in between. All four seasons have significant precipitation, with the summer months bringing thunderstorms and, in certain places, tropical storms, hurricanes, or cyclones. The predominant soil type in this climate zone is ultisol. Due to heavy summer rainfall, which washes mineral nutrients below the effective rooting zone of agricultural plants, these red and yellow soils are often less productive than those in temperate zones. The use of fertilizers to replenish these nutrients is a crucial part of sustainable agricultural systems. These soils can only sustain crops for a short amount of time before nutrients are exhausted and crop output is drastically reduced, even with fertilizers or lengthy rotations/fallow periods. Principal reasons of water scarcity in subhumid zones for agricultural production

Interception and Division of Soil Water

Site-specific and influenced by a variety of circumstances, the distribution of rainfall among transpiration, soil infiltration, deep percolation, and evaporation. Runoff and soil loss may vary greatly across locations and rely on the kinds of soil and how easily they erode, the landform, and management strategies. The primary biophysical factors that affect how rainfall is distributed across land. Surface runoff is regulated by soil surface conditions, soil characteristics, and plant elements at the first partitioning point, including root length and density, canopy cover, litter fall, seasonality of vegetation, and effect of vegetation on soil microbiology.

The partitioning between deep drainage and green water flow is controlled at the second site of partitioning by the interaction of soil, climate, and plant conditions. The main factor influencing rainfall partitioning is land management's impact on the biophysical determinants. Crop development will be directly impacted by organic and inorganic fertilizer, which will also alter the percentage of soil-water that follows the green water flow channel. By creating a shady, humid microclimate near to the soil surface and covering the soil with growing plants or dead crop debris, or "mulching," one may limit soil evaporation. Tillage is another method for lowering soil capillary rise. One of the most efficient strategies to reduce unproductive green water flow is to grow strong, ground-covering plants [7].

Distribution of Rainfall

Rainfall occurs as intense convective storms with high rainfall intensity and great spatial and temporal variability in many areas of humid and subhumid zones. A greater probability of dry spells occurring throughout the season as a consequence. If they happen at water-sensitive developmental phases, such as during blooming or yield production, even brief spells of water stress may have a disproportionately negative impact on crop yields. Yields will decrease by at least an equal relative amount and be decreased to half the maximum yield if the actual green water flow is just half the maximum green water flow. Plant development is hampered by soil moisture stress when plant water intake is reduced to 70% of its maximal level. Rainfall that is erratic and severe, particularly N losses, may have an impact. N is lost from flooded soils by denitrification, although N leaching is often enhanced with increasing water flow through soils. According to Jacks and Sharma in India, excessive rainfall has a negative impact on N leaching. These authors discovered that total nitrogen losses to groundwater from fertilization were minimal; however, leaching losses in years with extended dry seasons followed by intense monsoonal rains were equivalent to around 25% of applied nitrogen fertilizer.

Increasing the effectiveness of fertilizer via more efficient water usage

In order to increase the effectiveness of agricultural water usage and overall crop yield, suggest four goals or strategies. Increasing agricultural water yield via transpiration is one of them.

- Expand the amount of water that can be stored throughout time or space.
- Increase the percentage of inflows of water not used for agriculture.
- Reduce non-transpirational water evaporation.

The general approaches that catch water that would otherwise leave the plant root zone and develop it for use by crops are probably the most crucial in humid and subhumid environments. Agricultural dry periods and insufficient rainfall may be mitigated in two ways: either 1) enhance the ability of plants to absorb water, or 2) increase the amount of water available to plants. While these methods have a water management emphasis, there are other ways and practices that may be used to accomplish them. Rainfall distribution and plant water intake in the soil are both excellent performance indicators for all land management strategies, and crop and soil management may increase plant water uptake [8].

Lowering discharge into the surface and enhancing infiltration

When more rain falls on a soil surface than can be absorbed by it, the extra water will begin to pool at the surface. When the surface storage capacity is reached or the soil becomes saturated, runoff will occur. There are basically two methods for reducing runoff: enhanced infiltration or 1 increased surface storage by increasing soil surface roughness via tillage or surface covering. Because of the often enough rainfall, rain-fed agricultural systems in the humid and subhumid zones are especially well suited for cover crop mulch systems.

There are instances when growing infiltration should be avoided, specifically:

- In sandy soils, where extremely high infiltration rates can accelerate leaching and deep drainage during periods of heavy rain.
- In thin soils with little ability to retain water, where increased infiltration may lead to waterlogging and denitrification.

Evaporation Minimization

The quantity of soil-water required to develop agricultural plants will depend on how much precipitation has already reached the soil. By altering the microclimate, mulching the soil's surface with living plants or dead crop debris may minimize soil evaporation. According to a study by Zaongo et al. in Niger, mulch reduced evaporation-mediated loss to 28%, but the water saved from evaporation was not efficiently used for biomass production unless nitrogen was added to the soil, which further improved water use efficiency. This study serves as an example of the need to integrate water and fertility management. Vapor shift, which involves switching water flow from transpiration to evaporation in order to enhance the fraction of productive transpiration flow relative to total evaporation, is another approach that is especially suitable for humid and subhumid zones. Such a vapor shift may be achieved in two different methods. The first involves early planting, intercropping, or mulching to reduce early season evaporation. The second method involves raising the crop canopy cover to shade the soil surface and lower evaporation flux. These locations are significantly more viable to improve management in terms of a significant vapor shift than more dry zones.

Decrease in Deep Drainage

While reducing deep drainage might be tricky, it can be done by taking steps to boost soil fertility, improve soil structure, and lessen the harmful effects of soil acidity. This will lead to stronger crop root systems, which will increase plant water intake. Champoux et al. came to the conclusion that quantitative trait loci for root characteristics might be used to screen drought tolerance after finding that root growth parameters like as length, root thickness, and root: shoot ratio are connected with drought tolerance in both indica and japonica rice. Lynch suggests a variety of phenotypic traits that might enhance maize's intake of nutrients and water. With root development modification, it is anticipated that drought tolerance will continue to increase.

Nutrients in fertilizers and their effect on WUE

Yield/Evapotranspiration is the accepted working definition of crop WUE, therefore management approaches that raise Y independently of ET or without altering ET definitely raise WUE. The beneficial impact of nutritional status on WUE for a number of forage and cereal crops was initially noted by Viets. The adequate delivery of soil nutrients enhances or optimizes plant development and productivity, which is the cause of this synergism. The secret to increasing effective water utilization is balanced eating. All macro, secondary, and micronutrients must be present at the appropriate level, otherwise production will be reduced by the lack of that nutrient. Further information about fertilizer supply and management. In humid and subhumid areas, nutrients will approach the situation as parts of a larger system to provide the highest possible nutrient utilization efficiency [9].

Managed soil fertility holistically

Integrated soil fertility management is a collection of soil fertility management techniques aimed at increasing crop productivity and optimizing agronomic use efficiency of applied nutrients. These techniques must include the use of fertilizer, organic inputs, and improved germplasm with higher yield potential. Using strong agronomic and economic principles, all inputs must be handled.

Supplementation of Nutrients

More productivity per unit of water input may arise from the addition of fertilizer to suit crop demands. These scientists examined the rain-fed production of cereals and food legumes in North Africa and West Asia and came to the conclusion that fertilizer to boost crop yield was one of the most crucial elements to improving water usage efficiency for many crops. For wheat and maize, enhanced WUE with sufficient fertility has been shown in subhumid and humid zones. The use of fertilizers to reduce drought stress is probably only appropriate in situations when crops are nutrient-limited. When fertilizer is added, plants develop more vigorously and are thus better equipped to use the water that is available. With nitrogen fertilizer, plants normally grow larger, their roots expand, and their overall leaf area rises. Increased soil root penetration may open up more water access, which in turn expands the pool of stored water. Working in a maize-wheat system, the root length density of the two crops in a sandy loam soil using three treatments. Usage of fertilizer, use of N alone, and a mix of N, P, and K fertilizer. When all three nutrients were provided to both crops, they discovered substantial increases with N addition above the control and extra, albeit a lesser gain. Increased root mass and growth in response to more N is widely known and has been found in a variety of crops, including wheat, barley, and pea. The capacity of the plants to obtain water from deep in the soil profile and the overall quantity of water that is accessible to the plants are improved by increased root mass, root distribution, and root development.

Similar to this, the quantity of potential water transpired by the plant often rises as total leaf area grows. Higher yields are possible since greater transpiration is linked to improved plant development. The link between plant biomass and WUE under changing N rate settings was examined in a study of over 100 previously published studies by Brueck, who came to the conclusion that physiological, not stomatal, factors were more to blame for N rate impacts on WUE. Plants lost more unproductive water and carbon via respiration when N levels were low.

There hasn't been a lot of study done on how phosphorus affects crop WUE. Lower transpiration was seen in plants that were P deficient as compared to the well supplied control, according to a direct examination of the effect of P supply on plant transpiration. After wilting, the relative transpiration between the control and P-deficient plants changed. It has also been discovered that adding P fertilizer increases chickpea WUE. According to these scientists, increased WUE in response to P fertilizer was brought about by both higher yields and increased soil water usage [10].

The greater P fertility led to better cotton production, larger leaf area, and higher tissue water content in Western Australia while without explicitly monitoring total water usage. Similar to this, several research have looked at how mycorrhizae's increased plant P content affects water relations. To maximize plant development, a better knowledge of how different important nutrients work together is required. By reducing the pH of the soil in the root zone and making P more accessible, Blair et al. indicate that a preferred supply of NH4-N is more likely to promote the absorption of P in early maize plants.

Potassium has a crucial part in the water-relations of plants. Stomata opening and closing, water transport in plant vascular systems, controlling cell turgor pressure, and cell elongation are among processes that potassium plays a role in. It follows that it is clear that potassium is crucial in the reaction to a water shortage. Potassium nutrition may affect crop phenology in addition to the direct effect of plant physiological processes. It has been shown that a potassium deficit raises the amount of abscisic acid in the leaves, causing wheat to ripen prematurely. Similar to how maize in the US Corn Belt and a forage legume in the mid-Atlantic USA have shown reduced leaf area and plant performance under situations of potassium deficiency.

Positioning of nutrients

While the distribution of roots is influenced by fertilizer placement, the length or volume of the total root system are often unaffected. Yet, it has been advised to apply fertilizer below the soil's surface in order to affect the growth of roots in deeper soil zones and prevent the short-term soil drying that often takes place there. Starting fertilizer may boost plant growth when applied in a narrow area close to the seed. In several crops, including maize and vegetables, early season growth and accelerated maturation are practices. This promotion of early-season growth at a quick rate may last the whole growing season, protecting crops against dryness later in the year. With hybrids and cultivars with extended growing seasons, this impact is also known to be stronger.

Placement of nitrogen is often not thought to be crucial to achieving plant uptake since conventional nitrogen fertilizers are typically water-soluble and nitrate is mobile in soil. There are two exclusions. The first is the impact of applying nutrients early in the growing season, or as a "starter," which allows seedlings and young plants to quickly absorb the nutrients. Banding has also been reported to delay conversion to the mobile nitrate form, which may reduce losses and lengthen the amount of time N fertilizer is accessible. The second situation is similar in that banding N fertilizer into mineral soil lowers the possibility of N being immobilized by soil microorganisms in cropping systems when considerable prior crop residue is still present on the soil surface. As a result, a higher percentage of the applied N is immediately usable by plants. N fertilizer with urea and ammonium bases should be buried beneath surface residue to lessen the risk of ammonia volatilization-related losses. Reeves and Mullins reported that over the course of two years of study with average yields of g ha-1, deep placement of K fertilizer in cotton in the southeast United States using subsoil tillage resulted in 10-15% lower soil water contents compared with surface application of K. Their study site had a root-restrictive layer and low subsoil K content. They explained the enhanced root proliferation in the K-enriched zone as the cause of the larger soil profile water depletion.

Matching the availability of nutrients with plant requirements

Achieving synchronization between N supply from soils and fertilizers and the plant's N absorption need is a crucial step in increasing N usage efficiency. Conceptually, it is generally understood that in order to improve efficiency, N fertilizer delivery must be coordinated with the period of crop need. Nevertheless, site-specific factors and managerial choices make it difficult to implement this ideal in reality. Typically, crop nutrient absorption varies during the growing season and is characterized by relatively low nutrient levels early in the season, followed by a sharp rise as crop growth and demand rise. A sigmoid curve may be used to depict nutrient intake in response to relative crop growth in most crops [11].

Timing N delivery to coincide with certain crop growth phases may considerably boost efficiency and lessen the environmental effect of nitrogen losses when soil and meteorological conditions promote nutrient losses. For instance, the cultivation of rice often results in significant N fertilizer losses. Wilson et alresearch.’s shows that splitting the application of nitrogen throughout the growing season may significantly improve nitrogen efficiency. The scientists discovered that applying N two weeks after internode elongation resulted in more N recovery of 15N-labeled urea in panicles and reduced N loss. During the pre-flood, internode elongation, and 14 day-post internode elongation treatments, respectively, it was revealed that total N recovery was 63.2, 63.3, and 70.1%. Winter wheat may get two in-season N treatments in the sandy soils of the Coastal Plain area of the southern United States, one during spring green-up and the other at the start of reproductive growth. Compared to a single spring N treatment, this technique increases grain production while decreasing lodging. Crop production may be increased by adjusting the time of N fertilizer delivery to affect how crops utilise moisture that has been stored in the soil. Wheat in Australia has shown evidence of detrimental consequences of extra vegetative growth, driven by fertilizer application timing.

While there is a propensity for occasional water stress, this phenomena is unusual for subhumid or humid zones. Hence, when dry conditions continue in the early season, a technique that restricts preplant N delivery may be beneficial. The bulk of crop N will probably need to be given during the appropriate growing season, and the necessary equipment and manpower will need to be available to carry out this application. It has been shown that using N application to enhance the absorption of stored water increases the efficiency of N and water consumption in India.

Management of nutrients at Particular Sites

The best crop fertilizer rates vary geographically depending on soil type, drainage, and productivity, as well as seasonally depending on soil organic matter mineralization and climate. Site-specific nutrient management is a strategy for providing plants with the nutrients they need to best fit their innate spatial and temporal nutritional requirements. In Asia and Africa, experience with SSNM for rice and maize has shown that farmers profit much more financially, have larger yields, and make the best use of fertilizer.

- Indigenous soil nutrient supplying capacity is one of the key elements of SSNM.
- Nutrient uptake, recovery, and aftereffects of fertilizer.
- Relationship between the formation of yields and nutrient uptake.
- Demand for nutrients as they change throughout the cropping cycle.
- Crop production methods and crop management techniques.

Financial and risk factors specific to the area

Considering water availability when calculating the temporal and spatial needs for N. In humid and subhumid regions, crop potential and water availability have long been acknowledged by scientists and producers. The significance of integrating soil water-holding capacity and water availability in models that account for geographic variability in N demand. Some methods have suggested using direct, nondestructive measurements from the crop canopy as a substitute for determining the overall state of crops, which would always include the availability of water. With positive outcomes, these researchers and others have contrasted in-season variable rate N fertilizer with fixed rate strategies. According to Timlin et al., changes in weather mostly explained why temporal variables had a bigger impact on yield than did geographical variability. When taken together, these kinds of data demonstrate the significance of systems that take into account spatial and temporal variation to improve the efficiency of fertilizer and water usage. One of the keys to raising crop production overall in the future will be boosting productivity on the finest soils in the best areas of fields.

Sources with a slow rollout and delayed availability

Long-lasting fertilizer to increase N availability during a growing season and to lower possible N losses from the soil system, N materials are employed. Reduced water solubility, a slower rate of microbial degradation, delayed diffusion across an impermeable barrier, or resin coating of the substance are some methods for maintaining N fertilizer availability. By better aligning fertilizer delivery with the time of crop demand, reducing N losses from the system, and perhaps increasing crop yields, these products provide potential benefits in both water and nutrient usage efficiency. Reduced volatilization and leaching losses, with N reductions higher than 50%, are considered to represent these SR materials' largest potential benefits in humid and subhumid regions. Physical coatings or barriers that restrict the solubility or availability of N fertilizer ingredients have the potential to boost N absorption by improving the timing of N supply and demand.

As crop output and nitrogen requirement are directly related, maintaining and increasing nitrogen usage efficiency at comparable levels of water consumption will always be necessary. Efficiency of N fertilizer will also be heavily influenced by worries about greenhouse gas emissions and the effects of N fertilizer on water quality. In humid and subhumid regions, new cultivars and hybrids with more effective nitrogen and water utilization have the potential to drastically alter crop productivity. Understanding the relationship between plant and trait function and environment will provide new research challenges, however.

WUE under circumstances and locations with very low P availability will probably be improved by breeding crops that utilise phosphorus more effectively. Nonetheless, managers will often still need to provide P fertilizer to maximize crop development, thus programs should also include alternative options. Manure is often accessible for application to farmland due to the range of crops and crop/livestock agricultural systems seen in humid and subhumid regions. This cycle of fertilizer recycling is an example of a systems approach to agricultural fertility management. Similar to this, many cities across the globe are located in similar climatic zones, and in many cases, applying municipal sewage sludge to fields to produce crops may give P. As sanitation and water treatment systems improve and advance, this strategy may gain ground in poor countries. Systems that enable speedier fertilizer and water absorption will be required due to increased yield potential and increased nutrient uptake needs within a same growing season. To satisfy this increase in demand, it will be crucial to conduct further research that examine the ideal rate, location, and time for fertilizer supplies [12].

As agricultural yields grow, combining methods that improve water interception, collection, and productive storage will become more crucial. More efficiency in using rainwater is possible with agronomic systems that employ crop leftovers and/or cover crops to maintain soil cover and lower evaporative losses. In the future, it will be necessary to combine methods that increase rainfall conversion into useable crop water with methods that provide nutrients in the proper quantity, the correct form, and at the proper time. Multidisciplinary field and lab trials that assess fertilizers, water utilization, and other inputs as necessary to enhance agricultural yields should be the main emphasis of research.

CONCLUSION

It is crucial to increase the effectiveness of how nutrients and water are used because of the consequences of providing enough nutritious food for a rising population while preparing for the unknown effects of climate change. This is particularly true in humid and subhumid areas, where sufficient rainfall for agricultural production normally occurs and where climate change affects rainfall pattern and duration. Several drier places may experience a shortage of water accessible for agriculture due to the rise in demand for water for human use, increasing their dependency on food production in wetter areas as a consequence. It is of little value to worry about techniques that improve fertilizer usage efficiency if there is a lack of accessible water. In these humid and subhumid regions, very little study has been done on this subject to far. More rainfall will be captured and retained for agricultural use, however, thanks to enhanced water harvesting techniques that boost infiltration, minimize evaporative losses, and reduce runoff. We anticipate higher yields coupled with increased fertilizer and water usage efficiency when combined with methods that provide balanced fertility in an integrated system. If we are to feed the expanding global population, we must have a better grasp of how to enhance strategies for improved water and fertilizer usage efficiency in these locations.

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CHAPTER 7

MANAGING NUTRIENTS AND MAXIMIZING WATER UTILIZATION FOR RAIN-FED AGRICULTURAL PRODUCTION IN ARID PLACES OF THE WORLD

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ABSTRACT:

The primary biophysical barriers to agricultural production in farming systems in the dry zones, which make up around 40% of the earth's surface acreage, are insufficient and extremely unpredictable precipitation and typically inadequate soil fertility. Management measures may lessen these restrictions. In semi-arid regions where soil has been sculpted into basins to hold precipitation on the field, less runoff and evaporation may result in greater agricultural yields. Remaining moisture after the main crop is harvested, local practices to increase the storage of rainwater or snowwater, the addition of manure and maintenance of crop residues to improve soil structure, increase water infiltration into the rooting zone of crops and minimize evaporation losses, reduced tillage to conserve water, and improved fertilizer management, based on soil tests, and appropriate rates, timing, and other factors are other practices that improve the production of rain-fed crops.

KEYWORDS:

Agriculture, Fertilizer, Food Security, Management, Nutrients.

INTRODUCTION

Only the use of chemical fertilizers in conjunction with the effective recycling of organic materials, such as crop residues and farm manure, and the adoption of rotations with legumes, pulse crops, and green manures that fix nitrogen and improve soil quality will be able to maintain soil fertility in intensified farming in semiarid zones. Soil water and nutrient interactions must be understood in order to manage crops sustainably in semiarid conditions. Achieving the best nutrient and water usage efficiency is the aim of optimal management. This chapter describes the many variables supporting attempts to increase crop output in arid areas via better technology and emphasizes challenges associated with farmer acceptance of such technologies using examples from both emerging and developed parts of the globe. The 40% of the land surface on the planet is made up of dry places. Whether dry or semiarid, these regions have delicate ecosystems and are characterized by a lack of rain or a sparse amount of it that is often distributed unevenly.

In arid environments, low soil fertility is usually a complicating factor. The relevance of dry lands and their importance for civilization have been extensively discussed in literature. The management of such arid areas may have effects on society as a whole. Population growth throughout the world, particularly in less developed nations, has increased land use pressure, which has an impact on maintaining fragile, sensitive, and drought-stressed ecosystems as well as livelihoods and natural resources. The problem of helping nations dominated by arid regions to support their people is significant as a catastrophe in global food production looms. In semi-arid locations where irrigation is normally not an option, crop yields are determined by poor and variable rainfall, typically with low yields and frequently total crop failure. In dry regions, agricultural production is impossible without irrigation. Variable rainfall reduces the efficiency of inputs like fertilizers and raises the financial risk associated with their usage [1].

Notwithstanding this bleak outlook, there is reason to think that with better management, agriculture in arid and semiarid areas may be made more productive in a sustainable way. A combination of improved soil and crop management, such as the use of chemical fertilizers and the adoption of summer fallow, reduced tillage, and improved cultivars of drought-tolerant crops, can profitably increase crop yields in dry areas and decrease yield variation despite the crop production constraints associated with limited rainfall. While dry regions throughout the globe have a lot of characteristics, there are differences between dry regions in industrialized and developing nations in terms of how these regions affect society. Due to the availability of resources, technology, and socioeconomic support systems, the size of farming is much different in developed nations, such as the United States, Canada, and Australia, than it is in underdeveloped ones. In contrast, emerging nations in arid regions have various obstacles that reduce their ability to respond to drought.

Yet, farmers in every arid location require a plan that makes the best use of the scarce rainfall, either to increase its efficiency in being captured or to lessen its loss via evaporation. Hence, efficient crop use and in-field conservation are key factors in determining water availability. The amount of rainfall that is really accessible for plant development is dramatically reduced by runoff, evaporation, and deep percolation from the soil surface. Following low-cost, low-risk land and water management strategies, frequently based on practices from antiquity, can increase the amount of water available to crops from the local rainfall. Even small amounts of additional water can significantly increase yields in dry environments with high water use efficiencies - provided that factors that have an impact on water use are adequately addressed. Crop selection is another crucial management technique [2].

Essential plant nutrients, particularly nitrogen, phosphorus, and, to a lesser degree, potassium, certain secondary nutrients, and micronutrients, are the main determinants impacting crop yields and water usage efficiency. In order to ensure food security both internationally and in arid regions of the globe, crops must be given enough nutrition, particularly when chemical fertilizers are used. Traditionally, organic inputs applied externally were used to maintain the minimal soil fertility necessary for low-output agriculture. Although resource-poor developing nations continue to rely extensively on organic manures to sustain crop yields, chemical fertilizer application now accounts for more than 50% of global food production and is expected to continue to grow in importance. The amount of manure needed for fuel in developing nations is often influenced by the size and kind of the animals. Increased fertilizer usage combined with accessible organic sources will unavoidably result from the demand to boost agricultural yield in water-strapped places.

No matter the source of nutrients for upcoming crop production in these places, nutrient usage efficiency will be determined by rainfall or soil moisture availability, and the effectiveness of using the scarce water will rely on the availability of crucial crop nutrients. In essence, crop management in arid places revolves upon this interaction or synergy between the two elements, water and nutrients.

The development strategy for crop production in arid and semiarid areas has often concentrated on a specific aspect of the agricultural system, such as the usage of fertilizer, soil management, or water conservation techniques. This dispersed strategy has often failed to have a significant influence on crop production. Effective techniques to boost dryland agricultural productivity are likely to use an integrated strategy that includes fertilizer inputs, water and soil conservation measures, and soil conservation measures. Consequently, this succinct and broad study addresses the interaction between water and nutrients in the development of dryland crops, stressing technology for better water collection in farmers' fields and strategies for improving its use by the crop.

A recent book that provided a worldwide perspective and Peterson et al. comprehensive assessments of dry region agriculture are also available. Irrigation has always received disproportionate scientific focus because of the large productivity improvements it may bring. Contrarily, despite pleas to the contrary, semiarid areas that rely on little seasonal rain to grow crops have gotten less academic attention and investment for development. The emphasis of this selected analysis is on agriculture supported by natural rainfall and takes into account soil fertility management and water productivity from its collection in the field to its use by the developing crop in light of the rising relevance of rain-fed or dryland agriculture. This chapter uses examples from both established and developing nations to illustrate location-specific and integrated soil, water, and nutrient management practices that may result in sustainable agricultural systems in arid and semiarid areas.

Definition, traits, and Worldwide Distribution

Arid settings are those where the ratio of precipitation to evapotranspiration results in a proportion between 0.03 and 0.20; for semiarid areas, the equivalent percentage is between 0.20 and 0.50. While these ecosystems are quite varied in terms of their landforms, soils, water balance, and fauna, they are distinguished by their low annual precipitation, which occurs seldom and irregularly. Due to the very low rainfall, dry zones are characterized by no agriculture other than sparse grazing; in these situations, cropping is only conceivable with irrigation. Rain-fed agriculture may be practiced in semiarid regions with more or less sustained levels of output. According to the duration of the growing season for annual crops, dry areas have 1-59 growing days, whereas semiarid regions have between 60 and 119 growing days [3].

Most continents have areas of land that are dry or lacking in moisture. One-third of the world's arid zones are found in Africa, which also includes Australia, Central Asia, the Middle East, North, Central, and South America. Together with Russia, China, Mongolia, and the Indian Subcontinent, Asia is home to semiarid regions. Australia is mostly arid or semiarid. Argentina is the principal location of semiarid plains in South America. From Mexico to Canada, the Great Plains, the Pacific Northwest, and the Southwest Pacific area of California are all considered semiarid regions of North America. Arid and semiarid settings are found in three main climatic types: the Mediterranean climate, the tropical climate, and the continental climate. These distinctions are based on variances in temperature, the season in which rain falls, windiness, and the degree of aridity. The rainy season occurs in the fall and winter in the Mediterranean environment. Winter temperatures are pleasant, while summers are scorching and dry.

Southern Europe, North Africa, West Asia that extends into Central Asia, Chile, Australia, and portions of California and the US Pacific northwest that extend to British Columbia and Canada are among the major dryland agricultural regions with a Mediterranean-type climate. Rainfall occurs throughout the summer in tropical climates; the length of the rainy season shortens with distance from the equator. It's a dry and protracted winter. The majority of the world's developing countries are located in arid or semiarid region of the tropics, including Latin America, significant portions of West, Central, Eastern, and Southern Africa, as well as sections of India and South-East Asia. Even though there is a trend toward more precipitation in the summer, the continental climate has an equitable distribution of precipitation throughout the year. Parts of Australia, Russia, Central Asia, and the Great Plains of North America all have a continental climate.

Insofar as usually low input production methods are paired with highly automated large-scale farm lands, the semiarid regions of the Northern Great Plains of the USA and Canada vary from agricultural production systems from the rest of the globe. The predominant continental climate in the area is defined by lengthy, cold winters and brief, dry, scorching summers. A third of the yearly precipitation falls as snow in the winter, with almost half falling between May and September. Swift Current is an example of such situations. Snow is a potentially significant source of accessible water as it insulates and protects the soil from erosion.

DISCUSSION

Crop Production Restrictions

The very unpredictable and low rainfall, high temperatures, winds, low air humidity, soil deterioration owing to erosion, poor soil organic matter content, and nutrient deficiencies are all factors that limit crop yield in dry places. Especially in tropical climates where precipitation falls on warm soil surfaces in summer, resulting in fast loss of soil moisture owing to the high levels of evaporation and transpiration, a large portion of rainfall in these situations is ultimately returned to the sky through evapotranspiration. Strong winds, high temperatures, and low humidity all contribute to increased evaporation.

The SOM concentration in dry-area soils is typically low and quickly decreases when such soils are farmed. SOM content affects fertility and soil physical qualities, notably water-holding ability. Crop productivity in arid, water-stressed areas is impacted by how well the growing crop utilises the limited quantity of moisture as well as how much of the little rainfall is retained in the field and not lost. So, before examining the effectiveness of agricultural water usage, it is necessary to briefly outline the strategies employed for rainfall collecting in the landscapes of arid areas and on farmers' fields. A few local instances are shown [4].

Collecting and Preserving Rainwater

Effective rain-fed farming systems should decrease runoff and evaporation from the soil surface in order to enhance water usage efficiency, i.e., a larger percentage of precipitation must be utilised for transpiration. This is because crop yields tend to rise with increases in transpiration. Hence, catching, storing, and using extremely unpredictable and limited precipitation is the focus of farming in arid areas, along with avoiding loss from runoff and evaporation. In situ water conservation and water harvesting, as outlined by Koohafhan and Stewart, are two management techniques that may be used to accomplish this. In situ water conservation involves preventing runoff, retaining as much rainwater where it falls, and reducing evaporation. Water harvesting is the practice of collecting runoff and precipitation for later beneficial use in irrigating crops.

Localized Water Preservation

To improve in situ rainwater conservation, many technological solutions have been created and shown to be successful in arid areas. Technical solutions often need local community involvement to be successful since they frequently rely on regionally unique biophysical and socioeconomic factors.

Terraces

Because of the variety of the environment, terraces have been utilized for ages to manage runoff and erosion. Its design and construction are influenced by the local circumstances. The earliest kind of terraces are called bench terraces, and they are built by bringing dirt from an uphill side of a strip to the lower side, creating a level step or bench. The bench terraces in the Colca Valley of Peru were constructed at least 1,500 years ago, according to radiocarbon testing. Yemen has one of the largest terraced regions in the world. These terraces have been used for dryland farming for the last three millennia, and much of the original agricultural expertise is still present today. Terracing is still important nowadays; for example, from 1950 to 1984, more than 2.7 million acres of agriculture in China were terraced.

In order to supply more runoff onto level terraces where crops are planted, conservation bench terraces, also known as Zingg terraces, utilise a portion of the land's surface as a catchment. They are especially well suited for extensive mechanical farming, such the wheat/sorghum farmlands in the southwest of the United States. When rainfall is enough for appropriate crop production, CBTs reliably boost yields and efficiently limit erosion and total runoff in contrast to standard level terraces. The design of CBTs should be location-specific for the best functioning. Conservation terraces are probably not practical in regions with very little rainfall because to high installation costs.

The concept behind contour furrows, sometimes known as desert strip farming, is similar to that of CBTs but requires less soil movement. They are thus more common among small farmers and/or in regions with lesser rainfall. Following the contour at regular intervals of 1 to 2 meters are furrows or ridges. Cropping often occurs sporadically in strips or in rows when the catchment area is left fallow. Uneven ponding depth behind the bank may occur if the contour furrows are not put out exactly on the contours, but it may be prevented by building tiny bunds at an angle. In order to allow the runoff to overflow without causing harm during severe storms, the dug furrow is sometimes designed to catch water.

Using ties in the basin, contour bunds are constructed on a level slope. In order to minimize damage in the event that the basin is overtopped, a stone wall is constructed on the lower side of the earth bund. In Kenya, sorghum was cultivated using contour bunds with just 270 mm of rainfall and a 2:1 catchment ratio. 30% of the catchment's runoff was lost as runoff, leaving 162 mm and 432 mm accessible to the plants. Contour bunds are utilized for soil and water conservation in Ethiopia as well [5].

Land leveling using a laser and miniature benches

Mini benches and laser-assisted ground leveling are pricey but very effective in lowering runoff losses. As an example, in the Tadla district of Morocco saw significant advantages from this strategy, including 20% water savings, a 30% boost in agricultural yields, and a 50% reduction in labor costs while reaching 90% irrigation uniformity. Use of thin mini-benches, which may be built affordably on mild slopes of up to 2%, is an alternative to land leveling. Mini-benches have relatively shallow soil incisions, which greatly reduces the soil-fertility issues brought on by the extensive surface soil redistribution. Mini-benches are less costly to build since they don't involve moving a lot of dirt.

Tying Ridges

Both automated and labor-intensive agricultural systems may benefit from the soil and water conservation techniques of ridge-tying or furrow-diking. In order to block the furrows and preserve rainfall for infiltration, these techniques require planting crops on little ridges that run along the contour. On the contours, crops may be produced using any tillage method, including no-tillage and reduced-tillage techniques. Tied ridging hasn't been frequently used by small farmers, mostly because to its erratic advantages. While analyzing connected ridges, it's important to take into account the soil texture and rainfall patterns. Because to anaerobic conditions in the root zone and nutrient leaching, tied-ridges in East Africa were generally counterproductive above 700-900 mm of rainfall. They were successful at close to average rainfall.

Mulching on Surfaces

In North America, snow management methods, no-till farming, and stubble mulching are all widely used. Throughout the majority of the Great Plains, tillage practices that leave crop residues on the soil's surface are crucial for preventing wind and water erosion. Conservation tillage also enhances soil water storage during fallow times, which boosts crop yields and makes other advanced technologies, such fertilizers and better cultivars, more effective to utilize. Nonetheless, careful evaluation of the local circumstances is necessary when choosing effective water conservation techniques. Certain technologies may not provide favorable results for a year or more. Crop residues should be left on the soil surface as a mulch to save water and improve SOM in order for in situ water conservation methods to be successful. Although most Indian farmers only practiced cultivation across the slope as a kind of conservation, they understood the importance of mulches and the retention of stubble during the dry season but did not adopt the technique since chopped stubble was required for fuel and livestock feed.

Dhruva and Babu have proposed the following tactics dependent on the quantity of rainfall and the crop's water needs: When rainfall is less than crop requirements, increase runoff onto cropped areas, increase fallowing for water conservation, and plant drought-tolerant plants. When rainfall is equal to crop requirements, increase local conservation of precipitation to maximize storage within the soil profile and increase storage of excess runoff for later use. When rainfall is more than crop requirements, reduce rainfall erosion by draining excess r. The choice of strategy is challenging due to the large seasonal variation in rainfall/moisture because it is impractical to classify methods based on average conditions or to design strategies based on averages. Dual purpose strategies, such as methods that can be changed in the middle of the season, may be preferable, but very few methods support this flexibility.

Water Collection

Rainfall should, as much as feasible, be gathered where it falls. Water harvesting involves collecting rainwater from a modified or treated region to optimize flow for use on a cultivated field, for storage in a reservoir, or for aquifer recharging. Microcatchments, macrocatchments, and floodwater harvesting are the three main categories of water-harvesting methods that are used. Micro-catchment systems, which combine a catchment region with a nearby farmed area, are simple, affordable, and readily replicable. They significantly boost crop potential for smallholders in poor nations. It is possible to use natural depressions, contour bunds, interrow water harvesting, semicircular bunds, and triangle bunds as Depending on the circumstances in the area, microcatchments. Water collected and held in small-basin micro-catchments increased system efficiency in Jordanian regions with annual rainfall of less than 150 mm by 86%. Rainwater from sloped surfaces is collected in channels along slope breaks in Hamadan, Iran, and then transferred to parcels of land below the slope breaks. Several of these methods are the result of the capacity of the local population to sustainably manage their limited water supplies. By building simple contour bunds, Burkina Faso's micro-catchments used in runoff farming enhanced agricultural output because of greater infiltration [6].

Macro-catchments are enormous areas that gather runoff from a region far away from the farmed area. Hillside-sheet or rill runoff usage and hillside-conduit systems are examples of external catchments. In order to harvest floodwater from a streambed, the water flow must be blocked, forcing water to collect in the streambed, which is then used for cultivation. The streambed region must be level with no runoff-producing slopes on the nearby hillsides, and the flood and growth seasons must not overlap. Weirs, canals, dams, and bunds may be used to redirect and apply water to the cropped area of an ephemeral stream.

Evaporation Minimization

Water loss is mostly caused by evaporation, which occurs both during the fallow period and the crop growth season. By affecting the radiation balance, rate of heat and water vapor transport, and heat capacity of the soil, surface mulching with agricultural residues and plastic films alters the hydrothermal regime of the soil. During fallow times, mulches left on the soil's surface or dust mulch produced by repetitive plowing have proven useful in lowering evaporation. Dust mulch is no longer employed due to erosion issues, despite the fact that stubble-mulch methods are widely used in the North American Great Plains and minimum tillage and no-tillage are progressively increasing. Wet soil during sowing may be a concern when heavier mulch is used in conjunction with no-till farming. Organic mulches increase the effectiveness of rainfall while lowering runoff and surface crusting. Mulching with crop residues may raise WUE by 10–20% in the North China Plain and Loess Plateau by reducing soil evaporation and increasing plant transpiration. More than four times as efficient as cotton stalks, wheat stubble was nearly twice as successful as grain sorghum stubble in reducing soil water evaporation. With the help of rice straw mulching, maize yields in India's semiarid tropics rose by 16%, while sorghum yields rose by 59%. The residues left on the soil surface as mulch are the most helpful for minimizing evaporation when numerous precipitation events take place over the course of a few days since each subsequent precipitation event results in soil soaking to a higher depth. It is more difficult to reduce evaporation during the growth season. For instance, sorghum behaved differently to the presence of mulch throughout the growth season compared to how much soil water was present at the time of sowing. It's possible that throughout the growth season, shade from the plant canopy essentially took the place of mulch's positive effects[7].

Improving water usage effectiveness

The quantity of harvestable product generated per unit of evapotranspiration from crop sowing through harvesting is characterized as the water usage efficiency, a crucial component in rain-fed crop production in arid locations. Efficiency is determined by biomass generation, grain yield, and evapotranspiration. Evapotranspiration accounted for nearly 65% of total precipitation in two semiarid regions where wheat was cultivated, Texas in the United States and Shaanxi in China. The amount of water available to plants changed throughout the growing season and during the fallow period, but Texas saw a smaller shift than Shaanxi because Texas experienced less precipitation during the fallow period and had a much higher potential evapotranspiration. While there was more precipitation overall in Texas than in Shaanxi, Texas also saw more real evapotranspiration throughout the wheat-growing season. Overall, adopting more intensive cropping systems may improve the efficiency of how well semiarid regions utilise their precipitation, claim Hatfield et al. Effective nutrition management techniques may boost WUE even further.

Interactions between Dryland Nutrient and Water

Although the aforementioned strategies may help arid regions have more access to water, they cannot guarantee improved agricultural yields on their own. To optimize the advantages of increased water recovered or conserved, an adequate supply of plant-available nutrients is also necessary. For N, this is particularly true. Thus, it is important to briefly analyze how the dynamics of N are influenced by soil water and vice versa. Rainfall and its erratic distribution have an impact on many biological and chemical processes in the soil. The frequency and length of wet-dry cycles in the soil, as well as several elements of carbon and nutrient turnover, such as C and N mineralization, microbial biomass, gaseous losses, denitrification, and ammonia volatilization, may be directly impacted by water pulses. The buildup of inorganic N is one effect of the commonly seen flush of N mineralization in surface soil layers after wetting and drying episodes related to the bimodal rainfall season. Yet, since maximum soil and water N concentrations occur at various times throughout the year, there is an asynchrony between N and water availability, which results in poor N availability to agricultural plants in dry and semiarid habitats. In order to create management methods for generating high yields and efficient use of both water and nutrients in water-stressed locations, it is thus essential to understand the interaction effects of soil water and nutrients.

Managing nutrients to improve water usage effectiveness

Several studies have shown that fertilizers have a beneficial effect on WUE on nutrient-deficient soils, as documented in the proceedings of numerous international conferences. In addition to promoting plant development, fertilizer also encourages root growth, which enables water absorption from deeper soil layers, especially during periods of drought. By providing shade on the soil's surface, the fertilizer-induced fast growth of plant growth lowers the amount of water evaporation. Yet, early cereal tillers die off and heading is decreased if such early growth is followed by a dry season. Managing water to increase the effectiveness of fertilizer usage

Utilization of fertilizer and other agricultural inputs is improved through increased soil-water storage and availability to crop plants during crucial growth periods. In India, deeper soils with more water stored had larger yields of post-monsoonal sorghum than shallower soils, with responses up to 50 kg N ha-1 in the deep soil and only up to 25 kg N ha-1 in the shallow soil. a sandy area [8]. Mid-season rainfall in southern Niger's soil influenced millet output and fertilizer N usage effectiveness. Fertilizer N did not affect millet output during periods of low mid-season rainfall; but, during periods of normal or above-average precipitation, N application boosted millet grain yield by a factor of four to five.

While fertilizer N application at 30 kg N ha-1 resulted in a FNUE as high as 25 kg grain kg-1 N, a model connecting yield of pearl millet to mid-season rainfall projected modest responses to applied N in dry years, but stronger responses in years of ideal rainfall. The best yields in 16 years of maize trials in north-eastern China were in years with regular rainfall; responses of both P over N and of K over NP only happened in years with normal rainfall. P or K did not exhibit any significant reactions during years of drought or excessive rainfall.

The lowest yields, between 44.7 and 58.5% of normal-year yields, were in years of drought or waterlogging. 6.5 kg grain kg-1 N at Bellary, 9.7 kg grain kg-1 N at Bijapur, 19.0 kg grain kg-1 N at Solapur, and 27.7 kg grain kg-1 N at Kovilpatti were the responses of rainy season sorghum to applied N in India. The distribution of rainfall over the crop growth period, in addition to the seasonal total, has an impact on FNUE. The grain-filling period was found to be the most crucial for both fallow- and stubble-seeded wheat in a long-term rotation experiment at Swift Current, Saskatchewan, Canada.

However, precipitation at or near seeding time was almost as crucial for stubble-seeded wheat because it ensures the establishment of an adequate plant density. The quantity and distribution of rainfall throughout the vegetative and reproductive periods of rain-fed wheat in northern India was what influenced FNUE. The pattern of rainfall may also alter how well fertilizer is applied. For instance, in India, the advantage of broadcast application of fertilizer N put below the seed was less beneficial when rain fell immediately after planting wheat than when it did not. Water consumption was shown to be the most significant factor impacting spring wheat production in the semiarid Canadian prairies, accounting for 64% of the variability, followed by soil test N, which accounted for 20% of the variability.

Options for nutrient control in Rain-Fed Situations

Considering the interactions between water and nutrients that are known to exist, it is important to take advantage of these connections in order to maintain or boost crop yields in water-stressed situations. The developed world is represented by Canada in the next section, which includes instances of water-nutrient management strategies in a variety of arid developing nations, including the Mediterranean area, Africa, India, and China.

Areas of the Mediterranean and west Asia-north Africa

Significant advancements have been made in the Mediterranean and west Asia-north Africa regions over the past few decades to boost agricultural output. These advancements include the introduction of high-yielding crop varieties, mechanization, pest control, and, in particular, the use of chemical fertilizers as a supplement to the scarce supply of animal manures. Syria, which is primarily made up of arid desert and steppe land, has a sizable area in the semiarid zone where dryland agriculture is practiced. The main crops grown there are cereals, primarily wheat in the more favorable areas and barley in the drier areas, as well as feed and food legumes. Grazing animals have been an essential part of the cropping system for millennia. The dryland study that came out of Syria is relevant to the majority of the Mediterranean area since the range of rainfall and other environmental variables in Syria are typically comparable to those prevalent across most of the WANA region. Legumes historically played a significant role in preserving soil fertility without fertilizers, together with fallow to store rainwater in the alternate year. Some long-term rotation studies looked to provide farmers workable economic options in light of shrinking fallow owing to demand from land usage and other cropping system innovations. Ryan et al. then addressed the importance of crop rotations in agricultural systems, emphasising the importance of nutrients and rainfall [9].

In the WANA area, there was a clear correlation between rainfall, soil moisture, and N response; autumn and spring N treatment typically differed little, although spring top-dressing allowed for greater flexibility in relation to rainfall. Crop responses to N were influenced by the degree of SOM, which in turn was connected to the specific crop rotation, and were greatest in areas of favorable rainfall and smallest in areas of unfavorable rainfall when rainfall was below 250 mm. While urea is the most used N fertilizer, it has considerable losses due to volatilization. The loss is low, however, if the substance is incorporated into the soil, applied when it is colder, or top-dressed before or during spring rains. N losses from leaching in dryland environments were negligible. Crop yields in both rotational stages were taken into consideration in studies on WUE. Using rainwater most effectively, the wheat-lentil and wheat-vetch systems produced 27% more grain than the wheat-fallow system.

N, along with other parameters, had an impact on how rainfall over the rainfall gradient in northwest Syria affected agricultural yields. In sites where soil test levels for P were low and P accumulation was present, crop responses to P were detected. Little or no reaction to P treatment was seen because of frequent fertilization. Due to a stimulating influence on root development, responses to P tend to be stronger under drier environments. Dryland crop responses to N and P fertilization will be minimal unless toxicities or nutritional deficits are addressed. As a result, steps were made to encourage the use of micronutrient fertilizers and to create plants that can tolerate boron. Considering the WANA region's rain-fed crops' proven need for sufficient nutrients for profitable production, a cooperative soil test calibration program created criteria for fertilizer application for the major crops. Balanced fertilization received particular attention. Efficiency of nutrient utilization will become even more crucial in the years to come due to the steadily rising cost of fertilizers. This may be accomplished by taking into account a variety of site-specific elements that influence effective nutrient utilization. Modifications to fertilizer application techniques are needed for conservation- or minimum-tillage farming.

Semi-arid and arid Africa

In the arid parts of Africa, there have been reports of increased gaseous losses of nitrogen from applied fertilizer with increasing rates of application and independent of N sources. Pearl millet yields were considerably greater when calcium ammonium nitrate was used instead of urea for plant N absorption. However plants only absorbed a small amount of total N, and losses were substantial. In field tests on millet in West Africa, crop N absorption from point-placed CAN was three times greater than from point-placed urea, whereas crop N uptake from broadcast CAN was 57% lower than from point-placed CAN. NUE was raised by using N in two places. In the southern part of Niger, split applications, tilling the soil, and placing the fertilizer in the soil as opposed to leaving it at the soil surface all boosted plant responses to applied fertilizer N.

Combining mineral and organic fertilizers increases the sustainability of cereal grain production in semi-arid soils. In Sudan, sustained sorghum production was assured only when mineral fertilizers were coupled with manure. There is plenty of evidence that organic inputs from crop residues, animal manure, and green manures may increase fertilizer efficiency as well as crop yields across a broad range of soil types and climates. Certain legume plants boost P availability while simultaneously biologically fixing N at little expense, increasing crop yields. When fertilizer was supplied to maize following a grain legume in rotation, or a maize-legume intercrop, as opposed to continuous maize, grain yield profitability rose by 50% or more. Yet, there are several obstacles that prevent farmers from using legumes as green manures, including the need for a lot of effort and the scarcity of seed. The positive impacts of fertilizer application may be enhanced by efficient water conservation. When fertilizer and tied ridges were used together, sorghum grain yields in Burkina Faso were greater than when fertilizer or tied ridges were used separately. When planted on 1.5 m tied ridges in Zimbabwe, sorghum yields rose from 118 to 388 kg ha-1 and to 1,071 kg ha-1 after 50 kg N ha-1 were applied to the tied-ridges during a low rainfall season. The cropping system also affects how effectively nitrogen is used; for instance, in West Africa, mean grain yields for 4 years were lower for millet-cowpea and millet-groundnut rotations than for continuous pearl millet cropping supplied with 45 kg N ha-1. Similar findings have been observed for Zimbabwe's maize-cowpea cycle. In Malawi, maize after pigeon pea had an average grain yield that was 2.8 t ha-1 greater than maize following maize with an application of 35 kg N ha-1 yr-1 [10].

Evidence shows that crop yields decreased over time when just mineral fertilizer was used in the context of N fertilization. This was probably caused by nutrient mining, since greater grain and straw yields take more nutrients from the field than are provided, increased nutrient loss owing to volatilization and denitrification, and SOM reduction. There is a fundamental disconnect between the available fertilizer management options and resources and the issues faced by the farmers in regions of dry areas of Africa. In Burkina Faso, fertilizer N application to mono-cropped sorghum accelerated the annual rate of SOM loss from 1.5% without fertilizer to 1.9% with moderate rates of N fertilizer, and 2.6% with high N rates. Instead of concentrating on broad package recommendations that would merely optimize returns, it is smarter to provide gradual and adaptable suggestions that take into consideration the available resources and predicted cost-effectiveness.

The average amount of fertilizer used by farmers in sub-Saharan Africa is still approximately 10 kg ha-1, despite the fact that research on fertilizer usage has mostly examined very modest changes in kinds and typically high rates of expensive fertilizers. While there are strong grounds for increasing fertilizer usage in Africa, this cannot happen until the problems smallholder farmers confront are resolved. Since agricultural production cannot be increased with N fertilizer during years of low rainfall, the extremely unpredictable climate in the semiarid tropics raises the economic risk associated with fertilizer investment. By using a "responsive farming" strategy, which adjusts split fertilizer applications to anticipated rainfall events, this risk may be reduced. This strategy utilizes early rainfall events to determine the N fertilizer rates for the next season.

Moreover, when fertilizer applications are paired with techniques for preserving soil moisture, such as growing the crop on tied-ridges, production gains may result. Responsive farming in Zimbabwe boosted maize yields by 25–42%, generating 21–41% more profit than the previous fertilizer prescription method. The earnings of participating farmers were 105% greater in years with excellent rainfall than those of a control group of local farmers who were similarly successful. In addition to N, P plays a crucial role in crop development, especially in West Africa's acidic soils, and it focuses on the search for more acceptable and affordable fertilizer alternatives. P shortage in acidic soils has been shown to be corrected, as well as a positive residual impact, by direct application of reactive pebbles that have been pulverized. When P rocks were investigated, Tilemsi and Tahoua showed promise as soluble imports of P fertilizer substitutes. The low-reactivity phosphate pebbles' performance was enhanced by partial acidulation.

The implementation of regulations that ensure fertilizer supply and credit lines at accessible rates, as well as guaranteeing stable market conditions and appropriate product pricing, is arguably more crucial than technological advancements in N and P usage practices. In semi-arid areas of India, it is often advised to drill or apply the basal treatment 5–10 cm deep in the root zone for rain-fed crops. A part of the N dosage, as well as all P and K, are delivered basally during the rainy season. It is advised to apply adequate quantities of fertilizers for the whole crop season basally during the dry season when little or no rainfall is predicted. The proposed fertilizer placement strategy may increase output by 340 to 1,500 kg grain ha-1. Split application is crucial to achieving high fertilizer N usage efficiency and preventing harmful fertilizer effects during dry periods. The amount and time of fertilizer application must coincide with the pattern of rainfall; depending on the stage of crop development, 2-3 split applications are advised. In rain-fed crops, split applications of fertilizer N and drilling and band placement of fertilizer P result in significant improvements in crop output and nutrient usage efficiency [11].

The monitoring of all plant nutrient flow paths in agriculture is a component of integrated plant nutrient delivery systems, which are promoted in arid and semiarid parts of India. It entails the strategic and integrated use of organic manures, biofertilizers, and fertilizers as well as the development of legume cropping systems. Legumes, such as the twigs of N-fixing trees, are a crucial part of the integrated plant nutrition delivery system and may occasionally be as effective as 40–80 kg urea N ha-1. Similar results were obtained when loppings and twigs from N-fixing trees like Gliricidia maculata or Leuceana leucocephala were combined with urea in a 1:1 ratio. Finger millet production was stabilized at roughly 3,400 kg ha-1 after the application of 10 t FYM ha-1 and recommended fertilizer rates, with a crop yield index of 0.66 as opposed to 0.36 when just chemical fertilizer was used. Finger millet grain output decreased as a consequence of the continuous application of chemical fertilizers, falling from an average of 2,880 kg ha-1 over the first five years of the research to 1,490 kg ha-1 by the 19th year. In Vertisols, applying crop wastes for 50% of the prescribed fertilizer dosage and Leucaena leucocephala lopping for the other 50% increased the sorghum yield by 87, 31 and 45%, respectively, in comparison to applying 25 kg N ha-1 and 50 kg N ha-1 as fertilizer.

China is dry and Semi-Arid

Fertilizer is the most expensive agricultural input in China, and increasing usage of chemical fertilizer in dryland farming has already raised grain yields by a factor of two. FYM was the primary source of applied fertilizers prior to the 1970s. While the usage of fertilizer is rising, the N to P ratio is greater than the suggested ratio of 1:0.3 for dryland crops. In China's semi-arid areas, excessive N fertilizer usage, insufficient P and K fertilizer use, and disregard for organic manures are typical aspects of nutrient management. As a result, agronomic and recovery efficiencies of applied nutrients are extremely low, and yield responses to fertilizers are also quite poor. The predominant source of nitrogen fertilizer has been ammonium bicarbonate, which has a lower N usage efficiency and greater NH3 volatilization losses than urea. The majority of China's fertilizer-crop yield studies were short-lived and hence offered few information. Using chemical fertilizers and organic manures, when accessible, multiyear field experiments are required to provide more effective nutrient management recommendations in relation to the common rainfall regimes. Crop rotations, green manures, and grain legumes should all be included in that plan. In order to fully utilize the crop-growth factors, such as light, heat, and water, to achieve increases in yield efficiency and farmer incomes, it is important to adopt fertility-enhancing rotations, such as a grain crop with a summer green manure crop, a grain-oilseed-legume rotation, grain-legume intercropping, grain-grass intercropping, or wheat-potato intercropping. Northern Great Plains: USA and Canada

The most significant agricultural area in Canada is the semiarid prairies, which are both Typic and Aridic Borolls. Prairie soils are fresh and rich by nature. Therefore, fertilizer for crops is mostly needed for N and P, with S and K less often needed. Cereal farming has historically dominated this area, notably hard red spring wheat grown either in monoculture or with different amounts of summer fallow. The area used for cultivating cereals has been rather stable during the last 30 years, while the summer fallow land has steadily decreased and been replaced by pulse and oilseed crops. The output of oilseeds and pulses like canola, dry pea, and lentil has steadily increased as a consequence of the recent economic benefits of crop diversification, major advancement in crop breeding, and enhanced management techniques. Crop yields are limited by minimal precipitation, necessitating little fertilizer input. Farmers are switching to more intensive crop management techniques, such as minimal or zero tillage, from traditional stubble mulch tillage. The availability of soil water and nitrogen in the northern Great Plains of the United States and Canada, as in other semi-arid locations, often limits crop yield.

For example, cutting stubble tall to trap snow, choosing new crop types, and using extended and diversified crop rotations are all new or alternative crop production options that have been made available to farmers in this region. Many of these options improve overwinter water storage and water availability, lower crop evapotranspiration, lessen crop soil degradation, and increase grain yields. Moreover, it has been shown that, in contrast to the widely utilized fallow-wheat method, fertilizers used wisely, directed by soil testing, and appropriately distributed in the soil at or near the point of sowing will boost crop productivity and grain quality [12].

Many investigations have been made to determine how N and P affect yield, grain quality, water use efficiency, and N use efficiency in the semiarid grasslands of North America. According to the findings of a 44-year experiment that was first conducted in 1967, yield responses were higher after 1990 than they had been prior to that year. This is due to better precipitation in the case of P treatments and to increased precipitation as well as increased N in the case of N treatments. Water availability determines how much of an impact fertilizer has on output, and there is often a beneficial relationship between these two elements. For instance, Henry et al. showed how the relative relevance of water and N fluctuates according on the level of stress that each element places on the system. The contribution of the interaction factor is as great as or larger than the impact of the individual variables when these two factors are altered across any discernible range. Utilizing the long-term experiment at Swift Current's water shortage study, WUEs in the rotation experiment were typically higher for treatments that included N + P fertilizer, and they were at their highest after an increase in N application together with a favorable soil moisture environment in the study's final decade. When water availability was increased more than N rates were raised in a semi-controlled mini-lysimeter experiment conducted at Swift Current to examine the effects of water and nitrogen rates on stubble crop wheat yields, WUE rose. To improve overwinter soil water collection and decrease in-crop evapotranspiration, scientists in this part of Canada have shown that using no-tillage management in conjunction with snow trapping is an even more sustainable management strategy. It was shown that continuous cropping and no-tillage management might have even bigger beneficial benefits of fertilizer on WUE in semiarid grasslands.

CONCLUSION

There is no irrigation water available in a vast portion of the world's arid regions, and crops grown with just rain have poor and unreliable yields. Since that 60% of the world's population lives in drylands and relies on crop cultivation and livestock for both food and income, food security in these places is essential. The drylands are already vulnerable to temperature extremes, but the IPCC predicts that they will also be adversely impacted by climate change. In arid places with high WUE, the provision of even little quantities of water may result in a noticeable boost in agricultural yields if other conditions, including appropriate plant nutrient availability, are met. Through the use of low-cost, low-risk land and water management strategies, it is possible to provide crops with this extra water from the local rainfall in a number of ways. Infiltration may be enhanced and runoff can be utilised more effectively by pitting or tying ridges and roughening up the surface. With a reduced-tillage system, maintaining a cover of crops or crop leftovers on the soil may be even more efficient. If implementing these tactics is not feasible, crop moisture requirements may be met throughout the growing season by using water collection techniques like runoff farming. Because rainfall is sparsely distributed throughout the year, capturing rainwater during a fallow time and storing it in the soil for use during the succeeding agricultural season may also be effective. Manure application may enhance WUE and water infiltration.

Using the synergy of soil and water conservation measures, fertilizer availability via mineral and organic sources, and rain-fed conditions' sustained production in arid places. Nutrient balances for many agricultural systems are negative, which suggests soil mining. To better understand and stop this tendency, agricultural research and development faces a fundamental challenge. Due to socioeconomic limitations, only a tiny percentage of smallholder farmers in arid regions utilize fertilizers. As a consequence of intense agriculture and imbalanced fertilizer application, increased nutritional shortages in N, P, and other nutrients are to be predicted. The utilization of locally accessible organic resources as nutrition sources will continue. High nutrient utilization efficiency is achieved by placing fertilizers at depths, however newer technology and equipment are required. Strategies like "response farming," which uses early rainfall events to decide the amount of fertilizer for the approaching season, and "split fertilizer applications" that are adjusted to the expected rainfall events, need to be promoted in order to prevent the application of too much fertilizer during the years of low rainfall. Future studies focusing on increasing the effectiveness of water and nutrient usage in arid locations where farming families are mostly food insecure should aim for active farmer engagement, longer time horizons to properly examine residual impacts, and thorough economic analysis of findings. There is a need for more investment for rain-fed agricultural research and development.

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CHAPTER 8

INCREASED WATER AND NUTRIENT EFFECTIVENESS IN IRRIGATED AGRICULTURE

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ABSTRACT:

Without significant increases in both water and nutrient efficiency, the problem of feeding a growing world population cannot be met. A substantial consumer of freshwater resources and a crucial factor in food production is irrigated agriculture. Although while simultaneous application of fertilizers and water has considerable potential to increase productivity, it must be carefully managed. Fertigation is a great way to accomplish these objectives because, when done correctly, it can give the right quantity of nutrients and water. Any irrigation technique that enables the supply of both water and dissolved nutrients to crops may be used for fertilization. Yet, even water distribution is crucial since uneven irrigation systems may lead to areas of over- or under-watering.

KEYWORDS:

Agriculture, Fertilizer, Food Security, Management, Nutrients.

INTRODUCTION

Proper management of nutrient applications, including the correct source of fertilizer supplied at the right application rate, at the right time, and in the right area, may increase fertilizer efficiency. For instance, soluble nutrient sources are ideal for fertigation, but other less-soluble sources work well when applied to soil under irrigation. Fertigation makes it simple to modify the rate of fertilizer administration to suit crop demands. Another crucial method for increasing effectiveness is timing the application of fertilizers and water throughout the crop development phase. Many fertigation methods enable the placement of water and nutrients near to plant roots. It has been consistently shown that using these 4R strategies increases crop yields while enhancing both water and fertilizer efficiency. Providing for the rising need for food while preserving a healthy environment is a big problem for the expanding global population. To do this, it is necessary to preserve and use limited resources as effectively as possible. There are many places in the globe where it is possible to increase agricultural output in a sustainable way while also preserving resources.

The management of water and plant nutrients is one of the main causes of the enormous yield difference between high-productivity farmers and "average" farmers. Crop yields will grow as we make progress in better managing water and fertilizers. As urbanization, sanitization, groundwater availability, and environmental restrictions change, the availability and quality of water will continue to be key worldwide challenges. The usage of agricultural water and urban rivalry with crop and animal production are two major factors in many of these problems. Improved agriculture water usage would aid in achieving many social objectives since irrigated crops require a lot of water [1].

Almost 70% of all water withdrawals worldwide are used for irrigation. Farmers will need to become increasingly adept at growing crops with a restricted water supply as a result of the unavoidable rivalry between agriculture and other users of scarce water resources. Moreover, because 20% of all cultivated land is used for irrigated agriculture, which produces around 40%

of the world's food supply, demand to expand irrigated agriculture will increase. The 40% of the irrigated land employs groundwater sources, however the majority of the irrigation water now used comes from surface sources. While groundwater may be a dependable supply of water for home and agricultural use, groundwater levels have been quickly declining in many areas. Also, this significant overdraft of water might lower river base flows and harm aquatic ecosystems. In many regions of the globe, treated wastewater is presently used for irrigation to extend scarce water supplies. This resource has the potential to significantly contribute to the supply of agricultural water if properly processed. Recycled water will be utilized more often to irrigate both edible and non-edible crops as water needs rise. Significant amounts of untreated wastewater are also used in unauthorized ways, particularly in underdeveloped nations.

Efficient use of water

Due to the significant quantity of water that is transported from roots through the plant to leaves where it is transpired, the relationship between soil moisture and crop development is crucial. For one kilogram of dry matter to be produced by several popular crops, between 300 and 800 kg of water must be used. To generate one kilogram of harvested grain from major worldwide grain harvests, between 1,000 and 3,000 kg of water are needed. The amount of water that is really utilized for transpiration varies depending on the environment. Just a little portion of the rain that falls on crops that are fed by the rain as little as 5% is utilized directly for transpiration. The percentage of applied water that is utilised directly by plants in irrigated agriculture is often greater, yet it may also be low in various circumstances. The water uptake ratio may be raised using a variety of methods [2].

Any increases in water use efficiency must, to the greatest extent feasible, be linked to increases in agricultural output; nevertheless, WUE should not be a goal in and of itself. Improved WUE objectives should be taken into account as part of an all-encompassing crop production package that also takes into account relevant elements such tillage methods, nitrogen management, resource conservation strategies, and pest and weed control. All of these management techniques enhance the amount of crop that is harvested per unit of water contributed, but real advancement will only be made if more grain or harvested goods are produced per unit of water transpired.

DISCUSSION

Linking Plant Nutrients and Water

Fertigation is the process of supplying crops with nutrients from fertilizer in irrigation water. By precisely managing the rate and timing of water and nutrient supply, fertigation has regularly been shown to boost fertilizer efficiency and crop development when carried out correctly. The most popular additional nutrient utilized in fertigation is nitrogen fertilizer, although with the right management, any plant nutrients may be supplied. As nitrogen is the nutrient that is most often needed in the highest concentration and is easily lost from the root zone with water, it is the nutrient that is mostly covered in this chapter. The simultaneous control of nitrogen management and water consumption is necessary due to the strong relationship between the two. It is often possible to increase nitrogen usage efficiency by carefully giving enough nitrogen fertilizer as near to the time of plant requirement as is practical. Fertigation is well adapted to do this, and because the right quantity of nutrition can be delivered at the right time, it may consequently decrease nutrient losses.

The greatest crops for fertigation efficiency increases may be those whose yields respond strongly to nitrogen fertilizer. For both annual and perennial crops, this may be successfully achieved by avoiding the often used relatively high fertilizer rates that are administered at the time of planting or in a single mid-season treatment. Several applications considerably limit the possibility of fertilizer N loss. Several horticultural crops might be difficult to optimize for water and nutrition since both yield and quality must be taken into account. For these crops, the idea of maximum economic output is particularly crucial. For instance, a plant of average size could be produced by a limited quantity of nutrients and water, but there might be no commercial output. While choosing the procedures that will result in the highest yield or most marketable product, growers of high-value crops must concurrently balance a variety of considerations.

Both of these yield targets may be comparable since many of these crops have economic worth that is far more than the cost of fertilizer. It is challenging to take into account any negative environmental costs related to inefficient water or fertilizer consumption, yet these externalities must be taken into account. Controlled-deficit irrigation is becoming more popular. This method deliberately withholds water at certain periods of crop growth in order to save water while yet achieving sufficient yield and quality. A number of crops have successfully used this purposeful water stress strategy in closely supervised environments. The use of controlled-deficit irrigation most often researched in perennial crops, however if it is not done correctly, a considerable loss of productivity and vigor might result. Using CDI on short-season crops without affecting production or quality is more difficult, although it is possible for certain crops when they are at the right development stage. Applying CDI may make fertigation procedures more difficult since water stress is generated on purpose and is separated from real nutritional needs [3].

Uniform Water Application

Each irrigation system must take into account the uniform distribution of water across a field. Non-uniform irrigation systems cause areas of over- or under-application. While a well-thought-out irrigation system may maximize consistency, competent administration and routine maintenance are still necessary. The least amount of water should be lost by evaporation, runoff, or subsurface leaching. The consistent application of water may be maintained by keeping correct pressure, maintaining proper lateral line spacing, fixing leaks, and replacing broken equipment. Water distribution patterns may also be distorted by irrigation during severe winds.

It's crucial to apply water evenly and at the right rates to reduce nutrient percolation losses. Inappropriate water usage has the potential to negate any gains in nitrogen fertilizer management. The capacity of farmers to manage water in response to changes in climatic circumstances and the geographical variability of the soil determines how much nitrate leaching may be decreased in irrigated farming situations. Farmers' capacity to lower nitrate-leaching losses is significantly improved when they are able to apply nitrogen many times during the growing season. The rate of water infiltration and water-holding capability of the various soils within a field must also be taken into consideration while applying water.

The capacity to plan water supply according to crop needs is also a crucial factor, even though delivering the proper quantity of water in the right spot is crucial for maximum efficiency. Reaching this objective is not always an easy process. It entails fusing the currently available irrigation technology with current understandings of soil moisture, soil water-holding capacity, present and anticipated plant transpiration, and traits of the root system of the plant. Simple approaches and complex sensor networks that continuously monitor soil moisture via the soil profile and report over a wireless network to a central hub are both used to assess the water condition of a particular field. The acceptable level of complexity for these strategies will vary globally.

Climate factors and crop canopy growth are used to predict local water needs. To calculate crop evaporative requirement or soil moisture depletion, a variety of good approaches have been developed. The intentional addition of extra water must be taken into consideration while applying water. When nitrate levels in the soil are low, intentional leaching should mostly take place. For nutrient management to be improved, it is crucial to comprehend the necessity for water application and then exactly give that quantity.

Irrigation Techniques

Any irrigation technique that enables the transport of water and dissolved fertilizer to crops may be used with fertilization. Just allowing anhydrous ammonia to gently bubble into a ditch or canal before the water hits the agricultural land was one of the early fertigation methods. For this method to effectively spread nitrogen fertilizer over the field in furrows or in a flood condition, irrigation water must be applied consistently. Nutrient delivery cannot be more uniform than water distribution. Both upland crops and flooded paddies may employ this strategy. While there is sufficient evidence that this method typically leads to uneven nutrient administration, there is still some attraction in its simplicity. These surface irrigation techniques are improving at evenly dispersing water and dissolved nutrients as accurate land-leveling technology becomes more prevalent. Pressurized irrigation systems are increasingly often employed with modern fertigation. They may consist of various micro irrigation methods and overhead sprinkler systems [4].

Sprinklers in the Air

This sort of irrigation uses a range of tools, such as self-propelled systems, mobile sprinklers, and solid-set sprinklers. These systems are vulnerable to relatively significant evaporative loss and potential off-target applications since they apply water to the whole region. Compared to surface watering methods, sprinkler approaches often provide a more even distribution. Application efficiency can reach 0.9 or higher with correct design and system maintenance, however windy circumstances often make it difficult to reach this potential.

Self-propelled center-pivot and linear-move rolling sprinkler irrigation systems are the most used in the United States. These systems are well-liked because they can quickly cover a huge area, do not obstruct field work, and need less upkeep than microirrigation systems. Large fields are a good fit for them, and they may be modified for site-specific variable water and fertilizer delivery via nozzle controls, accelerating or reducing the rate of supply, or both. The pivot point of the center-pivot irrigation system is fixed. The whole span's length may vary from 60 to 800 meters. The sprinklers' water delivery rate is altered over the span, becoming faster the farther you are from the pivot point. Middle pivot with a typical uniformity coefficient between 0.7 and 0.9, systems may exhibit excellent uniformity under the right circumstances. While it is simple to adjust overhead sprinkler systems to add chemicals and fertilizers, the enormous amounts of water in comparison to the additional fertilizer result in a comparatively diluted solution. Thus, fertigation is a poor method for delivering foliar nutrients. The majority of the nutrients added by fertigation are first rinsed off the leaves before entering the soil.

Nutrient inputs often maintain a steady concentration of soluble fertilizer in the water in sprinkler irrigation systems. To obtain a variable rate of application, more or less of the water containing the fertilizer may be sprayed over the field, but this also leads to a variable rate of water application. The best solution for optimizing both water and fertilizer consumption is a center pivot system with separate management of water and fertilizer. Systems that apply both fertilizer and water via different delivery lines in a single irrigation system are currently being developed. The variety of soil characteristics present in a single field might result in an inadequate water application when irrigating big areas. For instance, changes in the rate of infiltration, water-holding capacity, subsurface conditions, and topography may all result in the application of an excessive quantity of water and soluble fertilizer at a single uniform rate.

It may be as easy as not overirrigating naturally drier parts of the field, avoiding overapplication on slopes to prevent runoff, and choosing the right sprinkler head to match the irrigation design to adapt site-specific approaches for overhead irrigation systems to optimize water efficiency. The control of end guns, managing the start and stop points, and modifying the sprinklers have all been used to further manage the water flow. With this sort of irrigation system, there is potential for even greater advancements in site-specific water and nutrient delivery since many center-pivot systems use a high degree of automation and have a broad coverage area with a single pipe.

Irrigation via drip

The efficiencies from more accurate water distribution have been a major factor in the quick adoption of micro-irrigation in agriculture. Nonetheless, the benefits of delivering nutrients and water at the same time are also well acknowledged. Several studies have noted the various advantages of fertigation over fertilizer broadcast treatments. Nonetheless, surface or sprinkler irrigation methods are still used to water the bulk of crops. Drip and trickle irrigation systems come in a number of forms. The main idea is to give water at a relatively modest application rate near to plant roots, with only partial soil wetting, in time with transpiration needs, with little soil surface evaporation loss, and with little deep percolation. Drip irrigation has an application efficiency of up to 0.9, compared to sprinkler irrigation's 0.6 to 0.8 and surface irrigation's 0.5 to 0.6. Drip irrigation also made it possible to cultivate crops on land with sloping topography that was previously impractical to water. There are several instances when farmers were able to quadruple the amount of area they were able to irrigate by switching from flood to drip systems [5].

Early adopters of drip irrigation were primarily motivated by the need to save water and save labor expenses, but enhanced crop yields and quality have now emerged as crucial considerations in adoption. When water is scarce and expensive, or when farmers and urban water users compete for scarce water resources, drip irrigation will continue to take the place of surface irrigation since it increases production and quality while lowering expenses. The use of drip irrigation systems is quickly gaining popularity as a means of achieving many agricultural production objectives, even in less developed nations. The ability to more easily maintain a good balance between soil water and soil aeration is another benefit of drip irrigation. The soil may momentarily get soggy with furrow and flood irrigation, which will reduce the oxygen supply to plant roots. Essential plant nutrients are carried away by the surplus water that unavoidably drains from the soil.

Plant root distribution in the soil will be affected by changes in how water is delivered to crops. A greater root system normally grows when a larger amount of soil is watered. The maximum root density forms in a specific area close to the water source when drip irrigation applies water to a small area of soil. For drip systems to maintain their high efficiency, continuous monitoring and maintenance are necessary. Even with intensive water filtering, emitters may get clogged and leaks might arise from mechanical damage. Salinity building has to be watched out for since it may happen at the wetting front's edge in the soil. It's possible that the soil wetness patterns created by drip systems are insufficient for seeds to germinate, therefore certain crops may need additional watering during the establishment period. By placing the drip system below the soil's surface, you may provide water and nutrients right to the root zone while also reducing soil evaporation. For a number of crops, simultaneous supply of water and nutrients to the roots has been demonstrated to be beneficial, reducing nitrate-leaching losses.

It is crucial to maintain a constant supply of moisture and nutrients during the whole development cycle since subsurface drip irrigation might limit the expansion of the root system to the wetted volume of soil. Throughout the germination and seedling stages of production, the spacing and placement of SDI lines might be crucial. While the usage of SDI systems may span many years, they may necessitate modifications to certain agricultural practices, such as tillage.

Micro-Sprinklers

For the purpose of irrigating perennial crops, micro-sprinklers are now often used. Little sprinkler heads come in a variety of designs and spray water in different directions. The typical flow rate is between 10 and 100 l per hour. They work best for irrigation of perennial crops since such plants have long-lasting root systems. The wetted area of micro-sprinklers is far bigger than that of a drip emitter, giving the root system a broader soil volume to explore. On a soil with a coarse texture where lateral water transport is restricted, this broader wetting pattern may be particularly significant. Drip systems provide water at a slower pace than micro-sprinklers, but an irrigation event often lasts less time, giving managers more management flexibility. Evaporation losses may be a little greater with micro-sprinklers than with drip or SDI systems since they spray water into the air. Equipment costs may initially be higher for micro-sprinklers than for drip systems due to the higher water application rates.

Effective Fertigation

The simultaneous application of water and plant nutrients has the potential to boost plant development and increase the productivity of labor, water, and fertilizer. Nonetheless, more management, training, and experience are needed. The absence of technological assistance prevents this kind of fertilization from being used more widely in many areas. The design features of the irrigation system, the chemical qualities of the soil, and other factors must be considered when choosing particular nutrient sources for use in fertigation [6].

The features of the particular fertilizer, irrigation water, and the plant's dietary requirements. Fertilizers used in irrigation water applications must be soluble in water and not chemically react with the water to produce precipitates that might clog irrigation equipment. There are several top-notch soluble nitrogen sources that may be used for fertigation. As potassium is not very mobile, with the exception of sandy soils, and is not prone to complicated chemical reactions in the soil or water, potassium fertigation is comparatively straightforward. As many phosphorous fertilizers are not easily soluble, have restricted soil mobility, and quickly create insoluble precipitates with calcium and magnesium in irrigation water, applying phosphorus with irrigation water is more difficult. Nonetheless, by paying strict attention to these difficulties, many farmers effectively fertigate using phosphorus. The recovery of plant nutrients will also depend on the irrigation technique used for fertigation. For instance, Edstrom et al. irrigated almond plants with three different irrigation methods using different potassium sources. They discovered that the trees recovered the most from potassium administered by micro-sprinklers, followed by a dual tube drip system and finally a single drip tube. They explained these variations by the amount of damp soil present underneath the trees.

Nitrogen Control

By carefully delivering inorganic nitrogen as near to the period of plant need as feasible, nitrogen utilization efficiency may be increased. This objective is easily accomplished by fertilization, which also reduces nutrient losses due to leaching. By using this method, it is prevented that there will ever be an excess of inorganic nitrogen in the soil, which might lead to unforeseen leaching loss. The relationship between nitrogen and water management necessitates precise coordination of the two. By avoiding the relatively large fertilizer treatments that are generally done at planting or in a single mid-season application, crops with a relatively high nitrogen demand may be best suited for efficiency increases via fertigation.

Managing nutrients with the 4Rs

By utilizing the correct source of fertilizer, administered at the right application rate, at the right time, and in the right area, it is possible to significantly increase nitrogen efficiency. All instances where fertilizers are utilized for crop development call for the adoption of the 4R principles of nutrient management. The final destiny of soil nitrogen is influenced by a number of variables, including the source of the fertilizer, the rate of application, water management, crop absorption, microbiological activities, and the soil's ability to leach nitrogen. Since nitrate is soluble, it tends to travel to the edge of wet soil; as a result, methods that restrict the amount of wet soil and prevent applying too much water may reduce nitrate-leaching losses [7].

Right Source

Fertigation enables the targeted supply of nutrients to crops, but it is important to comprehend the behavior of the right fertilizer source. A typical fluid nitrogen fertilizer, for instance, splits the total nitrogen content equally between urea, ammonium, and nitrate. The nitrate and urea in this liquid fertilizer may see beyond the root zone if it is applied in the early stages of an irrigation event. When UAN fertilizer is applied late in the irrigation cycle, it may not be evenly distributed throughout the soil and may linger in the irrigation line, where it may encourage the formation of algae that clogs the system. Adding fertilizer solution containing UAN to drip irrigation during the middle 50% of the irrigation cycle resulted in the optimum distribution of the fertilizer through the moist soil. They advised applying the UAN fertilizer for underground drip systems close to the conclusion of the irrigation event to enable urea and nitrate to build up in the zone with the maximum root density. Compared to urea and nitrate, ammonium exhibited the least initial mobility from the drip emitter.

Several simple or complex analytical monitoring technologies may be used to improve in-season fertilization rates. Electronic sensors, for instance, may monitor plant tissue health and soil nitrate concentrations, enabling producers to adjust nitrogen treatment. Schepers et al. showed how nitrogen fertigation rates for maize might be modified by monitoring crop demands using a chlorophyll meter and center-pivot systems. According to their findings, fertilizing based on readings from chlorophyll meters resulted in yields being the same while saving 168 kg of nitrogen per hectare in the first year and 105 kg in the second. Depending on crop and fertilizer pricing, the use of these sensor-based solutions may be more lucrative than applying nonprecise fertilizer.

A practical technique to track progress toward obtaining the correct rate is using nutrient budgets. Budgets solely take into consideration the rate of application, which might result in inaccurate assessments of nutrient stewardship. Budgets may be helpful indications of system improvement trends, but relying too heavily on them can prevent you from taking into consideration the wrong combinations of nutrition supply, rate, time, and site. Making major strides in increasing overall efficiency calls for an integrated strategy to the management of water and nitrogen. Many fertilizer options are influenced by the crucial factor of applying the right quantity of irrigation water. While fertigation is sometimes referred to as "spoon feeding," Obreza and Sartain caution gardeners that if water is supplied excessively, the additional "correct quantity" of nitrate will still be moved beyond the root zone. It is known that during a heavy downpour, a significant amount of dry nitrogen fertilizer applied to the soil surface may be exposed to a variety of losses. Yet, the same volume fertigation, a process that results in the loss of nitrogen fertilizer in numerous, little doses, if excessive water is frequently administered in an improper manner.

Right Moment

The danger of nitrate loss from excessive watering or during rain events may be decreased by having the option to administer many minor amounts of nitrogen throughout the growth season. Crop productivity and quality may also be increased by timing fertilizer applications to correspond with plant needs. Growers can immediately react with the right timing of nutrient administration that is linked with crop need thanks to fertilization capabilities. In addition, they react to alterations that take place during the growth season and to unanticipated nutritional deficits. For instance, a three-year study of irrigated crops produced between the French Alps and the Rhone Valley revealed that only 30% of the additional nitrogen was used successfully by the crops. The main cause of this inefficiency was incorrect application timing, when nutrient treatments were not adequately synced with crop needs [8].

Fertigation advantages include the ability to time fertilizer administrations more flexibly in response to growth circumstances. Nitrogen treatments may be readily changed to match plant need or account for weather-related factors, even though there are often no benefits to daily fertigation compared to weekly fertigation. Applications of nitrogen should be made in accordance with crop development and nutritional requirements. For instance, the first half of the cropping period is often characterized by poor growth and nitrogen absorption in many cool-season vegetable crops. The nitrogen intake rate rises throughout the second part of the growth season, and it may eventually reach a requirement of 3 to 5 kg N ha-1day-1. Several plants have the capacity to store more nutrients than are required at one moment and remobilize them later in the growth season. This accumulation allows for some time flexibility, reducing the requirement for too complex nutrition supply procedures.

Right Position

Nutrient placement close to the root zone is another crucial step for increased effectiveness. In shallow-rooted crops, where excessive irrigation may quickly transport soluble nutrients under the root zone, proper placement might be particularly crucial. If adequate water and nutrients are present in the soil, root systems have a tendency to grow rapidly. The biggest concentration of tomato roots was discovered close to the soil surface, close to the SDI line. Enhancing efficiency starts with applying water and fertilizers so that they are strategically close to the roots.

Keeping an eye on nutrition and water

Documenting efficiency gains is challenging because it is not practicable for farmers to detect nitrate migration through the soil profile during and after irrigation activities. In-depth soil sampling, soil solution extraction, and lysimetry are often used by researchers to quantify nitrate transport, however most farmers cannot employ these methods. Many computer systems have been created to help farmers achieve profitability with the least possible negative effect on the environment due to the intricacy of monitoring the crop, soil conditions, and water availability. These comparatively simple modeling tools provide practical recommendations for better water and nutrient management. It is commonly known that employing evapotranspiration as a scheduler for irrigation may assist prevent water from being applied incorrectly. When more water is provided than ET, nitrate leaching will inevitably rise. There are various effective strategies [9].

The University of California's Nitrate Groundwater Pollution Hazard Index is another excellent tool that may be used to forecast how susceptible an irrigated land is to nitrate leaching. To estimate the relative vulnerability to nitrate loss, the index incorporates site-specific information on the soil, crops, and irrigation. Several management methods are given to lessen the possibility of nitrate loss by leaching based on the computed findings. The CropManage program from the University of California offers another another useful example of how to manage water and nitrogen at the same time.

Undoubtedly, improvements in water and fertilizer management will result from advancements in soil moisture monitoring. For instance, Zotarelli and Dukes et al. observed that the application of irrigation water via a drip system was decreased by up to 50% when soil moisture sensors were used in comparison to the regularly scheduled irrigation methods. They claimed that sensor-based irrigation may significantly increase crop water utilization while lowering nitrate leaching and deep percolation.

Localized Fertigation

There are opportunities to enhance irrigation systems so that water and fertilizers may be applied just where they are needed throughout a field. With this development, microzones would be able to be independently managed, allowing for the spatially appropriate administration of water to any particular crop or soil condition. With the advancement of irrigation technology, this field of study is continually being improved. By opening and shutting valves, delivering a site-specific amount of water via an irrigation system is comparatively easy. This procedure may be carried either electronically or manually by field personnel. As fertilizer must be injected during the irrigation process, controlled nutrient delivery using water is more difficult. To provide independent control over each input, separate systems for the supply of water and nutrients may be necessary. Adoption is still hampered by the difficulty and price of installing several valves and switches [10]–[12].

CONCLUSION

It is obvious that with more careful management, large-scale improvements in the utilization of water and plant nutrients may be accomplished for agricultural output. Any advancements in fertilizer management must be combined with any gains in water usage efficiency for irrigated agriculture. There are various ways that these advancements may be used to the production of irrigated crops, but they all call for a higher degree of expertise and considerable advancements in crop management abilities. Reaching out to local and regional water and nutrient management specialists may hasten the implementation of these crucial ideas to accomplish these urgent aims.

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CHAPTER 9
MANAGEMENT OF NUTRIENTS AND FERTILIZERS IN RICE SYSTEMS WITH VARIED WATER SUPPLIES

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ABSTRACT:

Rice production across the world is largely reliant on the usage of fertilizer, irrigation, and high-yielding rice cultivars that are well suited to the environment. 90% of the world's rice-growing land is periodically or continuously submerged in rainwater and irrigation-generated water. A conducive environment is created for prolonged, continuous rice production through soil submersion and the resulting limitation of soil aeration. Submerging the soil in water reduces weed growth, modifies soil biological and chemical processes, increasing the amount of soil nitrogen and phosphorus that is accessible to plants, and preserves soil organic matter. Future rice cultivation will need less irrigation water due to competing non-agricultural uses. Increased air penetration into the soil would result from a comparable decrease or removal of soil submergence and saturation during rice cultivation.

KEYWORDS:

Agriculture, Fertilizer, Food Security, Management, Nutrients.

INTRODUCTION

This may reduce the amount of soil N and P that is accessible to plants, requiring more N and P fertilizer to get the desired yield. Reduced soil submergence may also make zinc and iron more readily available in calcareous soils while increasing zinc availability in acidic soils. Potassium is present in irrigation water, therefore when irrigation water input is decreased, crops may need more potassium fertilizer to grow. No matter how much the soil is submerged, N fertilizer has to be maintained to guarantee a sufficient supply of plant-available nitrogen to meet crop demand at crucial growth stages including tiller development and panicle initiation. Fertilizer use should be modified to meet the crop's need for additional nutrients at a revised goal yield when changes in water availability affect predicted crop production.

Using Rice and Water

The majority of people on planet consume rice, making it the most common basic meal. Every year, around 160 million hectares of rice are harvested in an estimated 117 nations. It grows in a variety of meteorological and hydrological situations. Asia is where almost 90% of the world's rice is produced. Over 90% of the world's rice-growing region has earthen bunds around the fields to collect rainwater and irrigation water, causing soil to sometimes or repeatedly get submerged in floodwater, often to a depth of 3 to 10 cm. Ecosystems reliant on rainwater alone or in conjunction with irrigation are included in this rice cultivation with intentional floodwater retention. Lowland rice, also known as wetland rice, refers to the method of growing rice on submerged soils rather than its altitude or geographic location. Paddy soils are those that are submerged for a long time in lowland rice cultivation systems that are both irrigated and rainfed [1].

The tropical wet seasons, which may saturate and drown the land due to heavy rains and extended periods of rain, make other main food crops unable to grow and survive. Rice is well-adapted to these conditions. A network of interconnecting air-filled spaces called the aerenchyma acts as a conduit for O2, which enters the plant from the atmosphere above the floodwater, to reach the stems and roots, allowing rice to withstand soil submersion. With the exception of taro Root, no other significant food crop has this channel. Rice has been grown sustainably for millennia at modest, but generally steady yields thanks to enough water for flooding the land. Modern high-yielding cultivars, fertilizer usage, and enough irrigation water for soil submersion were key components of the Green Revolution in rice cultivation. Around 75% of the world's rice supply comes through irrigation, which accounts for about 58% of the world's rice land. In tropical regions with high altitudes and moderate climates, rice is farmed once a year. In irrigated areas in tropical Asia, continuous rice farming with two and even three harvests each year is typical. In these situations, irrigation serves as a complement to rain during the rainy season, while irrigation is crucial for the rice crop during the dry season. Long-term tests show that it is possible to continue the cultivation of two to three rice harvests year by using a mix of newly released rice varieties that are resistant to pests and diseases, balanced fertilizer inputs, and enough irrigation to keep the soil submerged. In the subtropics of South Asia and China, rice is often grown in rotation with other crops, especially wheat. In tropical and subtropical Asia, the rice-maize cropping system is becoming more significant due to the rising need for maize as animal feed.

Almost 33% of the world's rice acreage is dedicated to rain-fed lowland rice, which supplies approximately 19% of the world's rice supply and is surrounded by earthen bunds to hold water. The time, length, and intensity of rainfall may vary widely in rainfed lowland rice habitats, leading to uncertainty and variability. Lowlands that receive rainwater are susceptible to both drought and unmanaged flooding, which may range from flash floods to continuous soil submersion beneath water that can be higher than the rice crop. The prevalence of soils with poor physical and chemical characteristics, such as soil salinity and acidity, results in further restrictions. Rice cultivation is mostly restricted to rain-fed locations with topographies varying from flat to steeply sloping without bunds for purposeful retention of water. This production method, known as "rainfed upland rice," accounts for over 10% of the world's total rice producing area but only contributes 4% due to poor yields. Except for short intervals after heavy or protracted rain, the earth is not waterlogged or swamped [2].

With an estimated 34–43% of the world's irrigation water going to rice, it is clear that rice is a significant recipient of irrigation water resources. Rice irrigation uses between 24 and 30 percent of the world's developed freshwater resources. A large portion of the world's rice is grown in nations with rapidly expanding economies. Economic expansion brings with it a competing demand for water consumption from homes, businesses, and other sectors outside of agriculture. Particularly in South Asia, groundwater has grown in importance as a source for irrigation. Yet, as groundwater tables decline in many places, the cost of pumping water rises and water supplies become scarcer. In certain irrigated lowlands, rice cultivation may thus expect future rises in cost and a shortage of irrigation water.

This may stimulate lowland rice cultivation with less water or encourage diversification to non-rice crops during the water-scarce season, which would cause lowland rice production to move to more water-abundant regions. Although a switch to more non-rice crops in a cropping system centered on rice would lengthen the period of soil aeration within the cropping system, the cultivation of rice with less water might minimize or eliminate soil submergence during the rice-growing season. Such increases in soil aeration and decreases in soil submersion might change biological and chemical processes inside soil, affecting nutrient availability and fertilizer needs. Land preparation and crop establishment procedures, which might vary with farm size, the availability of cheap labor, and access to technology, have a significant impact on water usage in rice cultivation. In Asia, where rice is often grown on fields with an area of less than one hectare, rice farming techniques have mostly depended on human labor, with small-scale automation becoming increasingly prevalent as labor becomes scarcer or more costly. On the other hand, large-scale machinery is necessary for the production of rice over enormous landmasses, such as those found in Australia, Europe, North America, and South America.

Establishment of Crops

In Asia, hand transplantation is used to establish a large portion of the rice on tiny plots of land. Before being planted in the main field, rice seedlings are initially nurtured in a seedbed for two to five weeks. Manual transplantation requires a lot of work. Mechanized transplantation may be an alternative to manual transplantation when prices and personnel shortages rise. Sowing germinated rice seed over the top of damp soil is a labor-saving substitute for transplanting. The seed may be mechanically dropped in rows using a drum seeder or dispersed manually. In order to achieve a uniform crop stand, wet-seeded rice is more dependent than transplanted rice on proper ground leveling and early water depth management. In regions with relatively high labor costs and effective irrigation water management, such as the Mekong Delta of Vietnam, the Central Plain of Thailand, Sri Lanka, and portions of the Philippines, wet seeding is preferred compared to transplanting.

Another option is to plant seeds in either dry or wet soil. The seed may be drilled into the soil or manually dispersed over the earth's surface. As opposed to transplanting, dry-seeded rice needs far less work and has traditionally been used in various Asian regions with rainy climates. Mechanized drill seeding into dry or wet soil is often used in large-scale rice cultivation in the south central United States because dry seeding is favourable to mechanization. In comparatively smaller-scale rice farming in India's northwest Indo-Gangetic Plain, dry planting is a new technique [3].

Soon after rice has been established, weeds may start to grow. Before weeds appear, transplanted rice seedlings are already several weeks old, giving them an advantage against weeds. On the other side, wet- and dry-seeded rice may emerge almost simultaneously with weeds, increasing weed pressure and the need for effective herbicide application.

Preparing the land

In Asia, almost all lowland rice fields are purposefully flooded before being plowed, harrowed, or rotavated. Puddling, or tillage of saturated soil, dissolves soil aggregates and leaves a hardpan behind a soft, muddy layer that is 10 to 20 cm thick. The hardpan prevents water from flowing downhill, which reduces nutrient loss via leaching and aids in maintaining a layer of floodwater.

The floodwater inhibits the emergence and germination of weeds. It also aids in eradicating certain pests that affect rice, such the root-knot nematode. Conventional tillage of dry or damp soil, such that used for wheat, is the most popular substitute for puddling. Reduced tillage and no-till systems are less popular options for the establishment of rice. In Australia, Europe, North America, and South America, non-puddled soil is often used to cultivate irrigated rice.

A soft topsoil layer is produced by muddling, which is good for transplanting seedlings and for wet-seeded rice but not for dry-seeded rice. Most non-puddled soils are used for dry seeded rice farming. In California, a kind of wet-seeded rice known as "water-seeded rice" is often sown aerially into floodwater after germinating. Although conventional transplanted rice on puddled soil may be less prone to weed problems than dry-seeded rice, mechanized transplantation of rice on non-puddled soil is now being researched as a potential water and labor-saving alternative.

On a rice field, water is flowing

A rice paddy needs water to puddle the soil before evaporation, transpiration, percolation, seepage, and surface runoff over the bund meet the outflows. Depending on the degree of water management and the amount of time between initial soil soaking and crop establishment, estimates of water usage for puddling each cropping season vary from roughly 100 to 940 mm. The soil in irrigated lowlands is normally maintained submerged to a depth of between 3 and 10 cm after crop installation. Flooding depth and duration in lowlands that get rain are very variable. In the south central United States, some irrigated rice is dry sown on non-puddled soil and watered slowly to allow for soil submersion. With this "dry-seeded, delayed flood" method of growing rice, the soil is submerged from the start of tillering until just before harvest. In a lowland rice field, the amount of irrigation water required for one cropping season, including land preparation, depends on the soil's characteristics, the level of the groundwater table, rainfall, and net water losses from evaporation, transpiration, percolation, seepage, and other sources.

Water entering and leaving a lowland rice field

A lowland rice field's water outflows come from transpiration, evaporation, percolation, seepage, and surface runoff over the field's protective bund. Water lost as vapor from the soil or water layer's surface is referred to as evaporation, whereas water released as vapor by plants is known as transpiration. Percolation is the vertical flow of water to the zone below the roots, while seepage is the lateral subsurface movement of water under or through bunds. The overflow that occurs when the water depth exceeds the bund's height is known as overbund flow or surface runoff [4].

On general, rice fields evaporate and transpire at rates of 4-5 mm per day during the rainy season and 6-7 mm per day during the dry season. In subtropical areas, they may reach 10-11 mm per day just before the monsoon season begins. For heavy clay soils, the combined seepage and percolation rates normally range from 1 to 5 mm per day, while for sandy and sandy loam soils, they range from 25 to 30 mm per day. 25 to 85% of all water inputs might be lost through seepage and percolation. Water enters a lowland rice crop by irrigation, rainfall, overbund influx, and seepage from higher fields. The flow of water from the groundwater table upward is known as capillary rise. Due to percolation, which prevents water from rising into the root zone, it is minimal in a flooded soil. In heavy clay soils with a shallow water table that immediately supplies water for crop transpiration, the total water input from rainfall + irrigation may be as little as 400 mm. On soils with deep groundwater tables, which do not offer water for crop transpiration, water inputs from rainfall and irrigation may, nevertheless, reach 3,500 mm. 1,300-1,500 mm is the quoted "average" amount for input from rainfall plus irrigation over the course of a complete farming season. This is equivalent to 13–15 mega liters per hectare.

Water that cannot be utilized again is lost via transpiration and evaporation, which are essential for crop production. Seepage, percolation, and overbund flow are examples of water losses from a field that are often reclaimed and utilized in fields downstream. At the size of the irrigation region or basin, they thus indicate reusable flows of water rather than water depletion, however the level of water reuse is often unknown. Reusing water within an irrigation region or basin may be restricted by the salinity of the water, which normally rises with reuse. Rice and wheat, both C3 cereals, have similar water productivity when measured in terms of generated grain mass per cumulative mass of water outflow by evaporation + transpiration.

Because to significant water outflows from seepage, percolation, and overbund flow in rice cultivation with soil submersion, the seasonal water intake from rainfall plus irrigation is often larger for lowland rice than for wheat. Rice would thus have poorer water productivity than wheat when measured in terms of produced grain mass per cumulative mass of total water input from rainfall + irrigation [5].

While researchers have discovered significant variety in rice germplasm for salt tolerance, rice is generally susceptible to salinity, particularly during early seedling development and the reproductive period. This encourages the creation of high-yielding rice varieties that are more tolerant of salt, which may allow irrigation with water that is more salinized than is now allowed.

Soil Activities

Air, which contains 21% oxygen, easily penetrates and flows through dry soil. Air is transported quickly, ensuring that soil microbes and plant roots get an adequate amount of oxygen. As soil is submerged, water seeps into the soil pores, covering the soil with a coating of floodwater. They significantly limit how much oxygen can enter and pass through soil because oxygen passes through water 10,000 times more slowly than it does through air. When soil is inundated, the oxygen that already exists in the soil is quickly used up by soil organisms via cellular respiration, and the floodwater hinders the transport of more oxygen into the soil. As soil oxygen levels drop, the oxygen-dependent aerobic soil microorganisms quickly perish and are replaced by anaerobic microbes that can respire anaerobically in the absence of oxygen.

The oxygen in the air that is carried by floodwater to the soil is quickly depleted at both the water's surface and in the soil itself. A thin layer of aerated soil results from the O2 barely penetrating a few millimeters into the soil. The majority of the soil, which is devoid of oxygen and home to anaerobic microbes, lies under this layer. Air containing oxygen enters the rice plant from above the floodwater and travels to the stem and roots via aerenchyma, a network of air-filled spaces. Part of this oxygen seeps through the pores in the soil around the roots, forming a thin layer of oxidized soil next to the anaerobic soil in the main. Aerobic bacteria in the rhizosphere protect the rice root from potentially hazardous soil elements [6].

In the absence of oxygen, anaerobic microbes utilise oxidized soil components for respiration. This causes a cascade alteration in soil elements, first with nitrate, then moving on to manganese, iron, and sulfate, and ultimately leading to the creation of methane. During soil submersion, nitrate quickly loses stability and is quickly converted into nitrogen gas by a process called denitrification. This demonstrates why nitrate-based fertilizers are not suggested for soils that are submerged. The transformation of relatively insoluble iron phosphate complexes into more soluble compounds as a consequence of the change in iron form increases the amount of phosphorus that is available to plants in submerged soils. In buried acid soils, sulfate reduction creates sulfide, which may bind zinc and reduce the amount of zinc that is accessible to plants. Instead of carbon dioxide, methane is ultimately produced as the gaseous end product from the breakdown of organic molecules due to the cascading cycle. High concentrations of Fe3+ and sulfate may stall the cascade series of events, which stalls and delays the generation of methane.

DISCUSSION

Management of Nutrients

According to data from 2010, 13% of the world's P and potassium fertilizer usage and 15% of the world's nitrogen fertilizer consumption are accounted for by rice cultivation. Fertilizer represents between 15% and 30% of the entire cost of producing irrigated rice in Asia, depending on labor prices and government subsidies, making it often the second-most significant input cost in the region after labor. On an estimated 144 million farms spread over six continents, the most of which are in Asia and are less than one hectare apiece, rice is cultivated. The usage of fertilizer, yield, crop management, crop response to applied nutrients, and nutrient balances on these small rice farms, as well as fields within farms, might vary, which has an immediate impact on the amount of fertilizer required. These geographical and temporal differences in the nutrient requirements for individual fields are not taken into consideration by conventional blanket fertilizer recommendations for vast regions or agroecological zones. The concept of site-specific nutrition management for rice first emerged in the middle of the 1990s as a substitute method for dynamically distributing fertilizer to rice fields in order to augment N, P, and K demands.

Nitrogen

The nutrient that restricts rice yield the greatest is nitrogen. An initial estimate of the total amount of nitrogen fertilizer needed for a field is required when using the SSNM technique. Necessitates the use of fertilizer N, which is subsequently distributed throughout the cropping season to meet crop demands. Setting a goal yield that can be achieved with the predicted crop management, water regime, and climatic conditions is the first step in determining the need for fertilizer N for a specific field and season. The goal production might be set somewhat higher than the farmer's present output for rice farmers who are not providing N fertilizer throughout the season in expectation of greater yields with better timing of fertilizer N. The maximum achievable yield is influenced by climate and variety. After the determination of the goal yield, the amount of fertilizer N needed to reach the target may be estimated using the expected increase in yield from applied N and a realistic fertilizer N usage efficiency [7].

N fertilizer should be regulated to guarantee an adequate supply of N to fulfill crop demands during the crucial growth phases of tiller development and panicle initiation, regardless of the rice-growing environment and water regime. A lack of N during tiller development might limit the number of tillers, which could lead to a lack of panicles needed to provide the desired yield. By resulting in fewer filled spikelets per panicle, a lack of N to fulfill crop need during panicle initiation might negatively impact production. In the cultivation of rice in Asia, there is usually enough manpower to manually distribute N fertilizer, usually in the form of urea, during tiller growth and panicle commencement. When drought or floods coincide with the planned period for fertilizer application, rainfed lowland rice habitats may need to make modifications to the timing and management of nitrogen fertilizer.

Broadcast nitrogen fertilizer is vulnerable to gaseous losses, particularly from ammonia volatilization, in lowland rice fields. Due to the low need for N by the rice crop, N fertilizer that is spread before to tillering is most vulnerable to loss. Rice absorbs nitrogen administered during tillering and panicle initiation more quickly and with reduced loss potential. By avoiding an excessive early input of N before tillering and making sure N is provided at rates that correspond to the crop's requirement for more N, it is possible to maximize the efficiency of N fertilizer usage.

Potassium and Phosphorus

The field-specific management of P and K based on SSNM principles incorporates a calculation of fertilizer P and K needs utilizing a combination of nutrient balances and predicted yield improvements from applied P and K, regardless of the rice-growing environment and water regime. According to observations of irrigated rice in Asia, when P inputs from organic materials are modest, fertilizer P needs determined by yield gain are often lower or equivalent to fertilizer P requirements calculated by nutrient balancing with P input equal P output. The inputs of K from irrigation water, management of crop residues, and input of organic materials all have a significant role in determining the amount of K needed for fertilizer as determined by field-level K balances. When all crop leftovers are kept in rice fields with irrigation, the input of K with irrigation may be comparable to the removal of K with harvested grain. Grain is mechanically harvested with a combine harvester, leaving all crop remains on the field. The field-level K balances in this situation would show little to no need for fertilizer K [8].

On the other hand, the fertilizer K needs calculated by K balance may be much greater than the fertilizer K requirements estimated by yield increase when most or all of the crop residues are removed from the field. In order to adequately address the trade-off between higher net income achieved with moderate K rates to overcome K deficiency but allow mining of soil K versus lower net income achieved with higher K rates to minimize mining of soil K, fertilizer K requirements can be estimated by combining the yield gain and nutrient balance approaches.

To guarantee enough P for early root growth, full P fertilizer is often advised just before or shortly after crop establishment. It is normally advised to apply all or the majority of the necessary K just before or shortly after crop establishment. Up to half of the total K fertilizer may be sprayed with N fertilizer at panicle initiation in areas with high K fertilizer requirements, high yields, and partial or full clearance of crop residues from the previous crop. This use of K may enhance grain filling. The SSNM technique offers algorithms for calculating the needs for field-specific fertilizer using decision-making tools. This program determines a field-specific fertilizer recommendation by using SSNM-based algorithms together with data from a rice farmer and other sources. The advice may be modified to account for expected impacts of irrigation water management on yields and the best time to apply N.

Organic Substances

In reaction to the growing expense of synthetic fertilizers, certain Asian nations have advocated the use of organic resources as sources of nutrients for rice cultivation. Rice may absorb nutrients in inorganic forms that are released through the biological breakdown of organic components. The demand for all yield-limiting nutrients by rice often exceeds the availability of nutrients from decaying organic sources. The amount of nutrients that are accessible to plants as a result of the addition of organic materials may fall short of certain nutritional needs while surpassing others for crops. Seldom do additional organic ingredients provide enough plant-available N to completely cure rice's N shortage. In this situation, it is necessary to combine the usage of commercial N fertilizer with organic materials in order to provide a high-yielding rice crop with enough nutrients that are accessible to plants. The value of using organic materials as a source of nutrients should be determined by comparing their costs to those of using industrial fertilizers in order to produce a desired rice yield [9].

Organic compounds, such as agricultural leftovers, may have negative consequences when added to submerged soil. Crop wastes and other organic resources may speed up the changes in soil components seen in Figure 3. This might hasten the conversion of sulfate to sulfide, which could precipitate zinc and restrict its availability to the rice crop. It could also increase methane production and emission and encourage the development of organic acids, which could have a negative impact on rice growth. These impacts may be lessened by aerating and drying the soil.

Production of rice on Soggy Soil

By decreasing the depth of floodwater and letting the soil surface dry before the subsequent irrigation water application, the consumption of irrigation water on puddled soils may be minimized. Controlled irrigation, intermittent irrigation, and alternating soaking and drying are terms used to describe the technique of delaying irrigation until several days after the floodwaters have subsided. Rice roots may get water in the saturated subsurface soil even without floodwater. Withholding irrigation throughout the rice-growing season until the water level falls to a threshold depth of roughly 15 cm below the soil surface is the practice of "safe" AWD, which is presently pushed for decreased use of irrigation water. In order to guarantee prompt water supply to the field during the implementation of AWD, excellent irrigation water management is required. Moreover, the crucial water-sensitive period of blooming, from one week before to to one week after the peak of flowering, needs sustaining standing floodwater. Safe AWD may cut irrigation water usage, decrease arsenic and cadmium buildup in grain, boost zinc availability in acid soil, and lower methane emissions as compared to irrigation with continuous soil submersion. Nevertheless, weed management may take more work, and the lack of floodwater raises the possibility of rat damage to crops. 'Safe' AWD often cuts irrigation water input by 15% while maintaining output. Actual AWD performance varies based in part on groundwater depth. AWD may conserve a little quantity of irrigation water on soils with a persistent shallow depth to groundwater of less than 40 cm without a yield loss. AWD may conserve more irrigation water on soils with groundwater below the depth that rice roots can reach, but there may be a yield trade-off.

AWD would reduce water output in direct proportion to decreased agricultural water demand. A decrease in evaporation signifies a'real' decrease in rice was able to utilise water that would not have otherwise been available. Water that is lost by seepage, percolation, and overbund flow may be recovered and utilized again downstream, therefore at the size of the irrigation area or basin they do not signify water depletion. Since isolated fields with AWD might benefit from inflows of water from higher fields not using AWD, a decrease in irrigation water usage with AWD in an isolated field may exaggerate the real water savings for AWD in an irrigation region or basin. The lower expenses for pumping irrigation water or for water with volumetric pricing are often what draw farmers to AWD. The use of less irrigation water by AWD would not immediately help farmers who pay a set charge for irrigation based on land area rather than water quantity, but there may be long-term or broader-scale benefits through lower use of the water supply in general [10].

The System of Rice Intensification is an agroecological technique for growing rice that was developed in Madagascar. Its fixed guidelines include the use of young seedlings, transplanting with just one seedling, wide plant spacing, controlled irrigation, manual and mechanical weeding, and the use of organic materials rather than synthetic fertilizers. In recent years, the word "SRI" has grown to be linked with sets of sound agronomic management techniques that often diverge from the SRI that originated in Madagascar. Now, the term "SRI" may be used to describe rice management techniques that vary across nations and rice-growing regions. The majority of the time, 'intermittent irrigation,' or AWD, is included, but when irrigation and drainage facilities are not well-developed, farmers may find it challenging to use AWD. The advantages of AWD as a standalone cannot be easily distinguished from those of other components of SRI since AWD is simply one part of SRI.

Rice production without muddying the Soil

It depends on the cracks in the dry soil right before soaking, the level of water control, and the amount of time between initial land-soaking and crop establishment before the initial soaking of rice fields before puddling and the subsequent puddling process, as is frequently done in Asia, how much water is actually used. When rice is transplanted, water is also needed to nurture seedlings. A rough estimate of the water input needed for land preparation and soaking is 200–300 mm. Using an irrigation system in the Philippines, Tabbal et al. found an unusually high water usage of 940 mm for field preparation and soaking before transplanting rice. Due to continual flooding of the whole rice production area beginning with seedbed preparation, it took about 2 months from the initial irrigation to the end of transplanting in the production area, which is the likely cause of this high water consumption.

The transition from transplanted or wet-seeded rice to dry-seeded rice with less-intensive tillage than puddling is often connected with the cessation of soil puddling, which lowers fuel expenditures. The absence of puddling makes dry-seeded rice more vulnerable to weeds' ability to reduce output and to water loss throughout the cropping cycle.

Rice cultivation on land that isn't permanently submerged in water or puddles In land that is not puddled, rice is normally dry sown. The water regime may be quite different, ranging from constant soil entrapment to alternating soil wetness and drying to unsaturated soil. Reducing irrigation and soil saturation during the rice harvest may help conserve water, but depending on how severe the water shortage is, there may be a trade-off in terms of output. Contrary to continuous soil submersion, irrigation frequency may be increased while still maintaining soil water content in the root zone between saturation and field capacity without reducing production. The amount of soil that may be allowed to dry out without reducing yields depends on the kind of soil, the quantity of drying cycles, and the timing of water stress. This "safe soil drying" requires proper irrigation management and efficient weed management. The Indo-Gangetic Plain in northwest India is getting this production strategy to utilize less irrigation water.

Growing rice, wheat, or maize on non-puddled soil without intentional flooding may conserve more water, but water shortages can reduce productivity. Using this method, the soil is kept aerated throughout the rice-growing cycle, and the amount of water in the root zone may go below the maximum allowable for the field, barring periods of intense rainfall. When rainfall is inadequate to keep soil moisture levels over a cutoff established between field capacity and wilting point, irrigation water is administered. This is known as "aerobic rice," because it is often planted dry. Underfield soil drying is known as "unsafe soil drying," and depending on the water shortage, it might reduce yield. In the northwest of India's Indo-Gangetic Plain, aerated soil with a high pH might be constrained by iron shortage as well as weeds and root-knot nematodes [11].

Diversity of Crops

Farmers may opt to produce a crop other than rice when irrigation water is scarce, such as maize, potatoes, or vegetables, which can be chosen depending on market values. Similar to the range for aerobic rice development, the non-rice crop would normally be cultivated on well-drained soils with water content between field capacity and wilting point.

Water use's effects on Soil Processes

By eradicating weeds and certain soil-borne pests and preserving soil organic matter, which acts as a source of nutrients, soil submergence promotes prolonged rice production. When rice monoculture on puddled and submerged soil is switched to production of rice with less water or to rotation of rice with other crops, some SOM and ability of the soil to deliver nutrients might be lost. It is the goal of resource-saving technologies to cultivate rice with little or no tillage and establishment by mechanical transplanting or drill sowing in order to decrease the loss of SOM. With the biological assimilation of atmospheric N2 by organisms resident in wet soil and floodwater, soil submersion provides to a steady intake of plant-available N. On plots lacking additional N fertilizer and organic materials, this source of native N for rice allows for the sustained production of rice at low yields. By improved phosphate ion mobility and the transformation of insoluble phosphate compounds into more soluble forms, soil submersion also improves the availability of soil P.

In submerged soils, ammonium is the stable form of inorganic N, while nitrate builds up in aerobic soils. In lowland rice production systems, nitrate may build up during the development of non-rice crops, the growth of rice on unsaturated soil, and the fallow period preceding rice planting. When the soil is flooded during the development of the rice crop or while the land is being prepared for a future rice crop, the deposited nitrate is vulnerable to fast gaseous loss through denitrification. Even on unpuddled soil, nitrate loss through leaching is often minimal in lowland rice cultivation. In sandy soils with strong downward water flow and limited availability of the organic matter substrate needed for soil microorganism capable of denitrification, leaching rather than denitrification may take place.

By encouraging the anaerobic breakdown of SOM and other organic components, soil submersion encourages the formation of methane, while soil aeration decreases methane emissions. Denitrification results in the production of nitrous oxide, a greenhouse gas with a larger global warming potential than methane. Continuous soil submersion usually results in insignificant or low nitrous oxide emissions; however, soil drying and subsequent floods, which cause nitrate to develop and be lost, favor nitrous oxide emissions. AWD, aerobic rice, and the addition of additional non-rice crops to the cropping system are examples of management strategies that may decrease methane emissions while increasing nitrous oxide emissions in response to water constraint. When evaluating a water management method, the combined GWP for the two gases must be taken into account. According to a pot research, when crop residues are absorbed into the soil, AWD has a similar or lower GWP than continuous soil submergence, but not when crop residues are removed.

Effects of water usage on nutrient control

As a general rule, a significant decrease in submergence may tend to increase the amount of N, P, and K needed for a given goal yield. Lower BNF and potentially lower net N mineralization in aerobic soil compared to submerged soil might result in a larger requirement for fertilizer N. The decreased soil P availability in aerobic soil might result in a greater requirement for fertilizer P. The management of crop residues and K inputs from irrigation water have an impact on the requirement for K fertilizer. Iron and zinc fertilization are required for dry-seeded aerobic rice because soil aeration may reduce zinc and iron availability on high-pH soils while increasing zinc availability on acidic soils. The predicted water-limited grain yield of rice should be taken into account while adjusting fertilizer amounts.

Although the extent and duration of soil drying are relatively mild, the use of safe AWD on puddled soil results in periodic soil aeration, and current research does not indicate a significant difference in SOM and plant availability of macronutrients for safe AWD as compared to continuous soil submersion. As a result, at a certain production level, rice's demand for fertilizer N, P, and K remains constant. If AWD does not cause water stress that lowers yield, nutrient best management strategies are the same for rice cultivated with both AWD and continuous soil submergence [12].

Alternating between soil drying and wetness in AWD may promote the sequential nitrification-denitrification gaseous loss of broadcast fertilizer N and soil N. By avoiding an excessive input of fertilizer N prior to tillering, the danger of N loss might be decreased. Due to increased competition between rice and microorganisms for ammonium before conversion to nitrate and for nitrate before denitrification, such N loss would diminish with increasing age of rice. The transfer of nitrogen into the soil, where it would be less likely to be lost by ammonia volatilization, may be ensured by broadcasting urea just before watering. Urea may be spread after irrigation to lessen the risk of N loss with irrigation water outflow in places where irrigation water travels over fields or where irrigation water is vulnerable to loss by overbund discharge.

During the wet season, when heavy rains bury soils and provide a climate for which rice is more suited than other important food crops, a great quantity of rice will still be produced throughout monsoonal Asia. This periodic soil flooding may continue to be advantageous for weed and root-knot nematode management as well as nitrogen availability from floods and BNF. Nonetheless, rice production will expand in a political, physical, economic, and social context that has a limited supply of irrigation water, higher irrigation water prices, higher labor expenses, and income prospects from crop diversification. This could modify how irrigated rice is farmed in certain regions, and adjustments to crop establishment, irrigation water management, and land preparation might impact the availability of soil nutrients and the need for fertilizer.

BNF, the delivery of soil-available N and P to plants, and the transportation of nutrients to crop roots are all favored by a sufficient amount of water for continuous soil submergence. When the following occurs due to a decreased availability of irrigation water for rice, the requirement for fertilizer may change:

1. Changes the local supply of nutrients that come from sources other than fertilizer.
2. Reduces the water supply needed to spread fertilizer into the crop root zone.
3. Risks yield loss because to a water shortage.

CONCLUSION

As with AWD, a decrease in irrigation water to "safe soil drying" for puddled soils is not anticipated to significantly affect BNF, native nitrogen availability, transfer of nutrient to roots, and therefore the demand for fertilizer by rice. As a result, it is anticipated that the optimum management strategies for managing nutrients would not change, but AWD may need more weed control expenditures. If irrigation water consumption is decreased for non-puddled soils without reducing production, BNF may be decreased and the availability of micronutrients may change. In high pH soil, the demand for micronutrients like zinc and iron may also increase under these circumstances, as well as the need for fertilizer N. When irrigation water is reduced to "unsafe soil drying" and yield is decreased, as is the case with aerobic rice on non-puddled soil, crop demand and native nutrient supply are altered. The crop absorbs fewer nutrients overall as a result of the lower yield, yet less K is given by irrigation water and less N and P are available locally. Due to decreased native nutrient availability and decreased input of K with irrigation water, more fertilizer may be needed to reach a given goal yield. By providing N at levels that correspond to the crop's requirements for N throughout the vegetative development phase and during panicle initiation, the efficiency of N fertilizer usage may be enhanced. Long-term "unsafe soil drying" may leave spread fertilizer on the soil surface, out of touch with crop roots, and vulnerable to gaseous N losses. It may be more effective to utilize fertilizer if irrigation water is used to get it to the crop's root zone.

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CHAPTER 10

PRACTICES THAT SIMULTANEOUSLY INCREASE FERTILIZER AND WATER EFFICIENCY

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ABSTRACT:

The experience of concurrently applying water and fertilizer is discussed. The first section of the chapter discusses fertilization, while the second section discusses irrigation utilizing wastewater that has been treated. The precise administration of nutrients in terms of time and place is theoretically made possible by fertilization. The effects of management tactics and soil features on water quality and mineral transport in soils are examined. The growth cycle and other environmental elements that have an impact on crop nutrient requirements are described. Conceptual strategies for enhancing fertigation synchronization to the nutritional requirements of crops, both physically and biologically, are discussed.

KEYWORDS:

Agriculture, Fertilizer, Food Security, Management, Nutrients.

INTRODUCTION

The features and content of TWW are specified in terms of the sewage supply, the method, and the rate of treatment. The osmotic and specific toxicity effects of high concentrations of salts from salty water or TWW on soil and crop are provided, along with suggested management measures to decrease salt stress. The impact of TWW application on crop availability of nitrogen, phosphate, potassium, and trace elements is examined. For each nutrient, special concerns with the use of treated water are noted.

Fertigation

Irrigation and fertilization are without a doubt the most important management tools that farmers may utilize to regulate crop yield and quality in arid and semi-arid environments. Fertigation, or the application of liquid nutrients using drip irrigation systems, allows for the benefits of nutrient delivery to crops in amounts and at times when they are most required by plants, as well as at locations where root absorption is most likely to occur. Constant application of readily soluble nutrients to the root zone by fertigation boosts economic output while lowering overfertilization and groundwater pollution due to salt and nutrient leakage. In dry and semi-arid areas, such as Israel and other Mediterranean countries, there is a rise in the use of treated wastewater for irrigation. Drip irrigation is one of the safeguards against pathogen contamination of TWW-irrigated agricultural products. As a consequence of the expanding use of TWW for irrigation, drip irrigation has been promoted to take the place of traditional irrigation techniques [1].

Since the early 1960s, drip irrigation has been extensively utilized for irrigation in greenhouses and outdoor fields since it requires less water and fertilizer than conventional irrigation systems. Microirrigation now covers just 4% of the world's irrigated agricultural land, although development is essentially linear and growing swiftly. Australia, China, China, India, Japan, and China all have expanding economies. Drip irrigation systems were used to water around 66,000 hectares of land worldwide in 1874; this figure rose to 2.98 million hectares in 1996; and to 10.3 Mha in 2012. China and India, the top two irrigators in the world, have seen the biggest increases, with 88-fold and 111-fold increases in micro-irrigation area, respectively, during the last 20 years. India now leads the world with more than 2 Mha. A 1 Mha yearly increase is projected in India. The majority of developing countries still use micro-irrigation with broadcast dressing and banding to apply nutrients. In Israel, where water availability limits agricultural productivity, micro-irrigation supplies over 75% of all irrigated land. Micro-irrigation and fertilization are integrated in Israel, which is probably a significant factor in the success of the nation.

Mineral and water movement in soils from point sources

How water is distributed on point source irrigated land depends on the properties of the soil and the dripper's discharge rate. Water from a dripper moves through the soil due to capillary and gravimetric forces. As a consequence, there is an area of wet soil with varying soil moisture levels throughout the soil depth. The shape of the wetted soil volume below and around a surface drip emitter is typically shaped like an onion, with the soil's maximum moisture content immediately adjacent to the emitter and its surface and a steady decrease in moisture as vertical and horizontal distances from the emitter increase until it reaches a sharp wetness. The stronger the emitter's discharge, the shallower the wetting front is and the further it is from the emitter horizontally. Light textured soil has a shorter horizontal distance and a deeper depth than heavy textured soil, which has a lower hydraulic conductivity. The two basic mechanisms that govern how soluble ions and molecules flow through soil are convection and diffusion. Neutrally charged molecules and soluble ions thus move away from the dripper and towards the direction of the borders of the wetting front, as seen in Figure 1. The kind of soil and emitter discharge rate have altered the distribution of volumetric salt content. In sandy soil, the downward flow of salts was three times greater than in loamy soil, while the lateral movement was about half as great.

When subsurface drip irrigation is used, the emitter is positioned in the center of the wetted volume, and the water is distributed unevenly above and below it, with a greater vertical distance below the emitter than above it. Several studies have shown a correlation between root density and root water absorption, which varies nonlinearly with depth in the soil profile. If soils are often irrigated, especially from the top, where they will remain relatively wet, the majority of the root water absorption will thus take place in the upper soil layers. Coelho and Or studied the two-dimensional root dispersion in drip-irrigated maize plants. By fitting Gaussian distribution parametric models to the corn root length density, they produced two-dimensional root distributions, which they then compared to the root water uptake patterns. The distribution of RLD has not been well investigated, despite the fact that it has been shown that actual water absorption patterns are a result of the complex interactions between RLD and other soil components, including water and nutrients [2].

Crop Nutrient Needs

The need for nutrients changes drastically and dramatically as a crop develops. As a result, understanding the crop's nutrient need as a function of time and environmental conditions is essential for effective fertigation management. While there are differences between the dry matter production curve and the nutrient intake curve that depend on the developmental stage and the specific nutrients, they are interconnected. There are considerable differences in intake rate and the time at which the maximum consumption rate occurs across crops and between cultivars of the same species. Instead of being monotonous, the consumption function often exhibits rapid fluctuations during critical physiological periods. Fundamentally, the two main processes that are associated with the rate of nutritional demand at each growth phase are the synthesis of new vegetative plant tissues and the development of reproductive organs. Daily nutrient uptake rates may be calculated using consumption curves, and the rates that provide the highest yield and product quality depend on the crop and the climate. If the fluctuations in the absorption rate over time are ignored, there may be periods of over- or under-fertilization. Over-fertilization may increase soil salinity, environmental pollution, and vegetative development, while under-fertilization can result in nutritional deficiency and lower productivity.

The rate of nutrient uptake by a leafy vegetable is characterized by an exponential curve, increasing sharply over time, as opposed to the three periods that have traditionally been associated with fruit-bearing crops: an exponential rate during initial vegetative growth, a linear growth rate after that, and finally the senescence period as reproductive organs develop. The quantity of nutrients taken in by determining plants like maize and fruiting plants like tomatoes are precisely matched by this consumption curve. When non-terminating plants, like tomatoes and peppers, were consistently grown in well-managed climatic conditions, their rate of nutrient uptake steadily grew until the formation of the first fruit truss, at which point it monotonously fell. For projecting known N, P, and K intake statistics to environmental conditions other than those specified, a first estimate should be employed. For instance, Xu et al. found that although the nutrient solution had the same percentage of nitrogen, pepper plants utilized 2.2–2.8 times more nitrogen overall in the summer than they did in the winter. The rate of growth and transpiration generally determines the overall amount of nutrients consumed, although the physiological stage of development has a greater influence on the absorption of certain nutrients.

Prevention of Terrorism

This section discusses the key fertigation and irrigation management factors that influence plant nutrient uptake, root development, and chemical reactions in the soil rhizosphere that influence nutrient bioavailability and root growth. We'll talk about the frequency of irrigation, the availability of N, and the timing of irrigation and fertilization. Two simultaneous processes, convection in the water flow and diffusion along the concentration gradient, transport nutrients from an irrigating source to the soil's root surface. The characteristics of the soil, the crop, and the growing environment have an impact on the relative importance of each phase. Since the nitrate ion is only weakly bound to solid objects, NO- is more mobile in soil. As a result, mass flow primarily absorbs the supply of mobile NO3 ions, while diffusion regulates the supply of less mobile components like P and K. Simulations and real-world data on plant nutrient uptake show that P was significantly influenced by the volumetric water content whereas NO was less responsive [3].

The distribution of applied easily transportable forms of N, such as NO3 and urea, depends significantly on the management of fertigation and the hydraulic properties of the soil. Cote et al. showed that injecting NO_3 at the beginning of the irrigation cycle in the highly permeable coarse-textured medium would greatly reduce the likelihood of solute leaching, as opposed to injecting NO_3 at the end of the irrigation cycle. As opposed to providing P in a suitable quantity as a main fertilizer, it has been shown that applying orthophosphate continually through irrigation water is better. Extractable P concentrations in the soil immediately around a point source were found to be 20 to 25% higher in continuously irrigated soil compared to pulsed irrigation. Biomass of developing corn plants and leaf P concentration the differences under continuous fertigation were 20 and 25% bigger, respectively, than under pulse irrigation.

Irrigation frequency is a key management element for water supply. Long known to have advantageous effects, high-frequency irrigation is now recognized as a successful technique for enhancing the root environment. As ions are added to the soil by irrigation water, their concentrations in the soil solution progressively decrease over time due to adsorption onto solid phases and the precipitation of insoluble substances. This results in oscillations between high or even excessive concentrations in the rhizosphere right after irrigation and inadequate levels over time when high nutrient concentrations are used in fertigation with occasional watering.

Through two main mechanisms a direct impact on the wetting patterns and water distribution in the soil volume, which modulate root distribution and growth, and an indirect impact on nutrient availability, particularly that of P irrigation frequency affects the efficiency of the root system, including root hair density and root system architecture. Improved nutrient availability, especially P, has been shown to be directly related to greater yields attained under frequent irrigation. Strong correlations between yield and P concentration in the leaves indicate that higher P mobilization and absorption was the main advantage of fertigation frequency.

Nitrogen source effects

NH + and NO - are two distinct ionic forms of N that plants may absorb. The main effects of 4 3 N source on plants include ammonia toxicity, changed rhizosphere pH, accessibility to other nutrients, and incidence of physiological issues like chlorosis and blossom-end rot. When nitrogen is present, the pH of the rhizosphere may be affected by three processes: nitrification/denitrification reactions, displacement of H+/OH- adsorbed on the solid layer, and release or absorption of H+ by roots in response to NH4 or NO3 intake. This method may work well since it just affects a limited volume very adjacent to the roots. The amount that the three aforementioned procedures adjust pH depends on the soil properties, wetted volume, plant activity, and environmental factors that affect nitrification rate [4]. Yet, since nitrification happens quickly in soil, the concentration of NH4 quickly drops. Regular fertigation with drip irrigation maintains the NO3/NH4 ratio in the soil at the same level as that in the irrigation water. Chlorosis, "little leaf," and "rosette" are a few instances of micronutrient deficiencies that cause development issues that may be resolved by lowering the pH of the growing medium, which is fuelled by NH + nitrification and root exudation of protons.

Fertigation's Advantages and Disadvantages

The advantages of fertigation over irrigation and broadcast or banded fertilization are listed below: Application is restricted to the wetted area, where root activity is focused; quantities and concentrations of specific nutrients may be customized to crop demands depending on crop stage of development; and administration of nutrients and water is precise and constant under all circumstances. In addition to preventing broadcast operations and using less water pressure than sprinkler irrigation, trickle irrigation keeps crop foliage dry, delaying the development of plant pathogens and preventing leaf burn. It also enables irrigation with more saline water than other irrigation techniques, reducing fluctuations in nutrient concentrations in soil over the course of the growing season. Fetigation does have a number of disadvantages, which may be summed up as follows: There is a requirement for extra capital expenditure since building drip irrigation systems with fertilizer injection devices and fertilizer tanks is more expensive than establishing sprinkler irrigation systems. Other safety issues include a higher chance of emitter clogging, a buildup of salts in the wetting front, a reduction in root volume, and avoiding chemical back-flow into the water supply.

The future of irrigated agriculture is in jeopardy due to the current or expected scarcity of freshwater, especially in semiarid and arid regions. The world's population's rapid expansion and improving standard of living have led to an increase in the demand for water resources, which is the main cause of this shortage. The constant increase in population and water demand per person necessitates the safe disposal or re-use of an increasing volume of municipal sewage water. TWW irrigation enables the utilization of water and nutrient resources that might otherwise go unused. The main issues with TWW irrigation are covered in the sections that follow.

Characteristics and composition of TWW

Wastewater effluent is recognized as a source of water for irrigated agriculture and as a substitute for potable water in semiarid and arid regions of the world. Municipal wastewaters, which include the outflow from commercial, institutional, and residential locations, often have domestic origins. Affluent nations tend to have higher loads of specific chemicals, medications, and personal care products as well as higher organic loads; countries with drier climates tend to have lower levels of dilution. Despite the fact that the components of domestic wastewater are frequently the same around the world. If industrial effluent is not segregated from domestic sources of wastewater, municipal wastewater may become enriched with unwanted substances, whose identities depend on the specific enterprises involved.

Secondary effluent is created by treating municipal wastewater mechanically or biologically in facultative oxidation ponds. Table 1 additionally contains the updated Israeli-allowed values that are pertinent to the TWW elements. After spending 30 days in the effluent of an oxidation pond, it was found that the amounts of suspended ppapers, total and fecal bacteria, N, and trace elements were all decreased. The 30% retention time demonstrates that evaporation is to blame for the 10% increase in Cl- and other conservative ion concentration. MBT with a nitrification-denitrification process shown noticeably greater success in reducing the bulk of WW components than OPE. If the effluent is ultimately used as irrigation water for agricultural crops, the considerable reduction in macronutrients and micronutrients during the MBT may be seen as an unduly excessive treatment. Yet, it is impossible to overstate the importance of MBT's contribution to the decline in the amount of heavy metal and OC. The biological treatment is not expected to reduce salinity components. Because of this, desalination or combined soil-aquifer treatment is the only way to sustain certain Israeli long-term irrigation ceiling concentrations [5].

Several causes of B may be prevented or handled in the source water with the application of modern legal and technological tools. Once it was realized that there was a problem with too much B in TWW meant for irrigation, rules and regulations in Israel were implemented that set a maximum of 0.4 mg l-1 B in effluent. Laws that forbade B from being used in laundry detergents and required that B be eliminated after processing in seawater desalination plants that supply water to communities were particularly crucial. Desalination technology is becoming more and more popular since it provides the opportunity to remove salts from source water and leave agriculture with water of a higher quality, which will boost yields and have a less detrimental impact on the environment. The primary objective of WW treatment is to lower pathogen levels to tolerable levels. According to regulations and suggestions based on public-health assurance goals as well as financial and technological capabilities, pathogens, organic materials, and nutritious components are eliminated from the WW to varying degrees. The characteristics and contents of WW products are more determined by capabilities and less often consider consequences for the effluent's use in various agricultural settings in more technologically sophisticated countries. With less time-consuming sewage treatment, more of the bioavailability and content of the incoming fertilizer would be kept. For agronomic end users, such a strategy is useful since it provides an additional source of nutrients. Also, cutting down on the amount of treatment at the WWTP will lower greenhouse gas emissions both on- and off-site.

It has been suggested that the additional pathogen eradication achieved by utilizing TWW in agriculture be taken into account in guidelines controlling WW reuse. The Israeli TWW irrigation guidelines, for instance, use a reduced risk approach. To achieve this, either the WW treatment must be advanced to meet fecal coliform regulations, or the appropriate treatment levels and on-farm prevention measures must be combined. The second approach is reliant on a number of FC barriers, such as TWW quality, crop type, farming practices, harvesting and irrigation procedures, as well as the features and intended uses of the product.

Risks and challenges associated with managing TWW's irrigation

Contaminants in TWW initially occur in irrigation and distribution systems, then move on to the soil, and lastly reach plants and crops, harming water management and making it more difficult. TWW and/or chemical fertigation irrigation systems may suffer from fouling pipes, equipment, and emitter clogs. The cause of obstruction may be physical, chemical, or biological. As suspended objects block flow paths, they really become clogged. Chemical obstruction occurs when soluble salts precipitate, most often carbonate, phosphate, or sulfate. Two biological processes that aid in obstruction are the growth of biofilms and algal or bacterial proliferation. All components of the distribution system may be affected by biofilms, which may also obstruct transmitters. The primary sources of biofilms in TWW are nutrients and organic waste. These root causes interact to produce clear fouling/clogging issues rather often. In microirrigation systems, it is crucial to prevent scaling and clogging since they become more likely and challenging as water flow paths become smaller. Clogging may be avoided, but it requires work and must be customized for a specific water quality. Ppapers in suspension may be removed physically filtered. Algal growth may be restricted by chemical treatments. The system will stop the development of bacteria and biofilm if biocides are injected into it. Acids and antiscalants may be dosed to stop the growth of scales. By flushing the laterals, potential clogging causes are typically eliminated from the system [6].

A few contaminants are dispersed throughout the systems as dissolved substances and tiny ppapers. They are carried by the water to the soil, where they may accumulate and affect the soil's physical properties. The deterioration of soil physical properties may be influenced by high concentrations of dissolved organic matter, suspended ppapers, sodium and the relative concentration of sodium to other cations, as well as general salinity. Clay swelling and dispersion may be made worse by irrigation with TWW because of the high salt adsorption ratio and DOM. Sodic conditions make clay soils more susceptible to swelling and dispersion, especially when overall salt levels are low. These, in turn, negatively affect the hydraulic properties of the soil by lowering its conductivity and impairing water infiltration and distribution. Recently, it has been shown that soils that have been watered with TWW have become more hydrophobic. Being water resistive reduces early penetration after being wet and results in uneven water flow and dispersion in the soil, both of which are negative qualities.

TWW often contains more salt than freshwater. Plants suffer severe effects when the quantity of salts in the root zone increases. How a plant responds to salt depends on all the variables impacting the root environment, plant absorption, and physiological activity. These variables include soil solution ion composition and concentration, crop type, cultivar and growth stage, climate, exposure time, and length of exposure. It is widely recognized that the composition and quantity of soluble salts in soil solution have a direct impact on plant growth by creating an osmotic imbalance and, more particularly, by releasing physiologically damaging ions.

While Ca, Mg, SO4, K, and HCO3 ions may sometimes be found in TWW, Na and Cl make up the bulk of the salt minerals. When these ions are present in soil solution in higher numbers, it is probable that both osmotic potential reductions and excess ion levels resulting in toxicity will occur. Plants react to osmotic effects fast. Yet, reactions brought on by toxic effects sometimes take much longer to show following accumulating in shoots. Sometimes toxic responses may happen quickly, especially when the toxicity mechanism takes place in the roots. The main issue is NaCl salt poisoning. Whether a crop is sensitive to one, both, or none of the Cl and Na ions depends on its crop specificity.

It is crucial to consider how the crop will respond to stress situations brought on by a range of various stress-causing factors while handling water with high salt concentrations. Field and lysimeter tests were conducted in Israel to find out how saline water-irrigated vegetable crops respond to high B concentrations and irrigation levels. The water quality utilized in the tests was designed to broadly replicate the expected properties of recovered municipal wastewater. When salinity is low, crop production increases directly as water is added, up to the point when evapotranspiration needs are satisfied. When salts are present, additional water administration is followed by a beneficial yield response because they prevent water from absorbing into and developing in the body. The mechanism behind this is the leaching of salts from the soil and the maintenance of a mostly salt-free environment for root activity. Crop biomass production and transpiration are both decreased by salinity in irrigation water. How much of a salinity response there will be depends on how much salt is leaking from the root zone. By supplying saline water in excess of what the crop requires for transpiration, it is possible to improve the soil's ability to absorb water and support plant development. The addition of such water provides a greater proportionate benefit as both the salinity of the water and the crop's sensitivity increase. Increased yields from irrigation application rates over 200% of the ETp may have significant economic advantages for a high-value but particularly salt-sensitive crop like bell pepper. Based on experimental findings in arid areas of Israel from lysimeter, field, and modeling studies, this conclusion was drawn. Leaching fractions were shown to increase as a result of reductions. In spite of the fact that crop sensitivity and source water salinity both lower overall yield, that salinity also increases the marginal effects of raising water application rate over ET requirements. In other words, when the water is salty, greater application results in a larger yield.

Producers are aided in their decision-making by taking into account yield forecasts connected to soil-crop-climate in connection to irrigation water quality and quantity. For instance, a farmer in a desert region irrigating with saline water cannot expect to receive more than 70% of the theoretical yield for a pepper crop, even with high rates of water application. The farmer can grow 90% of the potential yield of melon, a more tolerant crop, using the same water that generated 70% of the pepper crop's production. Leaching is necessary for long-term irrigation with salty water in dry conditions, which presents a challenge. For farming to be sustainable, leached salts and water must be collected and disposed of, or the leaching must be regulated. Reduced leaching can only be achieved by growing plants that are very hardy or by decreasing the salt of the water before watering [7].

Potential effects of various components of treated wastewater on the availability of nutrients. Using TWW for irrigation is a means to recycle both water and nutrients since it may contain considerable nutritional concentrations. Irrigation using TWW may provide additional advantages to the end user by saving fertilizer and maintaining soil fertility. In that the nutrients in TWW are applied to the field with the water and has similar advantages to fertigation, fertilization is similar to it. Because, unlike conventional fertigation, the producer has little control over the amount of nutrients provided by TWW, there is a risk of application overload and challenges coordinating treatment with crop demands. The decrease of greenhouse gas emissions from the manufacture and distribution of chemical fertilizers when nutrients are recycled through irrigation utilizing TWW is another benefit to the environment and society. However, fertilizer inefficiency in the TWW or an excessive nutrient load from normal fertilization and TWW irrigation may cause environmental pollution via soil accumulation, discharge into water reservoirs, and leaching into groundwater. The main nutrients whose concentrations in sewage water are higher than in the original freshwater are N, P, and K. Organic forms of N and P that are missing from freshwater are found in wastewater and TWW. In light of this, the plant availability of N and P applied by irrigation with TWW and their course in the environment vary from that of N and P fertilizers. Using TWW to water polluting the environment and reducing the ease with which plants may get micronutrients. The main issues with TWW irrigation and effective N, P, and micronutrient supplies are discussed below, along with any possible environmental risks.

Nitrogen

Mineral and organic N are present in substantial amounts in municipal wastewater, ranging from 20 to 100 mg l-1. N concentration in TWW decreases when treatment level moves from primary to secondary. When N is removed from the effluent by nitrification and denitrification processes during tertiary treatment, it falls even more. Hence, the range of the total N concentration of TWW utilized for irrigation might be 5 to 60 mg l-1. The average concentrations of total and ammonium-N in TWW used for irrigation in Israel were 23 and 31 mg l-1, respectively, according to Tarchitzky et al. For certain crops, the amount of nitrogen that is added to soils using TWW irrigation may even be more than the typical amount that is added via freshwater fertilization. The hazards of nitrogen runoff or downward leaching causing environmental contamination, nitrogen losses from gas emissions, and the limited availability of mineral and organic nitrogen to crops in the TWW are the primary drawbacks of using the TWW as a source of nitrogen. The primary determinants of N availability and its potential to contaminate the environment are the chemical reactions that take place in the soil as a consequence of the addition of inorganic and organic N. The transformation of organic nitrogen into inorganic nitrogen is known as nitrogen mineralization. In sandy loam, loess, and calcareous clay soils, NH + soon replaces TWW as the predominant N form due to the swift rate of biological N mineralization: 0.3, 0.4, and 1.1 wk-1, respectively. The behavior of the NH + applied with TWW in soil is affected by the nitrification, adsorption and fixation processes, and gas loss. Adsorption regulates the concentration of NH + in the soil solution for a short period of time after wastewater application.

The improved sorption and fixing processes minimize the sorption leaching in soils watered with TWW. In the last ten years, Kissel et al. and Francis et al. have studied the regulating reactions and environmental factors that influence NH3 volatilization from inorganic fertilizers and organic sources applied to soil. The concentration of ammonia in a solution is a function of the concentration of NH + in the solution as well as the pH of the solution. The depth of the slurry infiltration is the main determinant of NH volatilization from soils treated with various animal slurries. When the NH + used with TWW irrigation percolates into the soil, less volatilization is anticipated. Sprinklers come first followed by surface drip irrigation and then subsurface drip irrigation as possible N losses due to ammonia volatilization in irrigation systems. As a result, N loss from TWW irrigation due to ammonia volatilization is often modest and may be reduced with careful management [8].

Due to the quick nitrification process, nitrate is the predominant mineral N found in neutral to calcareous soils of areas watered with TWW, despite the fact that NH + is the most prevalent form of mineral N in effluents. It was shown that NH + was the predominant N form in certain acid soils watered with TWW. This is likely because the rate of nitrification decreases when the pH drops below 7.5, which is the ideal level. Nevertheless, Phillips found that ammonium from piggery effluent nitrified quickly at two Australian locations where the pH varied from 4.4 to 6.4. With TWW irrigation, high quantities of nitrite have been found in soil solutions. The greater sensitivity of nitrite oxidizing bacteria to high NH + levels than NH + oxidizers, the combined impact of the raised NH4 concentration and high pH, and the effect of the rise in osmotic pressure and chloride concentrations are possible explanations for these observations. Additional potential causes of nitrite buildup in soil irrigated with TWW include the presence of dissolved organic matter with low molecular weight, which slows nitrite oxidation, and oxygen stress brought on by the oxygen used for the organic matter in TWW decomposition. As a result, when TWW is used to water sensitive crops, the nitrite content in the soil has to be closely monitored.

Nitrogen given by irrigation with high N TWW may be less effective if nitrogen is lost through emission as N oxy gases and N2. Yet, the majority of research show that the amounts of applied N losses as gasses from TWW watered soils are rather modest. Denitrification is expected to rise in heavy, poorly drained soils watered with poor-quality TWW with high organic matter content. Nitrification is another possibility for the loss of these gases. Using TWW for irrigation might result in greenhouse gas emissions from denitrification. There aren't many direct measurements of how much N plants absorb from TWW. In a pot research using 15N enrichment, Feigin et al. showed that the availability of N provided with TWW was the same as N given by fertilizer with freshwater. Several indirect findings from field studies show that the reaction to N in TWW and N absorption of different crops are comparable to those for applied inorganic fertilizer. N . In a literature study, Bar-Tal et al. noted that the majority of the published papers noted an improvement in yield response and an increase in leaf N or total N absorption to irrigation with TWW.

TWW irrigation may cause considerable economic harm and raises the danger to groundwater quality from unchecked leaching of numerous elements, such as soluble organic matter, salts, and nitrates. As ammonium and dissolved organic nitrogen make up the majority of the nitrogen in TWW, nitrate fertigation should result in faster nitrate leaching than irrigation with TWW. The transport and leaching of nitrogen as nitrate in soils irrigated with TWW may occur quickly under situations of fast nitrification. In order to investigate the prospect of reducing N leaching from TWW irrigation of citrus and field crops, a number of long-term field experiments were carried out in Israel. Organic N has been reported to be more mobile in soils than ammonium and may be absorbed by soil colloids. As a result, irrigation with TWW having high DON may be harmful to the ecosystem, particularly in areas with poor drainage.

The quantity and timing of nitrogen absorption by the crop must be taken into account when secondary effluent as a N source is being examined. By taking into consideration the TWW-N in the fertilization application and by adjusting the irrigation volume, the leaching of TWW N in irrigated field crops and trees was reduced. Resources for above-ground water may become contaminated by runoff and horizontal movement of excess N from TWW [9].

Phosphorus

Depending on the water source, raw sewage water has significant quantities of organic and mineral P. between 4 and 36 mg l-1, the P concentration of raw municipal sewage water has a broad range. The overall P content in TWW is seldom affected by secondary therapy. By using a variety of tertiary treatments, including the addition of alum or lime to coagulate suspended solids and BOD, the formation and precipitation of struvite, which may be used as P fertilizer, and environmental factors that encourage microbial P consumption above metabolic requirement, the concentration is reduced to very low values of 0.1 to 0.2 mg l-1. According to Tarchitzky et al., secondary TWW utilized for irrigation in survey plots in Israel had an average content of organic and mineral P of 6.8 and 4.2 mg l-1, respectively. P added to soils through TWW irrigation meets and even exceeds the amount typically applied via fertilization with freshwater for irrigated crops in semiarid and arid regions, which is not only a beneficial economical characteristic for TWW use in agriculture but also a potential environmental pollutant. The chemical interactions between the additional inorganic and organic P in the soil are the primary mechanisms that affect P availability and its potential to cause environmental contamination. There are just two primary chemical traits specific to TWW that influence P destiny in soil: 1. P can be present in TWW in both organic and inorganic forms, and each has a different chemical makeup, mobility, and plant-use. 2. TWW contains organic molecules that have been dissolved and may chelate phosphorus, increasing phosphorus mobility in soil. There is not enough information on the organic P species in TWW. According to reports, phospholipids make up around 50% of the organic P in activated sewage sludge, followed by inositol hexaphosphate and humic compounds.

How do organic molecules impact the adsorption, precipitation, and mobility of inorganic P in soil? P precipitation reactions with other minerals are sluggish processes that take months to years to attain equilibrium. The rate of Ca-P mineral precipitation is significantly slowed down when soluble organic matter is present. Adsorption processes occur extremely quickly and may achieve equilibrium in a matter of seconds to days. Hence, it is anticipated that sorption reactions would regulate the P content in the soil solution immediately after TWW irrigation, whereas subsequent precipitation processes will alter the P concentration over time. In many experiments, P sorption decreased when humic and fulvic acids were present, pointing to competitive adsorption. According to Sibanda and Young, the impact of HA on P adsorption decreased with rising pH and disappeared at pH 7.6. P complexation is another process by which organic chemicals affect the sorption and mobility of phosphorus in soil. In contrast to immobile, stable organic complexes with P that increase its sorption and decrease P mobility in soil, dissolved and stable complexes promote P mobility in soil owing to lower P adsorption. According to many investigations, at comparable P concentrations and pH, IHP-P is better at adhering to clay minerals and metal oxides than inorganic P. This is most likely because IHP-P has a substantially greater charge density than inorganic P.

As shown above, mechanisms that regulate P content in the soil solution may be complicated by TWW's chemical makeup. In a laboratory soil column experiment, Bar-Yosef discovered that at a same P content in equilibrium solution, IHP-P was roughly 10 times more readily absorbed by a loess soil than inorganic P. In contrast, P was leached to deeper strata in field trials than P provided as mineral fertilizer with freshwater. In a non-calcareous sandy soil irrigated with TWW for 8 years, for instance, Lado et al. showed greater concentrations of accessible P than in fertigation with freshwater down to 90 cm deep. The difference in soil accessible P between TWW and freshwater in a calcareous clayey soil was smaller, and the depth of greater P concentration was just 60 cm [10].

Using TWW irrigation, the following techniques were proposed to improve P mobilization to deeper soil depths. According to Barton et al., preferential flow via macropores and soil fractures caused the leaching depth of P to be higher in soils watered with secondary effluents. An alternate mechanism proposed by Bar-Yosef to account for preferred P flow in soil is the coating of soil pores with hydrophobic material from effluents or biosolids. The hydrophobicity of the coating is more successful in reducing water flow in micropores than in macropores, which results in a reduction in the soil surface area accessible for reaction and, therefore, P adsorption. Water movement in soil is enhanced by reduced micropore flow, which results in higher water transport through macropores. The overall result is that P adsorption is decreased and P leaching is increased in TWW irrigated soils compared to freshwater irrigated soils.

Availability of micronutrients

In addition to containing and adding micronutrients to the soil, wastewater irrigation can also contribute sewage effluent constituents that can change the composition of the soil and solutions and processes that affect the solubility, mobility, and bioavailability of elements, particularly trace metals. Table 3 displays basic quality metrics and micronutrient content for raw WW and three different kinds of secondary effluents, illustrative of the first mode. Obviously, the effluent's vitamin and macronutrient concentration increases with decreased improved wastewater treatment. Secondary TWW varieties often have micronutrient concentrations that fall within the range required by different crops. By comparing element load to crop needs. Typically, nutrient solutions are administered at quantities between 10 and 25 percent of the maximum strength shown in Table 3. Iron is found as soluble organic complexes and the reduced, soluble form Fe2+ because to the high oxygen requirement of raw and secondary TWW types. During the soil aquifer treatment, recharging the TWW into the aquifer sediments. The soil features and characteristics that impact mineral stability and element solubility are the second way that TWW influences the availability of micronutrients. There are current in-depth studies available on the behavior of heavy metals in TWW irrigated soils [11].

According to Hass et al., agricultural irrigation with improved municipal TWW and low metal and TOC levels should result in little, if any, metal deposition in the soil and crops and provide little to no danger for metal leaching. This is particularly true in soils with pH levels over 6.5 and when irrigation is controlled based on crop water needs rather than requirements for wastewater disposal.Other geochemical processes that further affect the solubility of TWW- and soil-borne metals may be encouraged by TWW irrigation. According to TWW irrigation is expected to encourage the reductive breakdown of ligand in soil, depending on the soil's quality, composition, irrigation method, and irrigation loads. Such processes will liberate soil-borne metals and eventually cause the soil's affinity for transition metals to decrease because amorphous minerals and free oxides, particularly those of Mn and Fe, are more vulnerable [12].

CONCLUSION

Rules for TWW irrigation should take a reduced risk approach, which may be achieved either by giving WW advanced treatment to satisfy fecal coliform standards or by putting preventative practices and measures in place on farms. The latter depends on taking into account a variety of FC obstacles, including TWW quality, crop type, cropping techniques, harvesting and irrigation techniques, as well as the characteristics and anticipated uses of the crop. By fouling pipes and equipment and clogging emitters, irrigation systems using TWW and/or chemical fertigation might suffer. Clogging prevention demands effort and cost, and it must be tailored to a particular water condition. It is important to take into account both the need for leaching and the crop's reaction to stress brought on by any combination of potential causes when managing water with high salt concentrations. Long-term irrigation with salty water in dry circumstances is challenging since leaching is required. Leached salts and water must be collected and disposed of, or else the leaching must be reduced, for sustainable farming.

Using TWW for irrigation allows for the use of water and nutrient resources that would not otherwise be used. It will be less likely for N and P to pollute the environment if growers are aware of the need to modify N, P, and K fertilization by taking the composition of TWW into account. Uncertainty exists about how the organic P component affects the destiny of P in soil, and both laboratory and field research have produced contradicting findings. For a better understanding of the mechanisms regulating organic and inorganic P transport in soils irrigated with TWW, novel strategies and cutting-edge techniques are needed. To reduce nitrate leaching toward groundwater and nitrate and phosphate runoff to surface water resources, management techniques must be used. When crops are irrigated with sophisticated municipal TWW and little to no industrial inputs, there is minimal to no danger of metal buildup in the soil and crops or metal leaching. This is particularly true in soils with pH levels over 6.5 and when irrigation is regulated to fulfill crop water needs.

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CHAPTER 11

USING CONSERVATION AGRICULTURE TECHNIQUES, FARMERS CAN INCREASE THE EFFECTIVENESS OF THEIR FERTILIZER AND WATER USE

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ABSTRACT:

The rate of deterioration of Central Asian irrigated drylands has increased due to intensive soil tillage, poor irrigation water management, and improper fertilizer use. There are now considerable worries regarding the sustainability of the present conventional agriculture systems due to the growing water shortage and irrigation water quality issues. There is a need to develop innovative agricultural systems that increase the productivity of natural resources as well as of external inputs and aid in preventing soil degradation in order to address these environmental and economic concerns. Such answers are provided by conservation agriculture methods including minimal tillage, residue retention, and appropriate crop rotations, although research on CA in Central Asia is still in its infancy.

KEYWORDS:

Agriculture, Fertilizer, Food Security, Management, Nutrients.

INTRODUCTION

The effectiveness of various CA methods under diverse agricultural systems has been assessed in a number of research from the irrigated zones of Central Asia, which are reviewed in this study. Several studies have shown that growing wheat and maize on relatively permanent raised beds with residue retention may result in water savings of 12–23%. Raised bed systems reduced the amount of irrigation water used to grow rice by up to 70% when compared to traditional farming methods. Similar to this, permanent raised beds and nitrogen management based on crop need have increased the efficiency of nitrogen utilization in Central Asian irrigated drylands. The dryland ecosystems in the five Central Asian countries of Kazakhstan, Kyrgyzstan, Tajikistan, Turkmenistan, and Uzbekistan received irrigation to a total of around 8 million acres between 1950 and 1990. Due to this, irrigated land was extensively farmed instead of being used for mono-cropping in drylands. One of the greatest irrigated zones in the world, the size of the irrigation systems only made up less than 3% of the 397,000 km2 of Central Asian land.

During the Soviet era, this increase in the irrigated land was crucial to raising the output of irrigated cotton and ensuring the livelihood security of 70% of the 63 million people. Yet, in less than 40 years, water use quadrupled to around 96.3 km3, 90% of which was used to irrigate crops. The use of heavy agricultural equipment and the availability of irrigation water increased crop productivity, but they also caused soil compaction, erosion, water logging, soil salinization, and nutrient mining. According to estimates, soil degradation costs the irrigated drylands of Central Asia an estimated USD 31 million annually in lost agricultural output. The stability of the region's economy and way of life are threatened by this. Research efforts have been made to examine land use practices that increase water use efficiency, save irrigation water, and make effective use of soil fertility and fertilizer amendments such as nitrogen, which is the most limiting nutrient in regional crop production. These efforts are being driven by concern for ecological sustainability and future food security, especially given the predicted water scarcity in the region [1].

Agriculture in the area will need to become more effective and less polluting as it continues to expand. But, the agricultural community, which is in desperate need of alternatives, won't benefit from blueprint solutions. For example, agricultural techniques in Uzbekistan are changing after decades of extensive automation and intense input utilization, patterns reminiscent of the Soviet period. Notwithstanding progress, the nation still lags behind in terms of crop rotation, crop variety, and conservation farming methods. The current mainstream approach to fixing specific issues within the agricultural system is inadequate; instead, a better and more productive farming system is required, which may be delivered via CA techniques.

Conservation farming

Major adjustments to farm cropping practices are required by conservation agriculture, which emphasizes system viewpoints, and entail a mix of crop residue retention, minimal tillage, and optimum crop rotation. Depending on regional circumstances, several approaches are used to implementing these fundamental ideas. A departure from the following techniques is one of the primary transition methods from traditional to CA practices [2]:

- Excessive tilling, soil erosion, or very little tilling.
- Burning of residues or assimilation of residues into surface retention.
- Farm equipment may move freely in a regulated area.
- From crop-based to cropping system-based management.
- Crops that are intercropped or relayed together.
- Uneven fields may be leveled using a precision laser and in gravity-irrigated systems.

Nowadays, farmers on more than 100 Mha of land throughout the globe use CA methods. Farmers may save labor and money by using different reduced tillage techniques. Along with providing financial advantages, minimal tillage techniques also efficiently reduce soil disturbance, regulate soil evaporation loss, decrease soil erosion losses, improve soil carbon sequestration, promote water penetration, and increase the quantity of plant-available soil water. Permanent elevated beds make it easier to control or limit traffic, a crucial practice for CA systems to succeed. This prevents broad field compaction by limiting field traffic and allowing for the continuation of previously utilized tracks. So, under CA, the rooting zone experiences much reduced compaction, improving soil structure and increasing yields in comparison to farm gear that is allowed to run at full speed. Controlled traffic is important because it also results in fuel savings since tires have better grip on compacted tracks. An ever-renewable source of soil organic matter is crop residue. It has the potential to enhance soil's physical, chemical, and biological qualities, lessen water lost via evaporation, and boost soils' ability to retain water. The following advantages come from crop rotations that include legume crops in cotton monoculture systems or certain cereal crops in cereal systems:

- Disrupts the pest life cycle, which lowers pest numbers.
- A rise in biological N-fixation.
- Aids in the sustained gradual release of nutrients from sophisticated chemical compounds.
- soil enhancements resulting from deeper carbon inputs, and
- Assists in redistributing soil nutrients from deeper soil layers to the root zone.

- These procedures help cut down on input prices for chemicals and fertilizer.

Together, these CA benefits have the potential to significantly boost the crop's access to water and nutrients in both rain-fed and irrigated environments. Consequently, we anticipate similar advantages under Central Asian irrigation-based agricultural production. Based on data from Khorezm, Uzbekistan, this paper compiles and analyzes research findings on CA techniques for the three most common crop rotations in irrigated dryland regions of Central Asia: cotton-wheat-third crop, cotton-winter cover crop-cotton, and rice-wheat. This paperfocuses on the Improvements in water and nitrogen usage efficiency are made concurrently, and the reduced-tillage treatments permanent bed and zero tillage are used.

Leveling of soil using a laser

The only way to grow crops in the lowlands of Uzbekistan is via irrigated agriculture since the average annual rainfall there is typically far below 100 mm. Row/furrow irrigation and basin irrigation are two prominent uses for irrigation water. Due in part to the uneven micro-relief of the fields, irrigation water is often applied inefficiently. In Uzbekistan, land leveling was formerly a regular practice during the Soviet period, but these days, most commercially oriented and home farms seldom ever do so, while being aware of the detrimental effects. This is because they lack the resources, the necessary tools, and the necessary knowledge.

Due to substantial percolation losses from canals and water courses, excessive water application in uneven fields, and high groundwater table, more than 90% of Uzbekistan's irrigated croplands now experience variable degrees of secondary salinization. A tractor-drawn leveler with a blade or a wooden bar for transporting dirt from higher to lower altitudes is the most often used land-leveling method. Although this helps to level the ground to some extent, irrigation also highlights variances in soil salinization throughout the area and continues to reveal substantial, small-scale topographic variables that preclude equitable water distribution. The requirement for regular repetition of this leveling raises the expense. Unleveled fields feature larger weed populations, inconsistent crop maturity rates, and irregular crop growth patterns, all of which contribute to output losses [3].

The most effective method for exact leveling is laser-guided land leveling. Under surface irrigation circumstances, laser leveling improves CA in the same ways that traditional agriculture does. According to Abdullaev et al., crop cultivation benefits from laser-guided land-leveling because it increases crop water productivity by 32% and average cotton yield by 26% when compared to conventionally leveled fields. It also leads to improved water distribution, negligible water losses, and high irrigation water application efficiency. Follow-up studies revealed that while laser-guided land leveling initially cost more than traditional leveling techniques, the advantages in productivity and water saving more than made up for this. Water demands were cut by 25%, crop germination, establishment, growth, and stand uniformity resulted in a 24% increase in crop production, and up to 40% less weed infestation. Also, under CA, where no additional soil tillage is used and may potentially harm the leveled surface, the investment pays off for a longer time after the field has been laser-leveled.

To make the most of specialist equipment, groups of farmers may split the expense of acquiring laser-leveling equipment, and service providers could level fields for a fee. Moreover, laser leveling helps reduce production loss while switching from traditional to CA techniques. The results of a study conducted in the Khorezm area of Uzbekistan, where cotton yields did not vary considerably between both cotton-cover crop-cotton and cotton-wheat-maize cycle systems use conventional and CA methods. Overall, study results showed that laser-leveling prior to beginning CA practices may prevent yield decreases throughout the time of transition from conventional to CA, in addition to significantly reducing irrigation water use.

Application of water and productivity

The projections of growing water shortages in the irrigated regions of Central Asia described above highlight the need for solutions that improve water use efficiency, lower irrigation water demands, and boost yields. According to reports by Abdullaev and Molden, irrigated agriculture's water productivity in Central Asia has significantly declined during the last several decades. The Syr Darya basin's whole cotton-growing region, which is mostly irrigated using flood and furrow techniques, has an average water productivity of roughly 0.37 kg m-3, which is much lower than the global average of 0.60 kg m-3. Permanent raised bed planting methods make irrigation easier via the use of furrows, and are consequently regarded as a technique that conserves irrigation water and lessens soil erosion. In southern Kazakhstan, Kalashnikov discovered that PB systems outperformed standard flat planting in terms of agricultural yields, with improvements in crop yields of 24–32%. Devkota observed that in Khorezm, Uzbekistan, wheat and maize grown on PB enhanced agricultural water productivity by 27-83% and conserved 12-23% irrigation water compared to traditional methods in both cotton-wheat-maize and rice-wheat rotation systems. Similarly, the PB system reduced water use in rice by 70% while doubling crop water production compared to traditional methods. These decreases in irrigation water use have already been demonstrated, and given Central Asia's declining water supply and rising agricultural water demand, they are anticipated to be of major significance [4].

Moreover, crop residue retention in the PB system improves water usage effectiveness. The observed that, with the exception of cotton production in one season, irrigation water usage efficiency throughout the 4 years was enhanced by retaining all crop residues from the preceding crop. When PB was used in conjunction with complete crop residue retention, the efficiency of irrigation water consumption for cotton lint rose from 0.41 kg m-3 at the start of an experiment to 0.59 kg m-3 at the conclusion. Corresponding to this, soil moisture under PB with crop residue retention was greater than under residue removal. As a result, PB with residue retention may be more significant in Central Asia's dry areas since it may reduce irrigation water use and boost crop water production.

Nitrogen control using CA techniques

One of the most crucial minerals for crop growth is nitrogen, which is also one of the scarcest nutrients in Central Asian irrigation-based agricultural production. As compared to traditional systems, N dynamics under CA might vary significantly because of lower soil tillage and residue retention. With unincorporated surface residues present, it is difficult to apply top-dressed N fertilizer deeply in the soil. According to Carter and Rennie, many crop residues have high C/N ratios, which causes applied fertilizer N to get immobilized in the crop residues and typically results in reduced crop N-use efficiency during the early stages of CA. To balance off this early N immobilization, greater N treatments compared with traditional techniques without residue retention are advised. Similar to this, Hickmann and Sommer et al. proposed that crop residue retention should be done in conjunction with extra N treatments to balance off N immobilization during the transition from conventional to CA methods. Long-term crop N usage efficiency may be improved by subsequent re-mineralization of the N in better synchronization with crop demands, which is made possible by fewer N losses and increased retention of fertilizer N owing to immobilization. The use of the Turbo Happy Seeder machine, which cuts and manages the standing stubble and loose straw in front of the furrow openers and retains it as surface mulch, has been found to be effective in preventing the immobilization of top-dressed fertilizer N by surface residues. Deep placement of 80% of the total N between rows during seeding has also been found to be effective. A single baseline dosage of N proved to be just as efficient as split doses of fertilizer N given to irrigated wheat crops in the Indian

Punjab, according to a recent Singh et al. analysis. On the other hand, top-dressing N at anthesis increased grain protein content while having no impact on yield. The demand for N in irrigated crops did not change as a result of the transition between conventional and CA techniques, according to more recent research from Uzbekistan [5].

After one season of CA activities, crops grown on PB had a greater reaction to applied N under both low and high N application rates than in the traditional systems, with a wheat grain yield in PB under the same N levels as in conventional techniques being 6-14% higher. Similar to this, Limon-Ortega et al. observed that switching from the CT to the PB tillage technique boosted grain yield of wheat in a maize-wheat rotation system at both low and high N treatment rates. Agronomic and apparent N recovery efficiencies were greater in wheat and maize cultivated under PB than in CT systems in Uzbekistan following one season of CA practices. This was brought about by PB's superior initial growth and consistently greater soil moisture availability, which raised the amount of N available and boosted crop N absorption. Hence, we draw the conclusion that crops may be produced in PB with the same N dosage as in CT systems without a loss in crop production for both cotton-wheat-maize and cotton-cover crop-cotton cycle systems [6].

Without N treatment, crop residue retention in PB systems enhanced crop yields, but with N application, crop residue retention did not have an impact until the second cropping cycle. Using CA techniques, grain yields were marginally higher in the third cropping cycle. This shows that the advantages of agricultural leftovers accumulate over time in a high-production setting like the irrigated drylands of Central Asia. Although while residue retention is advantageous in both low- and high-yielding situations, it is not required to save leftovers from every crop in the cycle. This is particularly true in irrigated wheat-based systems where significant volumes of crop wastes are generated. In fact, retaining these residue levels as a thick surface layer impeded field activities including sowing, irrigation, and fertilizer management and decreased seedling emergence. Devkota proved this for the irrigated drylands in Central Asia, where the addition of a winter cover-crop to a cotton mono-cropping system decreased the leaching loss of nitrogen to the groundwater by a third and boosted nitrogen usage efficiency. This was largely because the cover crop's absorption of soil-mineral N decreased N loss during early-spring salt leaching.

Devkota et al. discovered larger losses of mineral N with full retention of crop residues than with total residue clearance in a two-year research on the rice-wheat systems in Uzbekistan. This only happened during the rice cropping cycles, when roughly 6-7 t ha-1 of wheat residues were maintained, and it happened in both PB and zero-till flat planting. The standing residues' shadowing impact, which reduced early rice development and total plant N absorption, frequent alternating wet and dry watering, denitrification and leaching loss, and immobilization of N in the crop residues all contributed to the increased N loss. This result highlights the significance of a research component in CA practices in the irrigated regions on the correct dosage and technique of N fertilizer management, quantity and method of irrigation, and dose and method of residue management, which are essential to maximize N usage efficiency in rice. N losses in wheat on either permanent raised beds or ZT flat planting were not seen since the subsequent winter wheat crop was not impacted by the standing rice residues. These findings all point to the need of residue management in the rice-wheat system when using CA techniques [7].

N management depending on Crop Demand

Due to the poor soil fertility in Central Asia and the sparse use of organic amendments, the careful use of artificial fertilizers is crucial for crop productivity. Fertilizer application rates that are higher than what is required by the plants and crops result in needless expenses for farmers and a possible degradation of the land and water resources. This is true in especially for N usage, which is the nutrient most responsible for restricting the output of irrigated crops. Nevertheless, with enhanced fertilizer application, such as with late administrations of N during anthesis/heading, protein content in the kernel improves, and therefore grain quality criteria of winter wheat may be satisfied. Under the current N fertilizer techniques in Uzbekistan, grain quality of wheat remained low.

Since N is lost by leaching and volatilization, current crop and soil N balances are often low. The N need for cotton in Uzbekistan's irrigated regions is in the range of 200 kg N ha-1 for maximum production, according to estimations by simulation models run in the Khorezm Region of the country. Conversely, Devkota et al. observed that the best cotton yields may also be obtained with N-fertilizer rates of roughly 150 kg N ha-1 in a research carried out in the same location for two years. The Khorezm Region's groundwater level becomes shallow during the cotton-growing season, from May to September, and drops to around a meter deep with a 4-12 ppm nitrate content. It indicates that N absorption from extra N inputs, as well as from groundwater and irrigation water, may have satisfied the N need of the cotton crop. Farmers are fully aware that larger N treatments cause cotton bolls to open later and raise the likelihood that growers won't get the greatest prices, which normally happen around the start of Central Asia's 4-6 week cotton harvest.

As a result, even though the amount of nitrogen leached into groundwater varied between 5 and 61 kg N ha-1, it cannot be said that all producers' reliance on this potential source of nitrogen is sustainable because reducing fertilizer N applications over time will gradually deplete soil and water N reservoirs. Further research revealed that the N-fertilizer dosage for crops in the Khorezm Area is site-specific and both economically and environmentally efficient. It is not a good idea to rely only on groundwater as a supply of nitrogen for cotton. Adapting application techniques that avoid or greatly minimize N leaching losses and improve fertilizer N usage efficiency is a superior course of action. In order to reduce the building of soil salinity before the crop is sown, one such typical technique in Central Asia is to leave the fields fallow and engage in significant pre-winter leaching. The concentration of NO3-N in groundwater is shown to be at its greatest during early spring leaching. Devkota et al. have, however, more recently found that the use of wheat as a winter cover crop in a cotton mono-crop may retain the free mineral N and therefore prevent N leaching to the groundwater.

According to Scheer et al., cotton has extraordinarily high N emission rates, with peak emissions occurring just after irrigation and N fertilizer applications. This implies that timing the delivery of N fertilizer specifically to coincide with plant requirements might decrease N loss via gaseous emissions and improve N usage efficiency. Therefore, N-fertilizers are best applied as subsurface placement of fertilizers or broadcast and deep seated with a pre-sowing irrigation, or applied with drip irrigation, as the majority of nitrous oxide emissions occur when irrigation and N-fertilizer are applied simultaneously under high soil temperatures. These solutions are all capable of lowering N_2O emissions. Also, prudent crop rotation decisions that take into account leguminous crops and crop residue management would increase soil carbon absorption and decrease N_2O emissions from mineral fertilizers. Yet, these techniques are not yet very common. When crop N demand and supply are balanced, first study results show a great potential to boost N usage efficiency [8].

Matching crop N supply and demand

Understanding the levels and fluctuations in the sources of N supply throughout the growing season is essential given the agro-ecological conditions present in the Khorezm Area and in many irrigated drylands in Central Asia. The ideal time and quantity of fertilizer N treatments will be determined by this information. The spatiotemporal high variability of N supply under irrigated settings necessitates the development of new strategies to match N treatments to crop needs. While plant tissue and soil testing are already used in Uzbekistan to determine N needs, these procedures call for expensive laboratory equipment, money, and time. Delays caused by soil and tissue collection, shipping, and processing prevent farmers from receiving timely information to meet demand for in-season plant-N. In Europe, India, and the USA, real-time N monitoring has been carried out using simple, non-destructive equipment. By timing N treatments with crop demand and irrigation cycles, optical devices like as the SPAD-502 chlorophyll meter and the GreenSeeker NDVI sensor have enhanced fertilizer N usage efficiency and decreased losses of N from the soil-plant system. These tools also have the benefit of providing spatially varying N suggestions within a field. The most sustainable and cost-effective solutions for crop cultivation in Central Asia's irrigated drylands may be the combined use of CA techniques and crop-demand-based N treatment [9]–[11].

CONCLUSION

All of the few studies that have been conducted on CA techniques in the irrigated drylands of Central Asia concluded that CA techniques outperform traditional production techniques in terms of crop productivity, nitrogen use efficiency, and water use efficiency. The promotion of CA on a big scale in the irrigated drylands of Central Asia is justified by two consistent pieces of evidence, comparable or improvements in yield and larger financial advantages. Additionally, using. When used in conjunction with permanent raised-bed planting, zero-tillage, and residue retention techniques, laser-guided land leveling increases productivity and maximizes the use of irrigation water and externally applied fertilizer nutrients.

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CHAPTER 12
AGRICULTURE MANAGEMENT AND THE IMPACT ON THE ENVIRONMENT

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ABSTRACT:

Agriculture will face the issue of ensuring food security for a rising global population without compromising environmental security as demand on the world's food systems increases in the next decades. Thus, in order to produce enough food and other resources, it will be required to apply contemporary technology in agroecosystems. The harm that chemical fertilization and improper disposal or re-use of agricultural wastes do to the environment. Combining biotechnology with nanotechnology has the potential to transform agricultural practices and provide answers to both immediate and long-term issues. They include the creation and use of intelligent fertilizers with regulated nutrient release as well as bioformulations derived from bacteria or enzymes. The purpose of this research was to give a critical analysis of data about present problems with food security and the significance of developing smart fertilizers for future food production. We focus on improvements in the creation of biofertilizers with controlled release as well as the utilization of harvesting wastes as coating and carrier materials.

KEYWORDS:

Agriculture, Fertilizer, Food Security, Management, Nutrients.

INTRODUCTION

Around 40% to 50% of the Earth's land area is made up by agricultural land systems cropland, managed grassland, permanent crops, including agroforestry and bioenergy crops that are necessary for human food production. By 2050, the world's population is projected to grow from 7.2 to 9.6 billion people, which would result in higher food consumption and feedstock needs. The UN set 17 sustainable development objectives in 2015 with the intention of eradicating hunger and severe poverty by 2030 while also protecting the environment and the world's climate. This suggests innovative agricultural intensification on currently used land via cooperation across several industries. The development of plant fertilization methods might be one way to increase agricultural productivity. As phosphorus and nitrogen are two necessary minerals for plant development, their application as chemical fertilizers has increased since the green revolution of the 1960s and has a direct impact on crop yield [1].

Inputs of fertilizer must continue in order to maintain and boost food output. Yet, due to crops' relatively poor nutrient intake in productive systems, there are issues with the usage of mineral fertilizers. High rates of fertilization result in N and P losses, which have an adverse effect on atmospheric concentrations of greenhouse gases and water quality. Nutrient 120 has to be improved immediately. Efficiency in agricultural systems and sustainable biogeochemical cycle management are used by Marcela Calabi-Floody and others. This involves the creation and use of contemporary biotechnological techniques as alternatives to traditional fertilization, such as plant growth-promoting rhizobacteria and diazotrophic N2-fixing bacteria.

A diversified, wholesome diet will need a variety of agricultural products that are produced all over the globe. Nonetheless, the three cereal crops rice, wheat, and maize will continue to be the most important sources of stable foods, which are most important for ensuring global food security. The goal is to enhance grain output globally in order to meet the rising demand. The quantity of harvesting leftovers that may be utilized as biomass feedstock or for animal feeding would rise as a result of higher output. The elimination of these residues by in situ burning, which has substantial negative effects on the environment, the economy, and human health , is regrettably one of the most prominent activities internationally. Harvesting leftovers have to be seen as a resource that may be used as organic raw material to enhance the quality and productivity of soil. The utilization of these wastes as composting agents is one strategy to benefit from them. It has also been proposed that pyrolysis of harvesting leftovers to create biochar is a beneficial technique that can provide both energy and a soil conditioner with the potential to boost plant growth and soil carbon sequestration. The conversion of harvesting wastes into raw materials for fertilizer manufacture might be another tactic. This review's objective is to demonstrate smart fertilizer technology advancements as a solution to scenarios of food security under conditions of a rising world population and the environmental effects of traditional agricultural practices. A way to improve environmental quality and food production may be via the use of smart fertilizers. We propose that these smart fertilizers may be built on the creative use of harvesting wastes in the context of a circular economy [2].

Management of agriculture and its Environmental Impacts

Around 58% of the yearly crop area is made up of three grains, which also offer roughly 50% of the dietary calories. As a Sustainable Agricultural Strategy, Rice and Smart Fertilizers 121 Maize accounts for more than 60% of commercial animal feeds, while wheat is a crucial source of energy for the populace of emerging nations. According to estimates of future population growth, the world's grain supply would need to expand annually by 0.9% to 3009 billion tons in order to keep up with demand. With wheat yields growing from 2.8 to 3.8 t ha-1, the average worldwide grain yield will need. The extent of non-agricultural land is required for other uses, such as providing habitat for endangered species, therefore expanding agricultural land may not be a desirable alternative. So, it seems that sustainable intensification that increases productivity on already-existing land area is the best choice. Because of genetic advancement and widespread use of mineral fertilizers, cereal yields surged during the green revolution.

Nevertheless, since the 1990s, yields have not risen further. Climate change, namely temperature rises and the lengthening of summer droughts, is one of the causes of stagnant yields. The loss of soil organic matter, as well as the extended and extensive use of agrochemicals, may have also contributed to the depletion of soil reserves. So, it is very doubtful that existing crop management and development techniques will be able to provide food security in the future. However, other elements like the shrinking rural labor, the demands of the biofuel industry, and climate change, which may have a significant influence on food output, may also affect future demand for agricultural goods. Also, the adoption of more sustainable technology is required owing to the detrimental environmental effects of the green revolution caused by the widespread usage of fertilizers.

Chemical Fertilizer is Available to Boost Food Production

N and P, which are necessary and irreplaceable nutrients for plant development and to sustain life on earth, have a significant impact on food production. For instance, historical data from the maize, rice, and wheat production systems between 1960 and 2010 showed that inorganic fertilizers provided around 48% of crop N. N and P, however, [3] reveal a substantial differential in terms of their availability . In this sense, the supply of N is now limitless since the Haber Bosch process, which generates around 100TgNyr1 of urea for industrial use, creates an endless amount of urea. The availability and cost of phosphate rock in the future, however, remain a serious problem since phosphate rock deposits are limited. According to Elser and

Bennett, the cost of extracting the P from the earth is more crucial than its quantity. Despite the fact that P is a limited resource, contemporary situations need constant inputs to sustain agroecosystem output. According to a recent meta-analysis by Valkama et al., initial soil testing for P do not always anticipate this behavior, and the yield response to P fertilization varied widely in grassland systems.

DISCUSSION

Environmental Effects of Traditional Fertilization Techniques

The kind of soils and how they are managed have a significant impact on how well conventional fertilizers are used. For instance, it has been said Cambisols, one of the main soil types used for agriculture, are poor in minerals like P and have an estimated surface area of around 1.5 billion ha under farmland. Additionally, in some Cambisols from central Africa, continuous application of N and P fertilizers along with unbalanced and suboptimal fertilization for extended periods of time has resulted in soil nutrient depletion, particularly when the entire crop biomass is removed from the land. In addition, urbanization today often results in the loss of productive soils for agricultural production [4].

As a consequence, marginal land with low OM and nutrient content is given agriculture permission. Using mineral fertilizers to such soils may hasten the acidification process and result in further nutrient and organic matter losses. Other soil types, including Andisols, which make about 0.84% of the world's soil area, are distinguished by their high OM content and high P immobilization ability. According to this definition, allophane dominates the clay fraction, which accounts for 35% to 60% of the soil.

The use of urea and other ammonia fertilizers results in acidification because of agricultural management to achieve productive systems and the allophanic character of these soils. For instance, over 50% of the Andisols in Chile have an acidic pH range of 4.5–5.5. According to Mora et al., one soil characteristic that contributes to P-fixation and lowers its availability for plant feeding is soil acidity. According to Borie and Rubio, more than 50% of the phosphorus added to these soils is fixed as organic phosphorus, which may contribute to the residual percentage. As a result, enormous quantities of traditional P fertilizer must be sprayed each year to keep the levels of accessible P in soil-plant systems constant.

Following harvest, crop waste management 3.7 Pg dry matter worth of agricultural wastes are produced annually globally . As the primary crop residues, straw, roots, shaft, and other tissues from maize, wheat, and rice make up about 40.6%, 24.2%, and 15.7%, respectively. Large quantities of agricultural leftovers burned in open fields all over the globe provide soil fertilization in the form of ash input. The 27% of the yearly worldwide biomass burnt is through residue burning. According to Bruhl Berger et al., Pongpiachan et al. and Udeigwe et al. it is a major source of air pollution that threatens human health as well as the atmosphere's [5] chemistry and the climate of the whole planet. According to numerous studies, burning wheat residues produces significant amounts of particulate material less than 2.5 m, GHG, volatile organic carbon, NH3, sulfur dioxide, and other pollutants.

With around 18% of the world's output of agricultural residues, China is one of the major producers. Sun et al.’s studies looked at CO2 emissions in China from 1996 to 2013 and took into account how burning leftover rice, wheat, and maize contributed to those emissions. These sources were estimated to be responsible for 22.5% of all emissions. According to Taladriz and Schwember , burning stubble is the most popular management technique in Chile, with 80%–90% of wheat stubble being burnt. According to estimates by Heard et al. , burning straw results in nutrient losses through volatilization of 98%-100% for nitrogen, 20%-40% for phosphorus and potassium, and 70%-90% for sulfur, which may have an impact on how well those nutrients are incorporated into the soil [6].

New Technologies for the Growing World Population to Ensure Food Security and Environmental Health

New varieties of intelligent fertilizers with controlled nitrogen release are required to increase nutrient usage efficiency. The creation of such fertilizers may rely on the usage of nanomaterials or biological fertilizers [7], [8] . In this context, multidisciplinary research in the field of nanotechnology is a promising, quickly developing area that has the potential to transform food systems. Nanotechnology comprises the creation, production, and use of materials with a size between 1 and 100 nm. The characteristics of individual atoms, molecules, or bulk matter are fundamentally different from the physical, chemical, and biological properties of materials at this size. Understanding biological, physical, and chemical processes better and developing better materials, structures, devices, and systems that may be employed in agroecosystems are both possible as a result of the capacity to alter matter at the nanoscale [9]–[11]. In Figure 1 shown the smart fertilizer on the soil-plant system are being shown visually.

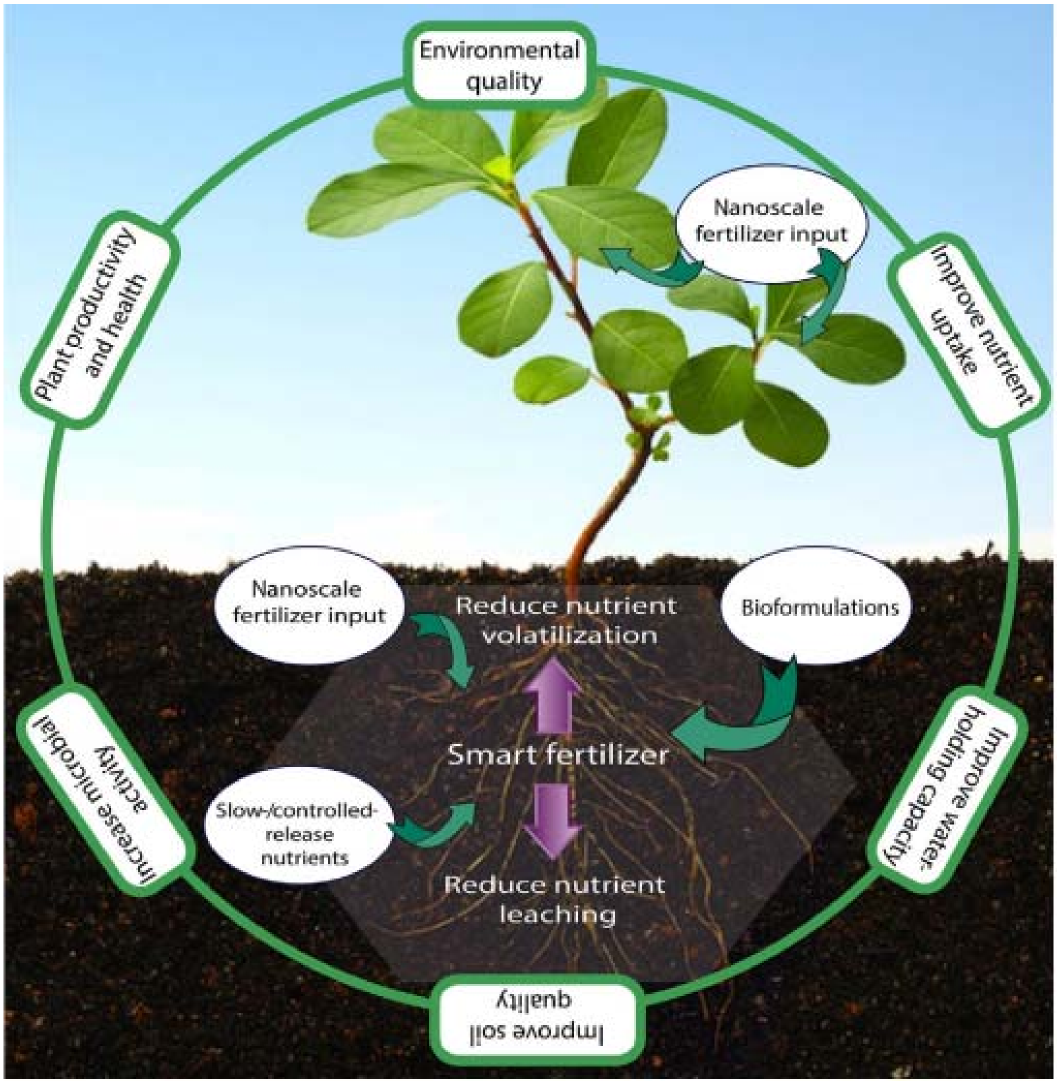

Figure 1: Effects of smart fertilizer on the soil-plant system are being shown visually.

CONCLUSION

Climate change, biodiversity loss, dead zones, deforestation, genetic engineering, irrigation concerns, pollution, soil degradation, and waste are only a few of the broader environmental problems agriculture contributes to. Environmental impacts are alterations to the built or natural environment that are a direct outcome of an activity and that may have a negative influence on the animals, fish, fisheries, fish, and other residents of the ecosystem. In conclusion, it can be said that people are a significant cause of environmental problems. Similarly, we are mostly responsible for the rise in the amount of dangerous gases and pollutants in the environment. Yet now, many are attempting to solve this issue after taking it seriously.

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CHAPTER 13

HARVESTING CROP RESIDUES FOR BIOENERGY: EFFECTS ON SOIL HEALTH AND PLANT DEVELOPMENT

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ABSTRACT:

It is thought that using agricultural leftovers as a bioenergy feedstock might help reduce greenhouse gas emissions. Crop residue collection, however, may have detrimental consequences on the health of the soil, plant development, and other ecosystem services. In order to identify and explore the key trade-offs and synergies associated with crop residue management for bioenergy generation, we have compiled the material that is currently accessible in the literature. Data again shown that crop residue harvesting and the resulting decrease in organic matter input into the soil caused C storage depletions over time, lowering the cycle, supply, and availability of soil nutrients, and directly harming the soil biota. Despite the fact that the biota controls critical processes in the soil, crop waste may also encourage the growth of several significant agricultural pests. Crop residues also serve as physical barriers that shield the soil from the effect of raindrops and temperature changes. Soil structure may deteriorate owing to intense agricultural residue harvest, which can result in soil compaction and higher erosion hazards.

KEYWORDS:

Agriculture, Fertilizer, Food Security, Management, Nutrients.

INTRODUCTION

There is disagreement over the possible effects of managing agricultural residue harvest on GHG emissions. Remains harvesting generally reduces CO2 and N2O emissions from the breakdown process but has little to no impact on CH4 emissions. Site and crop specific reactions to soil and climatic changes brought on by crop residue collection. Using optimum management methods may lessen the negative effects of harvesting agricultural leftovers. To comprehend and track the effects of integrated agricultural systems and to suggest tailored solutions for sustainable crop residue management in each area or landscape, long-term trials within important production regions are crucial. Also, for a better understanding of the potential environmental, economic, and social effects of using agricultural waste for bioenergy generation, private and governmental investments/cooperations are required [1].

One of the main strategies to reduce greenhouse gas emissions and the impacts of global warming is to gradually shift the energy mix by substituting renewable energy sources for fossil fuels. Thus, a major rise in bioenergy production is anticipated in the near future to meet the rising worldwide demand. To produce bioenergy, primarily cellulosic ethanol and bioelectricity, from agricultural leftovers, industry participants have raised their interest and investments. Presently, the majority of agricultural residue is underutilized for energy generation and is left in the field after harvest. Yet, agricultural residues are crucial for maintaining and enhancing the chemical, physical, and biological aspects of soil processes, which support plant development and other environmental services. Hence, because that the use of agricultural wastes for energy generation is a potential method on a worldwide scale, the trade-offs and environmental synergism related with crop residue management cannot be disregarded. Given the complexity of the topic, the majority of research has been done to comprehend mechanisms and discrete processes; however, very few studies have summarized and integrated this knowledge, which may aid researchers and decision-makers in the bioenergy industry. In order to better understand the possible effects of crop residue harvest on soil functioning, GHG emissions, as well as its effects on plant development and production in regions for bioenergy purposes, this review aims to consolidate, collect, and debate material already accessible in the literature. According to short-term government projections, Brazil may produce 10 billion liters of cellulosic ethanol, which is half of current production at existing plants. Another 1.5 billion liters will result from an increase in sugarcane milling, and the final 3.5 billion liters will come from new plants that will be put into operation starting in 2020. . According to EPE , the burning of sugarcane wastes provided 4% of all the energy used in Brazil in 2015, with the possibility of increasing to 18% in 2020 and 2021.

Maize crop wastes may be used to produce bioenergy with great potential. Despite the fact that this crop is farmed in many nations throughout the globe, the United States, which is the top producer of ethanol from maize grains, emphasizes the management of maize residues. Around 10 Mg ha-1 of dry material are left in the field after grain harvest, providing a sizable supply of biomass for cellulosic ethanol production. According to Wilhelm et al. , depending on production level, maize residue might provide about 1.7 times more C than barley , oat , sorghum Moench), wheat, soybean, and sunflower residues. The superior third of the plant's leaves and stem as well as the inferior third's cobs, leaves, and stem all contain varying amounts of carbohydrates. Nevertheless, these changes had little to no impact on the possibility of producing biofuel, indicating that the residual mass volume is the most important variable [2].

The ability for the United States to enhance the area planted with maize is limited. Hence, implementing optimum management methods and using plant breeding are crucial to achieving the national goal of producing 61 billion L yr1 of biofuel from agricultural leftovers by 2022. According to recent official predictions, there would be between 588 and 936 million tons of dry materials available for harvest in 2040, of which between 153 and 161 million tons will come from maize. Despite the fact that the manufacturing processes are still in their infancy compared to those for agricultural residues, forest crop wastes from the wood, paper, and cellulose industries are mentioned as prospective raw materials for bioenergy production. For an arboreal species to be economically viable, it must be mechanically harvestable throughout the year, produce wood with medium to high density and be readily dryable, in addition to having a biochemical composition suitable for the generation of bioenergy. The eucalyptus, which meets the majority of these characteristics and has significant potential for production in short rotation times, is an excellent example of a prospective raw material.

DISCUSSION

Agricultural residues with high C: N ratios may cause soil microorganisms to immobilize nitrogen, which might raise the requirement for N fertilizers in the near term. After three crop cycles, Ferreira et al. validated an average N recovery from sugarcane straw of 7.6 kg ha1, or 16% of the original N content in straw, which only contributed a little amount to crop nutrition in the near term . Yet, persistent use of sugarcane straw encourages a slow rise in soil nitrogen, which lowers the need to fertilize sugarcane crops with N. On the other hand, Khanal et al. showed that maize stover harvesting in Iowa, United States, resulted in a decrease in N in the soil. Hence, from the standpoint of environmental protection, partial harvesting of maize residues in areas with high soil levels of nitrogen might lower the amount of N that may be leachable and, as a result, the contamination of water bodies [3].

After crop residues have been harvested, there is a temporary decrease in soil P availability. This is due to I less P being released during the mineralization process and lower P adsorption to the soil minerals caused by increased soil organic matter in systems with high C input via crop residues. The amount of P extracted from the maize grains is five times more than the residue's P concentration. Yet, because 0.76 kg ha1 of P is removed from the field for every ton of maize stover, the amount of this element in the residue shouldn't be disregarded. According to Trivelin et al., sugarcane straw contains 0.41 kg ha-1 P per ton, or 40% of the P uptake by the crop.

Ionic K is not a component of any organic structure in plants and is quickly liberated from the plant waste. Since crop leftovers have high K concentrations, keeping them in place helps K build up in the soil. According to Karlen et al., maize residues make up 73% of the plant's total K extraction, and their exports of this nutrient might amount to 62 kg ha1 . In sugarcane, the straw contains 42% of the total potassium that the plant extracts , and potassium removal amounts to around 80 kg ha1[4], [5].

The short- and long-term effects of crop residue harvesting on nutrient cycling, storage, and availability in the soil. Hence, in order to maintain the system's sustainability, the proper replacement of the nutrients extracted from crop wastes should be carried out. Moreover, certain residue harvesting management techniques could reduce nutrient loss. According to many research, the content of nutrients varies based on the area of the plant that was examined. To reduce nutrient loss due to crop residue harvesting for bioenergy generation, it should only be gathered from the portions of the plant where nutrient concentration is lowest.

Crop Residues Versus Soil Structure

For many soil physical and hydraulic processes to work properly, crop residue care on the field is essential. Crop residue harvest is linked to soil structural degradation, according to the majority of studies. This is primarily due to lower C inputs into the soil, the absence of mechanical protection that disperses the pressure caused by machine traffic. Reduced macro-aggregation and aggregate stability are associated with structural deterioration of soils brought on by agricultural residue harvest, which results in soil compaction. The availability of water to plants is reduced by soil compaction because it reduces macro-porosity and increases mechanical resistance to root penetration.

As physical barriers, crop leftovers that cover the soil protect it from the erosive effects of rain and wind. Moreover, maintaining agricultural residues encourages infiltration and water storage in the soil. . Peres et al. found that compared to bare soil, water loss was decreased by around half in the presence of 15 Mg ha1 of sugarcane straw. Higher infiltration rates and water storage slow runoff, which reduces soil and nutrient losses. In a situation where climate change occurs, keeping agricultural leftovers on the soil may lessen the impacts of droughts and stop soil erosion brought on by more frequent, intense rainstorms [6]. Crop residues may also operate as a thermal isolator by lowering the rate of heat transfer between the soil and the atmosphere, which in turn lowers the amplitude of diurnal soil temperature. While the residue is young, its effect is higher; as the residue ages. When the soil is covered with maize stover , and when the soil is covered in sugarcane straw , the temperature of the soil-surface layer may be decreased by 5 to 10 °C and 2 °C, respectively . Moreover, when soil is coated with crop residues, a number of intricate processes that affect soil temperature result in less water evaporating from the soil.

Soil Biological Characteristics Versus Crop Residues

Biological characteristics are more responsive to changes in soil management than chemical and physical characteristics. The number of research to detect and measure the impacts of agricultural residue harvest on the soil biota has increased recently. Nevertheless, the consequences on the structure of the soil microbial community depend on the length of this system, the type of soil, and the climatic circumstances. During no-tillage, maize stover harvest has a considerable impact on the ratio of fungus to bacteria, particularly in the topsoil. The preservation of maize stover helps the microbial community remain stable throughout the seasons. Also, by increasing the abundance of the genes involved in N fixation and denitrification, the preservation of maize residues may have a substantial impact on the structure of the bacterial and fungal communities.

Research have shown the advantages of maintaining crop leftovers in the management of several soil pests and diseases. According to Qi et al., the germination, quantity, and weight of the sclerotia of the fungus Rhizoctonia and Bipolaris are adversely impacted by high concentrations of chemicals emitted during the breakdown of maize stover. According to Govaerts et al., maintaining maize crop leftovers increases the energy supply of microorganisms, which promotes the growth of antagonists and predators in the soil and reduces the population of phytoparasitic nematodes [7].

Neither the overall microbial biomass nor the microbial groups in annual or perennial systems were affected by the harvest of residues from several bioenergy crops, including maize, Andropogon gerardii, Miscanthus giganteus, Sorghum bicolor, Panicum virgatum, and cv. Shawnee. While slow, the remodelling of the soil microbial community is a result of changes in the amount of organic material inputs and should be seen as a long-term impact. Studies from all over the world have demonstrated that maintaining sugarcane straw encourages increases in microbial biomass and microbial community diversity, particularly in surface soil layers. Although the native vegetation-pasture-sugarcane land-use change sequence causes a significant decrease in the diversity of macroinvertebrates, the remaining straw supports the soil biota by acting as a food source, enhancing microclimate conditions, and providing shelter in sugarcane areas. As compared to control plots, complete sugarcane straw removal significantly decreased the richness and diversity of soil epigeic invertebrates, according to Portilho et al. The soil macrofauna was sustained by the presence of sugarcane straw, even though larger amounts had no discernible benefits. Also, keeping sugarcane straw on the soil may encourage the growth of natural enemies and stop the spread of phytoparasitic nematodes, which seriously harm sugarcane farms. On the other hand, maintaining sugarcane straw also encourages the growth of significant sugarcane pests like the root spittlebug and the sugarcane weevil that, if left unchecked, can result in significant losses in sugarcane yields.

Crop residues' effect on Greenhouse Gas Emissions

There is still no agreement on the precise effect of agricultural residue harvest on soil GHG emissions. According to certain research, agricultural residue harvesting increases greenhouse gas emissions. Nevertheless, some research show that residue harvest management does not affect GHG emissions and may potentially increase soil GHG emissions. The production and emission of GHG are influenced by a variety of variables, both directly and indirectly, which contributes to the wide range of findings reported in the literature. These elements can be ecological, edaphic, or connected to the kind and amount of soil-covering materials utilized. A lot of material remaining on the soil surface often results in the highest GHG emissions. Carmo et al. found that entire straw collection reduced emissions by 2.3 times compared to leaving 14 or 21 Mg ha1 of sugarcane straw on the soil surface. Comparing entire maize stover harvest versus no harvest, a similar pattern was seen.

In general, maintaining agricultural leftovers on the field is associated with an increase in soil CO2 emissions. In nine locations throughout the US Corn Belt, Jin et al. found that harvesting maize stover reduced soil total CO2 emissions by 4% in comparison to harvesting no stover.

Nevertheless, since this CO2 is cycled through the soil-plant-atmosphere continuum and is distinct from CO2 released from fossil fuels used for energy generation, which accumulates in the atmosphere, it is not included in research that build inventories of GHG emission in agriculture. Nonetheless, owing to the rise in warmth and decrease in soil moisture, crop residue harvest may favor CO2 emissions. Crop leftovers should be harvested throughout time in order to decrease soil organic C, which might have a substantial impact on CO2 emissions.

Also contributing to the initial rise in N2O emissions might be the continued presence of crop residues on the soil. Yet, if mineralized N from straw becomes accessible to the plants, this situation may be reversed in the long run. Hence, the primary source of N2O emissions in agriculture may be reduced by replacing N inputs with crop residues rather than synthetic N fertilizers. In this way, concerns have been expressed concerning the environmental sustainability of replacing fossil fuels with maize ethanol due to GHG emissions of N fertilizers during the agricultural phase. Residue harvest may also raise soil temperature, which will encourage microbial activity and N mineralization and increase soil N2O emissions [8].

Increases in CH4 emissions were seen, according to Signor et al., when sugarcane straw was left in place. However several studies have not seen a difference in CH4 emissions from soils covered with straw. Due to its low emission compared to CO2 and N2O, which is less than 1 and 10%, respectively, other studies did not take into account CH4 emission in agricultural soils.

Last but not least, it's conceivable that the collection of agricultural residues has little to no impact on the soil's redox potential or other elements that influence methanogenesis . Brazil and the rest of the globe still have little field measurements on the impact of agricultural residue harvest on GHG emissions. Model simulations and life cycle analysis evaluations have been employed in the majority of research on this topic. For instance, Liska et al. found that producing cellulosic ethanol from maize stover produces 7% less greenhouse gases than producing gasoline.

Crop residue use for bioenergy production has both direct and indirect consequences, such as a reduction in the need for land for feedstock production. Most doubts about the sustainability of biofuels are based on the GHG emissions brought on by changing land use . Hence, because there is no need to convert additional land to expand output, cellulosic ethanol production might potentially resolve some of these problems.

Adler et al. found that collecting 50% of the straw might boost ethanol production in maize fields by 35% without expanding the acreage, potentially lowering greenhouse gas emissions. Crop residue harvesting generally has the potential to lower both direct and indirect GHG emissions in agricultural regions, improving the sustainability of its industrial application. Moreover, given the potential economic benefits of cellulosic ethanol and bioelectricity, it is unlikely that a significant amount of straw will be kept on-hand in the field. Future research should thus focus on finding answers to problems about the appropriate amount of straw to remove in order to produce biofuels without raising GHG emissions.

Crop residues' effects on plant development and productivity

Crop output may be impacted by the management of agricultural wastes in both direct and indirect ways. Studies have shown that plants react differently in tropical environments when sugarcane straw is left on the soil. In comparison to sites where straw was burned, Tavares et al. found that maintaining straw on the soil surface promoted tillering and plant population. On the other hand, Campos et al. discovered that when all the straw was left on the soil surface at the conclusion of the cycle, there was decreased tilling, growth, and production of the plants.

In temperate regions, complete straw retention reduced sugarcane output, but burning straw before to harvest was linked to higher stalk yield. However, the positive effects of burning straw on productivity are typically only short-lived.

With a reasonable quantity of straw retained on the soil surface under subtropical circumstances, lower sugarcane tillering and growth were seen. While the straw may have unfavorable impacts during the crop establishment phase, no decrease in stalk production was seen. The extracts generated during the breakdown of sugarcane straw, which include a wide range of functional groups such phenols, alcohols, organic acids, ketones, ethers, and aldehydes, may be responsible for the deleterious impacts of straw during the crop establishment phase. Certain biological compounds may be hazardous at high doses and impair crop germination [9].

Using best practices for managing agricultural residues sustainably

As was already said, crop leftovers are crucial for maintaining or enhancing the health and quality of the soil, plant growth, and other ecosystem services. Yet, indiscriminate harvesting for the purpose of producing bioenergy might negate the advantages supplied by agricultural leftovers left on the field. Hence, best management practices must be included into crop residue management in order to mitigate the negative effects of agricultural residue harvest. The use of no-tillage and crop rotation, the use of annual or perennial cover crops, the use of manure and other organic amendments, and replenishment of soil nutrients extracted with residue are some best management techniques that increase the sustainability of residue harvest.

While maintaining soil C supplies, the application of conservationist tillage might significantly enhance the quantity of harvestable crop leftovers for industrial use. One of the primary factors in no-tillage systems that prevents soil C losses is the lack of soil disturbance. In sugarcane, soil tillage for unburned sugarcane renewal may result in a loss of 80% of the soil C that may have accrued in this soil layer over the course of one year of cultivation. As soil tillage is done annually with annual crops, soil C losses are significantly larger.

The impacts of maize residue harvest on soil C stocks are substantially more severe under conventional tillage than in no-tillage, reaching a soil C loss rate of close to 1 Mg ha1 yr1. No-tillage rotations with semi-perennial grasses or legumes also have the potential to enhance soil resilience following residue removal and encourage soil-profile C sequestration. The use of cover crops in the agricultural system may improve the sustainability of crop residue management under no-tillage. Depending on the cover crop species, soil type, and precipitation input, no-tillage cover crops may sequester between 0.10 and 1 Mg ha-1 yr-1 of carbon compared to no-tillage without cover crops, according to Blanco-Canqui [10].

The availability and cycling of nutrients in the soil are consistently reported to be negatively impacted by crop residue collection in the literature. Crop residue harvesting over an extended period of time depletes the soil of nutrients, necessitating their replenishment with increasing amounts of mineral fertilizers. As a result, manufacturing prices rise and the environmental effect increases. Also, the decrease in the amount of organic wastes added to the soil suggests a drop in C stocks directly, which is bad for the soil biota. Crop residue collection has negative impacts on macrofauna as well as soil microbial populations. On the other hand, as has constantly been seen in sugarcane fields, the increase in biological activity in the soil encouraged by the preservation of the leftovers not only benefits the plants but also encourages the spread of pests. Harvesting crop waste also increases the soil's susceptibility to structural deterioration, which may result in compaction, which reduces water penetration and storage as well as plant root development. Moreover, crop residues function as physical/mechanical barriers that shield the soil from the force of falling raindrops, lowering the likelihood of erosion. Crop residue mulch also functions as a temperature isolator, which lowers the amplitude of soil temperature and water evaporation [11], [12].

CONCLUSION

It is still necessary to conduct further field experiments to completely understand how crop residue management affects soil GHG emission. In general, collecting leftovers reduces decay-related CO_2 and N_2O emissions but has little impact on CH_4 emissions. Nonetheless, a negative C balance and increased N_2O emissions may result in places where residues are collected owing to the slow depletion of C and N stores in the soil and the replenishment of N through mineral fertilizers. Site particularity dictates how plants react to agricultural residue management. Consequently, elements inherent to the culture and management techniques are determinants in the plant response to residue harvest in addition to edaphoclimatic conditions that directly impact growth and crop yield. The majority of trials, however, have been operating for a few years, making it difficult to judge the sustainability of this strategy over the long term given that residue management for bioenergy generation is a relatively new practice.

Investments in research to better understand the effect associated with residue management are crucial to establish strategies for the industrial use of this raw material since agricultural residues have many functions in the soil that influence both directly and indirectly varied ecosystem services. Furthermore, integrating crop residue management planning with best management practices can help mitigate some of the negative effects of crop residue management and lead to the production of bioenergy that is more sustainably sourced. Last but not least, networks of cooperation between commercial and governmental institutions have to be supported in order to coordinate the creation of knowledge and its practical implementation, particularly in Brazil, one of the world's leading participants in the bioenergy industry.

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CHAPTER 14
ROLE OF WATER QUALITY IN AGRICULTURE

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ABSTRACT:

Water pollution is a worldwide issue that has become worse in both rich and emerging nations, threatening both the physical and environmental health of billions of people as well as economic progress. While concerns related to water allocation, efficiency in water usage, and quantity have received the majority of attention globally, the water crisis has worsened in many regions of the globe due to inadequate wastewater management. Not only is there a physical shortage of the resource, but there is also a global shortage of usable water due to the growing degradation of water quality in many nations.

KEYWORDS:

Agriculture, Fertilizer, Food Security, Management, Nutrients.

INTRODUCTION

The three main contributors to water contamination are human habitations, industry, and agriculture3. Millions of tonnes of heavy metals are dumped into water bodies by industry, and 80 percent of municipal wastewater released into water bodies across the world is untreated. Each year, solvents, hazardous sludge, and other garbage are dumped into water bodies. Water pollution is mostly caused by agriculture, which uses 70% of the world's water resources. Large amounts of agrochemicals, organic debris, drug remnants, sediments, and salty drainage are released into water bodies by farms. Water contamination as a consequence puts human health, aquatic habitats, and economic activity at risk.

Agriculture pollution now dominates contamination from towns and industry as the primary cause of the deterioration of inland and coastal waterways in the majority of high-income nations and many developing economies. The most prevalent chemical contamination in groundwater aquifers across the globe is nitrate from agriculture. 38% of water bodies in the European Union are seriously impacted by agricultural pollution. Agriculture is the primary cause of pollution in rivers and streams, the secondary source in wetlands, and the third primary source in lakes in the United States. According to the FAO, agriculture in China is mostly to blame for groundwater nitrogen pollution as well as a significant portion of surface water pollution. Large loads of untreated municipal and industrial wastewater are a serious problem in low-income nations and growing economies. Yet, agricultural pollution is also becoming a problem, made worse by increasing sediment runoff and groundwater salinization [1].

Crop output has increased globally, mostly due to the intense

Using inputs like artificial fertilizers and herbicides. The increase in agricultural acreage has accelerated the process, with irrigation strategically enhancing production and rural lives but also dispersing agricultural pollutants into aquatic bodies. In practically every nation, the output of livestock is expanding and increasing more quickly than crop production. Manure is among the associated waste, and it seriously affects water quality. Veterinary medications, which travel from farms via water to ecosystems and drinking water sources, have become a new class of agricultural pollutants in the past 20 years. Another important worry is zoonotic waterborne diseases.

Aquaculture has grown significantly and quickly in freshwater, brackish water, and marine habitats across the globe. Water quality is reduced by fish waste and uneaten feeds from fed aquaculture. A combination of increased output and increased usage of antibiotics, fungicides, and anti-fouling chemicals may have contaminated downstream eco-systems.

Agriculture-related water pollution has a direct detrimental influence on human health, as shown in the well-known blue-baby syndrome, which occurs when excessive nitrate levels in water produce methaemoglobinemia in neonates, a potentially deadly condition. Some broad-spectrum and persistent pesticides were widely banned as a result of the accumulation of pesticides in water and the food chain, which had been shown to have harmful effects on humans. However, some of these pesticides are still used in poorer countries, where they have acute and likely long-term health effects. Agricultural pollution also has an influence on aquatic ecosystems; for instance, eutrophication brought on by the buildup of nutrients in lakes and coastal waterways affects fisheries and biodiversity. Degradation of water quality may have negative direct effects on economic activities, such as agriculture. For instance, the cost of dam siltation brought on by the movement of sediment brought on by erosion is in the millions of dollars. Worldwide, the use of salty or brackish water for irrigation has reduced the amount of agricultural produce on hundreds of thousands of hectares. The environmental and social costs of agricultural water contamination in Organization for Economic Co-operation and Development nations alone are likely to be in the billions of dollars yearly [2].

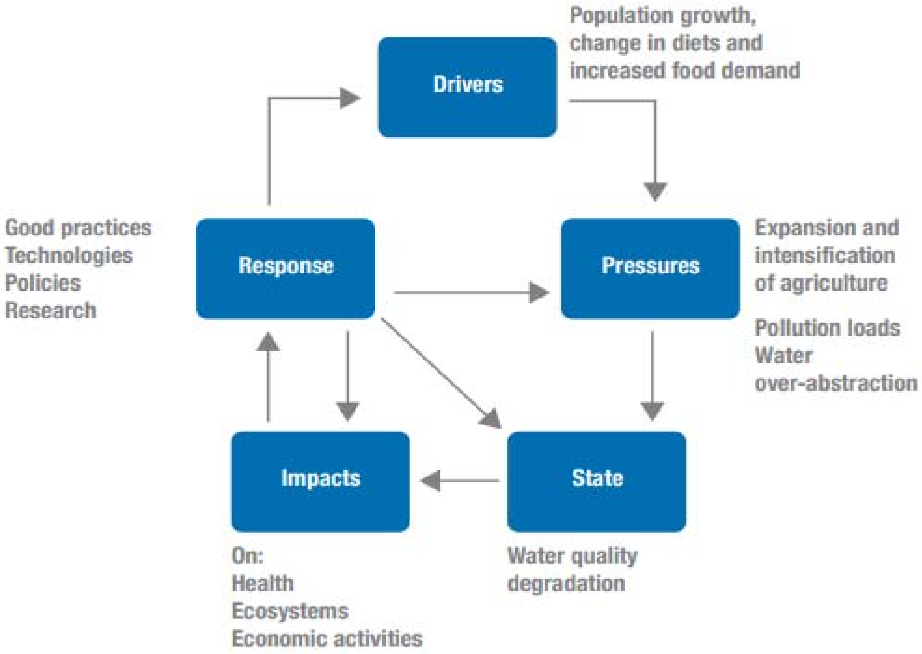

Figure 1: DPSIR approach for analyzing agricultural water pollution.

For the management of aquatic ecosystems and the prevention of negative effects on them, diagnosis, prediction, and monitoring are essential elements. Managers, planners, and lawmakers must understand the state of aquatic ecosystems, the nature and dynamics of the drivers and pressures that lead to water-quality degradation, and the impacts of such degradation on human health and the environment in order to design cost-effective measures for preventing pollution and mitigating risks, as shown in Figure 1. The parts that follow provide an overview of the causes and consequences of water pollution in agriculture as well as potential solutions to stop pollution and lessen its effects. These sections follow the logic of the Drivers-Pressures-State change-Impact-Response framework.

DISCUSSION

In order to meet the rising need for food, agricultural systems have grown and become more sophisticated. Higher pollution loads in water have been produced by land clearance and agricultural growth in absolute terms, but some unsustainable patterns of agricultural intensification have probably had the most effects. Higher pollution loads in the environment, including rivers, lakes, aquifers, and coastal waters, have been caused by the abuse and misuse of agrochemicals, water, animal feeds, and medications intended to boost production. The sections that follow examine the unsustainable course taken by agri-food systems and pinpoint areas where crop cultivation, livestock raising, and aquaculture may be the main causes of the deterioration of water quality [3].

Cropping Techniques

The output of grains virtually tripled, vegetable production expanded fourfold, tomato production climbed fivefold, and soybean production increased eightfold between about 1970 and 2015, but the global population roughly doubled at that time . By the extension of agricultural area, the introduction of new crop types, and the more intense use of agrochemicals and agrotechnologies, this enormous rise in productivity was made possible. Agriculture is becoming more intensive due in large part to irrigation. Large irrigation projects have proven effective ways to improve food security worldwide, but especially in underdeveloped nations. Yet, drainage and irrigation have often been linked to a decline in water quality brought on by salt, pesticide, and fertilizer runoff and leaching.

While mineral fertilizers have been used to enhance natural nutrient supplies and recycle to develop crops and animals since the eighteenth century, their usage has greatly expanded in recent years. In comparison to the 1960s, the globe now uses 10 times more mineral fertilizer. According to Rockström et al. , nutrient mobilization may already have surpassed thresholds that will cause rapid environmental change in systems at the continental to planetary scales. The global consumption of fertilizers has not increased equally. There are significant differences between regions of the globe with an excess of nutrients and those with an inadequate amount [4].

North America, Europe, and portions of South and East Asia are important areas where extra nutrients are being discharged into water bodies. The rise of industrial and intensive livestock production methods, which often entail enormous numbers of animals concentrated in relatively limited areas, is linked to the fundamental structural changes taking place in the livestock industry. Intensive livestock systems increasingly rely on locally and globally traded feed concentrates. The ecology and water quality in particular are coming under increasing strain from these developments. The majority of the water used for drinking and cleaning cattle returns to the environment as liquid manure, slurry, and wastewater.

Significant amounts of nutrients, oxygen-depleting agents, infections, and, in intensive systems, heavy metals, medication leftovers, hormones, and antibiotics are all present in livestock excrement. As livestock is concentrated, the waste generation that goes along with it often exceeds the ecosystems' ability to act as a buffer, contaminating both surface waterways and groundwater.

Production of Aquaculture

In the last several decades, the demand for fish and shellfish has increased more quickly than that for any other agricultural product. Since wild fish captures peaked in the 1990s, aquaculture which has drastically increased and is now producing almost half of all fish consumed has been responsible for all gains in fish output. According to FAO, 167 million tonnes of aquatic animals were produced globally in 2014, of which 146 million tonnes were reportedly directly eaten by people.

The majority of aquaculture expansion has occurred in developing countries, which account for 91 percent of worldwide production; low-income developing countries have the highest concentration of aquaculture. Almost 90% of the world's aquacultural production comes from Asia, with China leading the pack with 45.5 million tonnes produced annually[5].

Also, there has been a continuous rise in the number of aquaculture-fed species that need food that is produced elsewhere; now, this kind of production makes about 70% of all output, up from 50% in 1980. Feces, uneaten feed, and medications may be exported to aquatic bodies as a consequence of fed and intensive aquaculture. Aquaculture relies heavily on carnivorous species, which need enormous quantities of fishmeal and other pelleted food. Several non-fed aquaculture practices, like mussel farming, may clean and filter water, while others, like intense caged crab culture, may disturb natural nutrient cycles and worsen water quality. Increased production intensity and greater concentrations of one species are being caused by market forces and differentiation. Because of these changes, people are using more medications, which leads to contamination farther down the food chain.

Organic Substance

Significant water contaminants include organic matter from animal waste, uneaten animal feed, the animal-processing industry, and improperly managed agricultural leftovers. Wastes associated with livestock have some of the greatest biological oxygen demands. For instance, pig slurry has a BOD of 30 000–80 000 milligrams per litre, as opposed to household sewage's usual BOD of 200–500 milligrams per litre . Aquaculture may have a significant role in the localization of organic burdens in water. For instance, in Scotland, the untreated organic waste from the production of salmon accounts for 75% of all pollution released by people. Bangladesh's shrimp farming produces 600 tonnes of garbage per day. When organic matter breaks down, the dissolved oxygen in the water is consumed, significantly causing hypoxia in aquatic bodies. The likelihood of eutrophication and algal blooms in lakes, reservoirs, and coastal regions is further increased by the release of organic materials.

Newest Pollutants

In the last 20 years, new agricultural contaminants such antibiotics, vaccinations, growth boosters, and hormones have developed. As well as by the application of manure and slurries to agricultural land, they may enter the water through the leaching and runoff from livestock and aquaculture operations. Another major danger is the presence of heavy metal residues in agricultural inputs like animal feed and insecticides. There are already over 700 developing contaminants, as well as their metabolites and transformation products, recognized as existing in aquatic habitats in Europe [6].

With the use of wastewater for irrigation and the application of municipal biosolids to land as fertilizers, agriculture not only contributes to the spread and reintroduction of such pollutants into aquatic habitats, but it is also a source of developing contaminants. The indirect use of wastewater affects 35.9 Mha of agricultural land, according to estimates. It is important to pay attention to the possible dangers to human health provided by exposure to developing contaminants via contaminated agricultural products.

Models provide representations of actual systems, a comprehensive comprehension of issues by highlighting connections, and forecasts of the future . Models can model how pollutants behave and how that affects the environment. Status of water quality and aid in comprehending effects on ecosystems and human health. Models may also be used to estimate the costs and efficacy of corrective measures. Knowing the present state of water quality as well as the geographical and temporal patterns of any pollutant emissions, loads, and concentrations in aquatic habitats is essential for efficient water-quality management. For instance, determining where, when, and by whom the pollution sources are discharged is crucial to provide proper responses if pollutant loads exported to a certain aquatic body are excessive. At the right geographical scales, well-calibrated models represent the main interactions between pressures, states, and effects. Moreover, current models are becoming more and more reliable, enabling analysis of "what if" scenarios including outcomes under current, historical, and predicted future situations.

As more expertise was gathered, a wider variety of measurements emerged. Current studies indicate that a mix of methods is more effective than only regulations. Agriculture-specific water pollution policies should be a component of a comprehensive national or river-basin water policy framework that takes into account all pollutants and polluters [7]. Economic tools are being used more often to enhance or replace straightforward legal rules or laws. Taxes, "set-asides" , and payments to limit production or the intensity of land use are some examples. For instance, Norway and Switzerland pay farmers significantly for "landscape maintenance," and the United States of America's Conservation Reserve Program pays farmers to take land out of production for predetermined periods.

The best way to stop pollution at the source is to implement policies that alter farmer behavior and encourage the adoption of beneficial practices. Such regulations must provide training and consultations for farmers. It has also been shown successful to explain farmers the financial advantages of adopting excellent practices. By comparing farmers' performance to that of their colleagues, benchmarking might encourage behavioral change in them. The use of fertilizers, insecticides, and manure and slurries may all be benchmarked. The integration of environmental modules into school curriculum and enlisting students in bringing up environmental concerns in their communities are more subtle forms of persuasion.

1. Water quality protection laws must be enforced.
2. Ought to be reasonable, time-bound, and they must weigh the expenses of implementing.
3. Solution and the advantages of improved water quality.

Time gaps between the implementation of a given practice and quantifiable results must be taken into consideration when setting objectives. Planners must determine the most cost-effective combination of policy tools after a goal has been established; normally, pollution avoidance will be less expensive than restoring damaged aquatic habitats. Priority should be given to significant polluters and water bodies with the greatest levels of pollution when developing and implementing regulations. Prioritizing measures may be aided by the astute identification of pollution hotspots, such as those found, for instance, in regions with high livestock densities [8], [9].

Lastly, policies must be logically consistent. While it may be difficult to do in reality, interventions focused at boosting food production and farm revenue and at reducing pollution should be mutually supportive or at least not competing. For instance, the regular pesticide subsidies do not serve as a motivator for effective usage because rather promote cultivation on more vulnerable terrain. To improve policy coherence, efficient interministerial coordination channels are needed [10]–[12].

CONCLUSION

It is clear that the most effective way of mitigating pressures on aquatic ecosystems and on rural ecosystems more generally is to avoid or limit the export of pollutants from where they are applied: the costs of mitigation increase greatly once pollutants are in an ecosystem. Simple off-farm techniques, such as the construction of riparian buffer strips or constructed wetlands, can cost-effectively reduce loads entering surface water bodies. The remediation of contaminated waters such as lakes and aquifers is a longterm and expensive undertaking and in some cases may not even be feasible. Buffer strips are a well-established technology. Vegetated filter strips at the margins of farms and along rivers are effective in decreasing concentrations of pollutants entering waterways. In agriculture and forestry, buffer zones usually comprise strips of vegetation that act as filters for sediment and their attached pollutants.

Buffer strips can also perform other functions, such as stream shading, carbon sequestration, biomass production, channel stabilization, water purification and the provision of terrestrial and stream habitats, and provide cultural and recreational services. Constructed wetlands have been employed mainly to treat point-source wastewater, including urban and agricultural stormwater runoff. Such wetlands can also be used to treat agricultural drainage and remove sediments, nutrients and other pollutants. The risks associated with brackish and saline agricultural drainage need to be managed. Water management options include minimizing drainage by conserving water, treating drainage water, and reuse. Such approaches require planning at the watershed scale to adapt agricultural practices and crops to increasing salt content at different cycles of reuse, which may include the production of prawns and fish using brackish or saline waters. Integrated aquaculture agriculture forestry systems in which crops, vegetables, livestock, trees and fish are managed collectively can increase production stability, resource-use efficiency and environmental sustainability. Integrated farming ensures that waste from one enterprise becomes inputs to another, thereby helping to optimize the use of resources and reduce pollution.

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CHAPTER 15

HYDROLOGY AND ECONOMICS OF WATER RESOURCE MANAGEMENT IN AGRICULTURE

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ABSTRACT:

It controls our planet's weather patterns and makes water accessible to all living things. The ground cleans the water as it infiltrates, removing impurities and pollutants. Freshwater is continuously provided to all life on Earth through the water cycle. The Hydrology and Water Resources Programme (HWRP) supports efficient environmental management at the international, regional, national, and basin levels by promoting the appropriate use of hydrology in sustainable development to lessen the risk and effects of water-related catastrophes.

KEYWORDS:

Agriculture, Economics, Hydrology, Management, Water Resource**.**

INTRODUCTION

Hydrology Both within and within OECD nations, there is a considerable degree of variety in the hydrological conditions and agricultural systems that operate in a wide range of political, cultural, legal, and institutional settings. The choices for managing water resources in agriculture are varied. They include agricultural methods that are entirely reliant on rain, with on-farm conservation techniques that emphasize storing water in the soil. Use of additional surface water, groundwater, and, in certain situations, alternative water sources is growing as climatic conditions get drier and dry season shortages more common. Agriculture in semi-arid and dry locations may be entirely reliant on irrigation using groundwater and supplies of surface water that have been saved. Irrigated farming may also be dominant under monsoon circumstances, but these systems focus more on managing the heavy amounts of rain that are received during the wet season and making sure there are enough resources available throughout the dry season.

In OECD nations and across the world, irrigated agriculture has been linked to considerable advantages that help farmers both personally and publicly by increasing food production and by having positive externalities like promoting rural development. Agriculture benefits from irrigation's flexibility and competitiveness, particularly in areas where farming would be very challenging without it due to seasonal rainfall patterns. While evaluating the negative externalities and inefficiencies with improper irrigation methods and system management, the advantages of irrigated agriculture must be taken into consideration. Agricultural water resource management systems in OECD nations can be broadly divided into two groups, which include first, those nations where irrigation plays a significant role in the farm sector, both in terms of the share of total agricultural production and agricultural exports, and, second, nations where farming is primarily rain-fed. According to how quickly the region is being irrigated and with comments on trends over the last 20 years about the occurrence and severity of flood and drought events as they affect agriculture, Figure 1.2 further classifies nations within these two major groups [1].

Water consumption in agriculture differs significantly from water use in home and commercial settings in many respects. The amount diverted for consumptive use is almost always more than the amount actually used, with the remaining amount returning to the water system. In the majority of OECD nations, agriculture typically consumes the largest proportion of water withdrawals for consumptive use, [2], [3] with evapotranspiration accounting for 40–60% of agricultural withdrawals and up to 70% with repeated reuse in contemporary irrigation systems. Agriculture may have both beneficial and negative effects on the hydrological cycle in various irrigation systems, such as groundwater recharge and water purification functions, excessive pumping, and pollution. Agriculture's use of water is a significant water policy challenge, particularly when there is a water shortage. Some water is irretrievably lost to the hydrologic system due to site-specific reasons. The time, place, and quality of what is recycled into the water system are often changed. The features of irrigation losses in particular have significant ramifications for the success of increasing water efficiency in attaining net water savings. Although a decrease in water consumption may be achieved by increasing physical efficiency, the amount of water actually saved is less certain because of variations in the area irrigated and water usage per hectare [4].

DISCUSSION

Economics In the past, attention was often focused on affecting farmers' productivity by manipulating the hydrologic cycle through technical solutions, such as constructing new dams and canal networks, to solve some of the hydrologic difficulties. Yet, many nations are putting more of a focus on improving the economic and environmental efficiency of the water system by offering financial incentives that take into account the price, value, and demand of water in agriculture. In the late 1980s, the policy focus switched to taking into account the economic and environmental components of water due to growing intersectoral rivalry for water and increasing attention on environmental externalities related to agriculture. The Dublin International Conference on Water in 1992, which emphasized that "managing water as an economic good is an important way of achieving efficient and equitable use, and of encouraging conservation and protection of water resources," was a significant turning point in the history of water policy.

The supply and demand for water is more complicated than that of other economic products and services due to a number of particular economic characteristics, including: • Water's qualities as a private good and a public good entail various distribution methods. When utilized on a farm, water is a private product, but when left in its natural state, such in a lake or marsh, it is a public good for which there are often no commercial markets. The mobility of water, in that it flows, leaches, evaporates, and has the potential to be reused, distinguishes it as a commodity in contrast to land, for example, even if it is predominantly used by the private sector. Additionally, agriculture can positively influence the hydrological cycle through functions like groundwater recharge and water purification; it can, however, also contribute to surface water and groundwater pollution and through excessive extraction may result in the diversion of water from supporting ecosystems; Heterogeneity of water in terms of space, quality, and variability over time, which presents difficulties in balancing supply and demand and structurally [5]:

When compared to other commodities, the cost of providing water has several distinguishing characteristics:

a. It is bulky and expensive to transport relative to its value per unit of weight, unlike electricity, which typically has a national grid.

b. There are significant economies of scale in water supply, such as the use of a dam to store surface water, while the physical capital in the water industry is typically long-lasting, such as irrigation canals; and,

c. Water supply professionals typically charge a premium for their services. Fixed costs predominate due to the irrigation infrastructure's capital intensity, duration, and economies of scale [6].

The exception of the expenditures associated with pumping water via the delivery system, the short-run marginal cost of water supply for irrigation systems may be quite low. This makes it probable that there will be a monopoly provider in any particular region, necessitating a high level of administrative and societal supervision. This gives an incentive to increase surface water storage capacity at a single moment in time rather than spread out over time, which might imply that it may take a significant amount of time before demand materializes to utilize this capacity. This is also due to the capital lumpiness in water delivery. In policy-related applications of the economic valuation of water, a difference has to be established between the marginal and average or total worth of water. Although farmers often have some access to water, policy interventions in the area of water in agriculture sometimes include altering the amount and/or quality of access.

So, it is required to evaluate the marginal value of water in the agricultural uses that would cease to be produced without the new increment of water in order to quantify the benefit from an increase in water supply for farming in the receiving regions. This is due to the fact that the profit from farming includes a return on labor, land, other fixed assets, and variable inputs in addition to a return on water as an input. In addition, the return to water is not constant and decreases when more water is provided since farmers would probably change their planting patterns in response to changing water supply. Although while fewer than 20% of farms, or less than 25% of the total irrigated land in the US, have access to various water sources, there are many irrigated locations where surface and groundwater supplies may be substituted for one another [6], [7].

This is partially because it is difficult to assess opportunity costs and the costs and benefits of the environment. However, the water fees paid by agricultural are often much higher than those paid by urban water users, which may be justified for a variety of reasons, some of which are stated below. If water is delivered over the same network to both farmers and other customers, it may be undercharged to all users since most water agencies set fees to reflect the historical cost of a water delivery system rather than the anticipated replacement costs. Due to the unevenness and lifespan of surface water delivery systems, there is sometimes a significant difference between historical and prospective expenditures. As a new water supply project's initial supply capacity often exceeds the existing demand, there is a strong incentive to just pay for the short-run marginal cost of the project.

It is best to transition to a charge scheme based on long-run marginal cost as demand increases and the capacity is more fully used, but often public water agencies become "politically" constrained to simply recovering previous expenses. In the past, water used to irrigate farmland in the majority of OECD nations has been given via public irrigation schemes, and as a result, it has often been provided at a rate that merely covers the operating and maintenance expenses of water delivery. Price comparisons are challenging since agricultural water, unlike urban water, is often not treated and therefore not accessible on demand through a pressurized system. In many cases, irrigators do not have the option to trade their water entitlements with other users because there are currently no markets for doing so, there are frequently legal and administrative barriers to creating such markets, the transaction costs of water markets can be high, the supply and demand for water are uncertain at a given point in time, and water delivery systems for agriculture, urban, and industrial users are not typically physical.

For the purpose of developing or maintaining the physical infrastructure and preventing the degeneration of the water delivery system, financial instruments must be used to pay for the expenses of delivering water to irrigators. Recovery of financial expenses must also take equity into account since, in cases where public investment has been made, society may demand farmers to pay back the advantages they have received. Yet, in addition to economic optimization, governments may justify funding the capital expenses of irrigation projects for a number of other goals, including rural development and goals for water and food security [8].

Selling water rights may stimulate farmers to engage in water-saving technology and boost the diversification of agricultural output, particularly toward higher-value crops. Yet, as water is just one of the inputs used in agricultural production, the adoption of water-saving technology or the diversification of the production line are seldom motivated only by water pricing or water shortages. However, substitution between water and other inputs and market possibilities are expected to be the driving forces behind changes in agricultural technology choices and output patterns [9], [10]. The amount and kind of government assistance given to agriculture also affects the markets for agricultural input and product in the majority of OECD nations. Trade may help distribute water among competing consumers and purposes and give the market a price for scarcity. According to this logic, increasing water costs would shift water away from low-value agricultural uses and toward high-value ones, such usage for more valuable agricultural commodities, urban and industrial users, and the improvement of social welfare. While the possibility that fully operational water markets may lead to such a conclusion, there are a number of challenges to overcome, as was previously covered in this chapter.

Transfers of water rights between various users may also be influenced by governmental rules and the rigor of the market. A market regulator may determine the price, price restrictions, and act as a broker, for example, to promote market operations. Surface water allocations can be exchanged during a season, between seasons, or permanently. Effective trading of water between agricultural and other users requires a thorough understanding of and monitoring of hydrologic conditions, a cutting-edge hydraulic infrastructure, well defined water property rights, and well-established legal, institutional, and regulatory frameworks [11]. There are several significant contrasts between utilizing water charges and trading for groundwater management and the discussion above, which has mostly concentrated on using water charges and trading for surface water irrigation. Farmers often have the right to use any subsurface aquifer on their land as long as they follow a system of permissions and restrictions that limit groundwater abstraction. The resource may eventually run out due to a lack of enforcement of groundwater restrictions and illicit groundwater pumping, which has caused a decline in groundwater tables and an increase in the cost of pumping water. This suggests that the farmer has no motivation to restrict resource extractions since others may still pump the resource. As all farmers would need to construct facilities for them to be useful, there is no motivation for the farmer to develop drainage systems in salty groundwater regions. When salty groundwater is overused, it may result in a variety of risks to aquifers, such as secondary salinity and salinity intrusion in coastal regions [12].

CONCLUSION

The challenge of pricing the environmental externalities linked to agricultural usage of water resources stands in the way of employing water charges and trade to solve environmental challenges in agriculture. Although there is a growing body of literature on the value of ecosystem-related environmental assets, there is less study on how these values might be included into the costs of production and resource consumption, and there are few instances of this being done in reality. This reflects, as in the case of opportunity cost pricing, calculation, implementation, and enforcement issues as well as the social and political difficulty faced by farmers who often believe that society as a whole is responsible for these externalities.

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CHAPTER 16

CURRENT TRENDS AND THE FUTURE OF AGRICULTURE'S WATER RESOURCES

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ABSTRACT:

Water contamination is mostly caused by agriculture, which uses 70% of all freshwater globally. Large amounts of agrochemicals, organic debris, drug remnants, sediments, and salty drainage are released into water bodies by farms. The primary sector required for human life is agriculture. To increase output, vast water resources are needed. Water shortage in many parts of the world is a danger due to the massive and haphazard usage of water resources. A major factor in climate change is also the lack of water supplies. Water management in the agricultural industry is so crucial and demands prompt attention. Future water management difficulties in agriculture are highlighted in this report.

KEYWORDS:

Agriculture, Agrochemicals, Groundwater, Water Resources, Water Management.

INTRODUCTION

For various OECD nations, irrigated agriculture contributes a rising and significant portion of the value of farm produce and exports, and also sustains rural employment in a number of locations. As a result, irrigated agriculture uses the majority of agricultural water and will likely keep doing so as certain nations' agricultural productivity increases. Higher agricultural output has been attributed to improvements in agriculture's physical water productivity via improved management, adoption of more efficient technology like drip irrigation, and use of other water-saving farming methods. From 1990–92 and 2002–04, the average OECD water application rate per irrigated hectare fell by 7%, despite an increase in agricultural output in the majority of situations. For instance, in the United States, efficiency improvements in irrigation water usage throughout the 1990s led to a 7% decrease in per-hectare application rates.

Several nations with significant irrigated agriculture have similarly reduced water application rates per irrigated hectare, most notably Australia, but also to a lesser degree France, Mexico, Spain, and the United States. Yet, in some of these nations, irrigation water usage efficiency has declined. It is becoming increasingly commonplace to use low-pressure sprinkler systems, drip irrigation, and other water-saving techniques. Around 25% of the total irrigated land in Australia, France, Czech Republic, Greece, Italy, Spain, and the United States is covered by the use of more effective water management systems. The efficiency of water consumption in agriculture is also being increased by improving flood irrigation systems and covering mud irrigation pipes with concrete to cut losses [1].

A growing portion of agriculture's water needs are being met via groundwater abstraction. Despite incomplete statistics, the industry used more over 30% of the world's groundwater in 12 OECD members in 2002, including Greece, Japan, Korea, Mexico. Notwithstanding the paucity of statistics, agriculture used more groundwater than any other sector in 2002 in a third of OECD member nations, accounting for a rising portion of its supply. By lowering water flows below minimum flow levels in rivers, lakes, and wetlands, overusing water resources by agriculture in certain locations harms ecosystems and has a negative impact on the recreational, fishing, and cultural uses of these ecosystems. The economic sustainability of farming in impacted areas is also being harmed by the overuse of groundwater for irrigation in certain locations. Moreover, farming is also a significant and expanding cause of groundwater contamination in many nations [2]. This is especially concerning given that a significant portion of drinking water sources for both people and agriculture come from groundwater. More use is being made of desalinated water from saltwater and salty aquifers and recycled wastewater in areas where a lack of freshwater is a problem.

Although these sources of water are important for agriculture in some localities within countries, particularly those that are close to densely populated areas and coastal regions, such as those that are just starting to emerge in some OECD Mediterranean countries, such as Spain, they are still only marginal in the majority of OECD countries. Another method being investigated to change virtual water trade flows is changing cropping patterns. Some experts believe that virtual water trading might help nations whose water supplies are being stressed by competing consumers save water. In a nutshell, virtual water commerce is the importing of the least water-efficient crops from countries with lower water opportunity costs and better output by water-scarce nations.

Around the middle of the 1990s, the phrase "virtual water" started to emerge in the literature on water resources. The word was chosen by Professor Tony Allan of London University to describe the water used to grow commodities sold on worldwide markets. The virtual water idea has proven very beneficial in attracting the attention of public authorities and policy makers tasked with promoting prudent use of scarce water resources during the last 15 years since its beginnings. By analyzing the water needs of agricultural and animal goods traded internationally, some writers have undertaken empirical evaluations of "virtual water flows" and come to the conclusion that certain nations are "net importers of virtual water" while others are "net exporters."

Moreover, they advocate for water-scarce countries to buy commodities and services that need a lot of water while water-rich nations should export items that require a lot of water. While seeming straightforward, this line of thinking is not supported by a sound conceptual foundation. As a result, the policy suggestions that result from this kind of virtual water study may be inaccurate and deceptive. The absence of an underlying conceptual framework is the basic flaw in the virtual water notion, which keeps it from being a useful instrument for prescribing policy. Virtual water has been wrongly compared to or portrayed as being compatible with the economic idea of comparative advantage by certain scholars. The virtual water idea is most often used when contrasting or discussing nations with ample and scarce water resources.

Virtual water provides an application of absolute advantage rather than comparative advantage by concentrating on the endowment of the water resource alone. Because of this, the policy recommendations that result from virtual water conversations are not ones that will maximize the overall advantages of doing business internationally. The relevant economic idea is comparative advantage, while virtual water merely takes into account absolute benefit. The discrepancy between hypothetical water prescriptions and actual trade patterns is typically confirmed by recent empirical investigations of international trade data. Many authors have started outlining the crucial role of non-water factors in deciding on the best production and trading strategies, such as the significance of taking into account population densities, historical production trends, national food security goals, targets for reducing poverty, and the availability of complementary inputs when deciding whether to transfer water from one region to another or to achieve desired results alternatively by transporting or trading [3], [4].

In order to determine if an area or nation is utilizing resources in a sustainable or unsustainable way, from a global viewpoint, the concept of water footprints explains the amount of water necessary to support production and consumption in specific regions or countries. One of the numerous inputs used in such tasks is water. As a result of simply depicting the usage of one resource, predicted water footprints are slightly flat. Moreover, the effects of water consumption are not covered by water footprints. They simply take into account how much water is utilized for production and consumption. However, since ecological water footprint analysis does not take into consideration the net benefits produced when resources are utilized, it is insufficient for establishing the best policy options. The opportunity costs of water resources and the methods in which water is coupled with other inputs in production and consumption determine a major portion of the costs and benefits of water usage. Water footprints make it possible to compare predicted water consumption by individual or overall between nations, but they are insufficient for determining the additional costs, benefits, or effects of water use on the ecosystem. Because of this, empirical estimates of water footprints do not provide enough data to evaluate environmental effects or formulate objectives and strategies for water resource policies. Water footprints, like the virtual water idea, draw attention to crucial policy challenges, but they lack the conceptual underpinning and breadth necessary to facilitate policy analysis [5]–[7].

DISCUSSION

estimates from the OECD Environmental Outlook baseline scenario The OECD Environmental Outlook's projections of agriculture's use of water resources up to 2050 indicate a number of new trends that should worry policymakers as well as water users and consumers. The Environmental Outlook's OECD baseline scenario findings. They forecast present policies into the future to depict what the world would look like in 2050 if current policies are maintained. Moreover, no effects of climate change are included in the baseline scenario. The Environmental Outlook's primary baseline forecasts for water and agricultural connections are summarized here. Generally, the problem of water shortage is growing in many nations and areas as populations rise, water supplies are damaged by pollution and abuse, and there is more rivalry among competing uses. 1.4 billion People now reside in water basins where water use rates are higher than recharge rates. Compared to 44% of the global population, 35% of people in the OECD lived in regions with severe water stress in 2005. A projected 3.9 billion people, largely in non-OECD nations, are predicted to be living under severe water stress by 2030, an increase of 1 billion from the baseline year of 2005 [8].

Agriculture, climate change, climatic variability, and water resources

"Observational records and climate projections provide abundant evidence that freshwater resources are vulnerable and have the potential to be strongly impacted by climate change, with wide-ranging consequences for human societies," the Intergovernmental Panel on Climate Change report on climate change and water concludes. The IPCC anticipates that the principal water-related consequences of climate change on agriculture will manifest as changing and more variable hydrological regimes, as summarized in Box 2.4. More than one-sixth of the world's population presently resides in major Asian mountain ranges, and the IPCC predicts a drop in the amount of meltwater from these mountain ranges. The operation and functionality of the current water infrastructure as well as water management are predicted to be impacted by climate change.

However, present water management techniques may not be strong enough to handle how climate change will affect things like water supply dependability, flood risk, agriculture, and ecosystems. The IPCC predicts that changes in water quantity and quality brought on by climate change will have an impact on food availability, stability, access, and utilisation. Irrigated agriculture may have a twofold impact as a result of climate change. This may happen if agriculture uses more water or if the region that is irrigated uses more water. These changes are a result of both global climate change and the increased frequency of severe events brought on by climatic variability. Changes in seasonality of precipitation, which are particularly significant for agriculture as they impact the timing of annual rainfall patterns or times of snow pack melt, are another worry of climate variability that calls for the redesign of irrigation storage systems. A more firm basis for tackling climate change in the future may be created by improving our knowledge of climate variability and extending risk management strategies in agriculture to contemporary climate variability [9].

According to this analysis, the majority of OECD nations have seen an increase in the frequency and severity of floods and droughts, which has placed strain on irrigated farming in drier and semi-arid regions. This tendency often reflects higher dangers brought on by climate change. Several of these nations also predict that as a result of climate change, the frequency and severity of flood and drought events may continue to rise, and other studies agree that the hydrologic cycle is continuously becoming more intense. Agriculture, renewable energy, and water use Energy costs have significantly increased since the turn of the century, and worry about climate change has grown. Increases in energy prices may have an impact on rain-fed agriculture by making it more expensive to transport agricultural products to markets and by boosting the price of agricultural inputs like pesticides and fertilizers.

Irrigated agriculture must also deal with rising water costs when energy prices rise since water transport and irrigation systems demand electricity. In several OECD nations, there is significant interest in boosting bioenergy output as a result of recent rises in energy costs. As part of this progress, agricultural feedstocks have been used to produce ethanol and bioenergy, which may have an impact on agricultural water usage. It is complicated and unknown how supporting agricultural feedstocks for the production of biofuels and bioenergy will ultimately affect water balances. It has to be evaluated in a manner that compares the results of different uses of resources since it is essentially an empirical topic. Yet, research indicates that the amount of water necessary to manufacture ethanol from first generation feedstocks is substantially higher than the water required to produce each unit of energy from second generation biofuel feedstocks. However depending on the environment and the methods used, this may change [10]–[12].

CONCLUSION

Food availability, stability, access, and use are predicted to be impacted by changes in water quantity and quality brought on by climate change. The effectiveness and efficiency of current water infrastructure, such as hydropower, structural flood defenses, drainage and irrigation systems, as well as water management methods, are all impacted by climate change. The dependability of the water supply, flood risk, human health, agriculture, energy, and aquatic ecosystems may all be impacted by climate change in ways that current water management approaches may not be able to withstand. The conventional belief that previous hydrological experience serves as a reliable indicator of future circumstances is being called into question by climate change. Demand-side and supply-side strategies must be incorporated into adaptation alternatives for ensuring water supply under normal and drought situations. By lowering the severity of the effects of global warming on water resources, mitigation initiatives may lessen the need for adaptation. It is obvious that managing water resources has an influence on many other policy sectors, including energy, health, food security, and environmental preservation. There are a number of observations and research needs connected to climate change and water that remain unmet.

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CHAPTER 17

RISK MANAGEMENT FOR DROUGHT, FLOODS, AND CLIMATE CHANGE

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ABSTRACT:

By reducing the danger that people confront and the potential harm that a crisis may create, climate-smart disaster risk reduction helps save lives. Communities may use it to more efficiently plan for and deal with natural disasters. This strategy is essential since catastrophes occur more often each year. Existing mitigation strategies are increasing the risk of catastrophe to an unacceptable level. The demand on water and food security is increased along with the frequency and severity of threats, as well as the exposure and susceptibility of communities and people.

KEYWORDS:

Agriculture, Adaptation, Climate Change, Management, Mitigation.

INTRODUCTION

Government-sponsored research on the potential effects of climate change on agricultural water management is underway in almost all OECD nations. Nevertheless, the focus of study differs across nations, reflecting the disparate predicted implications of climate change on agricultural and water resources among OECD countries. For almost all nations, the main areas of interest in climate change research are the effects on agricultural production, the regional effects of anticipated changes in precipitation and water availability, and the effectiveness of various farming practices and systems under various climate change scenarios. Climate change research is specifically focused on analyzing soil conditions and land use compatibility, enhancing water use efficiency, and producing drought resistant novel crop types where challenges of water shortage are already placing pressure on agricultural output. A rising number of nations are already taking climate change studies into account when making decisions about how to manage their water resources in relation to agriculture. Researching the effects of climate change on agricultural and water resources is still a priority in the majority of nations, along with educating the public and decision-makers about the problems and difficulties.

Nonetheless, almost a quarter of OECD countries claim that the present level of consideration given to climate change in policy decisions relating to the management of agricultural water resources is between medium and extremely substantial [1]. The 2008 Australian National Plan Water for the Future, one of four key priorities for the Federal government, the French Water Act, the inclusion of climate change in the Spanish Hydrological National and Basin Plans, the United Kingdom's Environment Agency, and the French Water Act are just a few examples of the increasing importance of climate change in policy decision making in agricultural water resource management. Increased government spending to help farmers and the rural communities, as well as increased costs for commercial insurance, are the results of the frequency and severity of drought and flood occurrences. The fragmentation of responsibility and lack of policy coherence in agricultural, environmental, land, and water policies to address these concerns frustrates efforts to handle flood and drought occurrences in agriculture and society as a whole. Because farmers are assured government assistance during flood and drought catastrophes, this does not provide them the essential incentives to increase their independence and risk aversion. In order to decrease farmers' financial losses and water flows over farmland, increased regulatory attention and investment will be needed in drainage and water management, water retention, and agricultural methods and practices.

Agriculture and flood policy

The most important natural danger on the planet is flooding. Extreme downpour events may have caused more than 320 billion dollars in damages and over 10,000 fatalities in OECD nations between 1985 and 2008. While urban areas bear the [2] majority of the financial consequences associated with floods, agriculture still covers a significant percentage of the terrain and is crucial to both flood protection and adaptation. There is abundant evidence from several OECD nations that flooding events have become more frequent and severe over the last few decades, with negative effects on infrastructure and agricultural output. Increased runoff and constricted channels are the results of human modifications to the hydrological features of watersheds. Land-use regulations have also promoted urbanization in places vulnerable to floods, raising the financial burden of a particular flood occurrence.

Given the effects of climate change and shifting catchment land use, it is anticipated that similar occurrences may increase in frequency in the future. Flooding might be considered a concern to the environment. Hence, a flood event has a source, such as an intense rainfall event, that has the potential to create flooding and is transmitted to a receptor where flooding happens via a conduit, the land surface and hydrological system. The chance of a flood happening and its effects if it does depend on the danger of flooding to individuals and communities. With a mix of adaptation and risk reduction, the risk may be decreased. In order to lower the likelihood that a flood may occur, mitigation refers to efforts that have an influence on the source or course. Actions done to lessen the effects of floods in receptor regions are referred to as adaptation [3], [4].

DISCUSSION

The connections between floods and agricultural land management techniques must also be examined in the context of regional land use planning and larger, more comprehensive economic mitigation plans to reduce flood hazards. Less groundwater retention caused by urban growth and increasing impermeable surfaces causes base flows during droughts to be more intense, and vice versa. The potential cost of flood damages rises as agriculture in floodplain regions is converted to non-agricultural activities, but the potential utility of same lands as a flood sink decreases. This emphasizes the idea that regional land use planning shouldn't be separated from planning for the sustainable use of water resources in agriculture. Agricultural terrain often experiences floods. The effect of flooding on agriculture varies greatly depending on the crop or land use activity in question's tolerance to additional water as well as the event's frequency, length, depth, and seasonality. In areas where flooding is common, land use may be restricted to low-productivity, flood-resistant businesses. Less frequent floods might harm higher value land uses and result in losses. Farmers will need to adjust if the chance of flooding is likely to grow in the future by switching to more flood resistant or resilient companies and implementing methods to speed up recovery after a flood occurrence. These modifications might also open up possibilities for complementary improvements, such increased biodiversity via wetland restoration and improved accessibility [5].

In OECD nations, national approaches for managing the risk of agricultural floods have combined adaptation and mitigation. Public investments in flood protection and land drainage to assist agricultural output have been the major forms of mitigation. Despite worries that rural land use may increase flooding, there aren't many regulations that directly reduce flood production from farmland. Agri-environmental plans now incorporate several elements that are expected to lessen runoff, which helps to prevent soil erosion and disperse water contamination. The management of flood risk is believed to benefit from numerous strategies that aim to affect agricultural land use in order to reduce soil erosion and diffuse pollution. These policies often take a non-regulatory stance, focusing on a variety of voluntary actions, backed by financial incentives for farmers, and offering guidance on better environmental practices. The major components of adaptation measures that lessen susceptibility to floods include the provision of flood warning systems, advice on constructing flood resilience, and disaster assistance and compensation in OECD nations.

Policies also include adaptation measures designed to take use of any possible landscape synergies. Initiatives that integrate biodiversity, flood risk control, and agricultural livelihoods in floodplains are examples of agri-environment programs. Examples of this include the development of wetland areas and washlands. Several national programs, including "Creating Room for Water," "Space for Rivers," and Hungary's Improvement of the Vásárhelyi Plan, have sparked a reconsideration of floodplain land management choices. To lessen the danger of flooding elsewhere in the watershed, agricultural land in washlands, polders, and flood retention basins may be utilised as floodwater storage. They provide land managers the chance to supply a variety of advantages, including as floodwater storage and biodiversity improvement, and they may also offer them other sources of revenue.

The flood risk management policy framework in New Zealand has also been reviewed, with a focus on the need for local and national governments to modify present procedures in order to adapt to climate change. New Zealand uses a combination of rules, voluntary actions, and other methods to minimize the danger of floods connected to agriculture, but not financial incentives. Agriculture and drought management the evidence is overwhelming that drought events have become more frequent and severe in many OECD nations over the last several decades, having similar negative effects on agricultural productivity as floods have. Due to climate change, it is anticipated that these occurrences will become more often in the future. In OECD nations, there are not many national policies that specifically target agricultural drought risk management; but, when they have been enacted, they often include adaptation and mitigation strategies. Most nations' mitigation strategies typically include enhancing water retention and storage on and off farms [6], [7].

In addition to providing farm advice and technical guidance to reduce the risks of drought, mitigation measures have encouraged the adoption of agri-environmental practices that increase soil moisture retention, such as switching cropping systems to drought-resistant crops and implementing conservation tillage. In the context of climate change, technical advancements in water use and crop adaptation will play a part in the creation of methods for monitoring and assessing drought conditions, backed by research and experimental development. Except from the extensive use of disaster relief payments and loans, there haven't been many programs that specifically aim to adjust agriculture to drought hazards. Several nations have recently started reviewing their current drought policies in response to rising worries about the predicted rise in drought occurrences as a result of climate change. For instance, Canada, Hungary, Turkey, and the United Kingdom are all now reviewing how their national drought policies influence agriculture. In the midst of the worst spell of agricultural drought on record, Australia is also reviewing its national drought regulations. As compared to the long-term average, precipitation and runoff patterns have been on the decline over the last 20 years, particularly in arid regions, prompting Spain to take a number of actions in response to climate change [8].

Little progress has been made in water policy research and monitoring of the connections between agriculture, the environment, and hydrology. If this divergence persists, it might lead to poorly informed decision-makers and poor implementation and evaluation of policies. As agricultural and water resources move into an age of uncertainty, increased unpredictability, and higher hazards as a consequence of climate change, these gaps in knowledge, research, and monitoring are exacerbated. Most OECD nations are now making a significant effort to resolve information gaps in order to better inform policy-making. The monitoring of minimum water flow rates in rivers as a component of environmental planning in many nations are encouraging examples. Moreover, extensive studies of river basins are being done, for instance, in the EU under the Water Framework Directive and in Australia under the National Water Initiative. The public at large and policy makers might benefit from advancements in understanding, research, and monitoring of water resources in agriculture in five major areas.

Increasing understanding of the connections between surface water and groundwater flows as well as the interactions between agriculture and water availability. Intensifying efforts to build up reliable databases on trends in the use of water resources by agriculture, as well as information on the sources of water used, better calculations of the physical and economic efficiency of water use in agriculture, and other data pertaining to on-farm water use and the off-farm environmental effects where water is recycled into the water system, including better quantifying the net costs and benefits of water resource use by agriculture. Improving data on cost recovery rates for water delivered to agriculture, both in terms of quantity and quality. Currently, utilizing and comparing statistics on cost recovery rates and agricultural water levies requires a great deal of care.

Realizing that climate change may make historical data on precipitation and temperature trends obsolete, scientists and decision-makers will need to be open to this issue when managing agriculture's use of water resources. In addition, policymakers will increasingly need to take the findings from the extensive research on climate change, agriculture, and water resources that is being conducted in many OECD countries into account when making decisions. Promoting a more thorough analysis of the relationships between policies and the results in terms of the environment and the economy in the context of managing agricultural water resources, as well as as a contribution to a more general agri-environmental policy analysis. The replies of member nations to an OECD questionnaire have shown that, apart from academic studies on these connections, there is minimal government assessment of the environmental efficacy and economic efficiency of agricultural water resource management programs [9]–[11].

CONCLUSION

Moreover, managing river flows in real-time and meticulously tracking extractions are required for water entitlements and trade. Long-term river health and hydrologic performance assessments, evaluations of the efficacy of monopoly water enterprises, and analyses of the effects of changes on agricultural productivity are all necessary for a sustainable water entitlement system. All of this information is neither cheap nor simple to collect, yet without it, changes will fail. Also, there is a significant demand for better information to enable the optimal application of economic concepts to the management of irrigation infrastructure. Information is required on the cost-sharing agreements between irrigation users and public irrigation providers, as well as the effects of improved infrastructure on water savings at the project and basin levels. Decisions on how to best maintain irrigation infrastructure might be effectively informed by robust data and prudent use of economic principles.

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CHAPTER 18

WATER RESOURCE AND AGRICULTURAL DEVELOPMENT ARRANGEMENT

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ABSTRACT:

Many variables impacted how water resources were used for agriculture, which is the primary use of regional water resources (e.g. landform, climate, precipitation and water system). The amount of water needed will change based on the kind of crop grown there. While determining the amount of water needed, the controller takes into account a number of factors, including the kinds of crops grown in the region, the humidity, temperature, and wind speed. According to a case study, the ideal irrigation plan may increase productivity while conserving water compared to the traditional irrigation schedule, which completely irrigates the whole area. By source, transit, irrigation, conservation, and use of agricultural waters, the aforementioned techniques maximize the disposition of agricultural water resources following the earthquake. They might also improve usage efficiency, lessen adverse environmental effects, and guarantee the sustainability of agricultural output.

KEYWORDS:

Agriculture, Environment, Humidity, Management, Water Resource.

INTRODUCTION

A centralized entity in control of all the water resources accessible in North East Province must be formed in order to carry out the policy foundation mentioned above. The North East Province should provide this authority complete control over the development, upkeep, and enhancement of all the river basins and aquifers that make up the region's water resources [1].

The Authority in charge of water resources development will have the following primary goals:

- Development of Water Resources for Drainage, Flood Management, Household and Industrial Water Use, and Irrigated Agriculture (Surface and Lift).
- Providing irrigation and drainage infrastructure for areas that may be used for agriculture in irrigation and drainage projects.
- Water management to improve the effectiveness of irrigation.
- Creation of Groundwater
- Groundwater Potential Monitoring.
- Potential surface water monitoring
- Consolidation of the lands covered by the current irrigation systems.

The following responsibilities of the Authority in charge of Water Resources Development will result from the aforementioned goals: - Creation of Master Plans for the Different River Basins for the Best Use of Land and Water Resources. Irrigation, water supply, flood control, reclamation, and agriculture project formulation and detail designs. Building irrigation and settlement projects for the preservation, diversion, and distribution of water via lift irrigation to new and existing areas for farming by farmers for flood crop production. Building drainage, flood protection, and salt water exclusion projects to safeguard cultivable land so that it may be farmed with rainfall for food crop production while posing the fewest risks possible and to enhance the quality of ground water [2].

Operation, upkeep, rehabilitation, improvements, and water management for medium- and large-scale drainage, lift, and gravity irrigation projects. Studies in agriculture, land use, engineering geology, groundwater development, hydraulics, hydrology, soil mechanics, and water management as they relate to projects for developing water resources. Offering consulting services in the areas of water resource development, foundation engineering, quality control of concrete and earthwork, hydraulic and groundwater model studies, and land use planning to government agencies, statutory boards/corporations, public and private institutions, and individuals.

Arrangements for Organization

The proposed authority should include a centrally located head office with at least four divisions, including one for agriculture, one for groundwater development and management, one for surface water development and management, and one for water supply and drainage. At least ten regional offices should be set up at the field level to design plans for developing the water resources that are present in a given area and to carry out maintenance and monitoring of those resources.

To execute the aforementioned policy basis, there should be at least three to four divisional offices under each regional office [3]. To handle the research and specialist constancy services for the regional and divisional offices, the following specialized units will also be formed at the head office level in addition to these arrangements.

- Ground water and engineering geology Division; Hydraulics and Hydrology Division; Soil Mechanics and Engineering Materials Division
- Division of Agriculture and Land Use Policy Planning
- Water Management Division; Institute for Capacity Building.

DISCUSSION

Agricultural diversity and Additional Crops

In well-drained rice fields, crop diversification will be encouraged with the use of supplemental irrigation as needed. There will be built pilot initiatives to show that these techniques are feasible in situations when they are needed. High value vegetables, various field crops, and fruit crops like bananas and grapes will be part of a diversification plan. For the fruit crops, water-saving irrigation techniques like micro irrigation will be used.

The distribution of seed materials and the organization of private sector marketing will lead to an increase in the production of black gram, ground nut, green gram, pigeon pea, soybean, sesame, and sun flower on high lands in Maharashtra.

This will guarantee a sufficient supply for export and processing. The output of oil seeds for the industrial manufacturing of vegetable oils will increase. Similarly, in order to support the establishment of a livestock feed manufacturing business, the growing of manioc, maize, and soughum will be encouraged via the distribution of seeds and planting supplies as well as through the organization of private sector marketing. The cultivation of sugarcane will remain a significant activity. On existing land and water, measures will be implemented to boost productivity while lowering production costs [4].

Seed Production, Research, Training, and Extension

The research extension, training, and seed production activities need to be reorganized and strengthened in order to support crop diversification and extend commercial cultivation of selected high value crops through the introduction of superior varieties and location-specific technology while also resolving farmer's issues. To provide commercially viable services for the envisaged horticulture development In-depth study on a few fruits and vegetables will be conducted at a location adjacent to the commercial orchards by nucleus/out-growers. If required, a new horticulture substation will be built.

Universities will be given research contracts to work on the creation of new technologies, notably for post-harvest operations (storage and processing), in an effort to cut losses brought on by overproduction and low pricing as well as to produce processed goods for the markets. Seed testing and certification will be handled by the local research stations rather than shipping samples to outside labs. This will reduce certification delays and, as a result, the department's capacity to provide farmers with high-quality seeds when they need them. The proposed Authority's Agriculture and Land Use Division would develop a medium-term seed and planting materials production plan for a number of different crops and kinds, with yearly implementation goals. Three things will be part of this strategy [5], [6].

In order to generate the greatest number of registered seeds and other planting materials, government farms must be strengthened. To multiply enough certified seed, contract growers are used. Engaging private business owners in the manufacturing of planting supplies and commercial seeds for both domestic and international markets. A logical staff development plan will be implemented, and the province extension system will be reorganized. We'll propose an integrated extension method. The private sector will be allowed to plan the commercial production and selling of certain crops and live animals as well as to provide specialized consultancy services for a charge. The revamped extension system would fully use the support provided by NGOs and farmer groups. The extension services will organize these services in accordance with the suggested extension plan. To execute the plan, the Provincial Council will conduct a review of the people resources, skills, and specialized knowledge that are already accessible. To address the demands of the agricultural and fishing industries, the council will establish a suitable human resource development plan.

Marketing and Processing

The primary goals will be to sell quality goods, increase the value added component of agricultural products, and maintain an institutional framework for improved marketing.

Listed below are the goals of the processing and marketing strategies:

1) The Regional Industrial Advisory Service Center's mandate will be expanded, and appropriate institutional arrangements will be developed to include the whole province, in order to encourage processing and enhance marketing alternatives. This center will set up facilities for conducting market research, offer investors information and advice, facilitate production investment, connect buyers with producer organizations, offer support and incentives to those interested in investing in agro-processing industries, and act as a forum for resolving market-related issues.

2) It will be made easier for local and international private sector investors to establish joint ventures with small producers. To increase the capacity of existing facilities, 50% of the cost of importing machinery and equipment will be covered by the province. Moreover, promising items will be targeted by offering revolving credit lines (medium term) to the enterprises involved, allowing them to expand their operations [7].

3) To assure sufficient supplies for processing and sale to local and international markets, the province will focus on the production of black gram, groundnut, sunflower, sesame, green gram, and soybean. Production of sorghum, maize, and cassava will be encouraged in order to support the development of a sector that produces animal feed. In order to facilitate the manufacture of dairy products on a small scale for the local market, milk production will be promoted.

Financial Resources

The plan for infrastructure development would include the backlog caused by the major development programs that were not implemented in the past, the significant. Damage and losses that have already happened, current needs, and the need to promote sustainable growth that keeps up with progress in other provinces are all factors.

Watering

1) Small tanks will be restored with the double goals of supplying water for paddy and other field crops via lift irrigation, providing water for people and animal usage, and recharging ground water resources. To identify investment priorities, criteria for such tanks' repair will be created.

2) The province will see to it that the central government's large tanks are repaired as quickly and urgently as possible to suit the demands of the province.

3) The Batticaloa lagoon's water resources are not being completely used for agricultural reasons. Continuous quality monitoring will be used to encourage the use of this resource, together with the identification of crops and associated technologies.

The economic possibility of turning some of the lagoons into fish water reservoirs will be studied[8].

1) Farmers organizations will be established, with administration of irrigation projects given to them. Particularly for maintenance of canal, desilting and water delivery. If they deem it essential, the organizations will be free to charge for water.

2) The province will carry out empirical studies on water management and resource conservation. With the help of farmer associations, effective water management and conservation techniques like those used in Iranamadu will be applied to other programs.

3) In regions with access to subsurface water resources, assistance will be provided for the construction of agro-wells. To make it easier to cultivate other horticultural and food crops. Based on a groundwater resources survey, this will be done. A monitoring method will be implemented to maintain a balance between exploitation and recharge in order to avoid overexploitation, depletion, and deterioration of ground water quality.

Livestock

The province will place a strong premium on livestock development, with one of the key goals being to turn the subsistence livestock industry into a commercial one. The Priority attention will be given to enhancing the stock, management procedures, and healthcare system. It will also be given to increasing feed supplies, creating processing facilities, and enhancing the marketing system. Priority will be given to dairy growth in the province, next goat and poultry production [9].

The main strategy will be to support intensive livestock management and combine it with crops on lots of small farms. The combination of animals and crops has various benefits. Cattle use crop wastes, manure improves the land and serves as a fertilizer alternative, dairy products improve family nutrition, and total family income rises. The strategy in places with big herds will be to strengthen the herds and develop livestock management capabilities.

1) The first strategy will be to improve the current population by cross breeding programs using high genetic potential Indian stud animals and/or artificial insemination utilizing frozen semen. Breeds like Holstein and Jersey will be employed for upgrading under an intense system.
2. Producers' associations or crops will be enlarged and reoriented to provide group support services such feed supply, veterinary medical care, artificial insemination, as well as collecting, processing, and marketing of milk and value-added products. Loans will be provided to these producers' cooperatives to carry out these initiatives.
3. Reasonably priced feeds are necessary for the dairy business to grow. The province's main strategy for luring companies into producing both conventional and non-conventional animal feeds would be cost sharing arrangements. Locally manufactured rice bran is of inferior quality. To encourage millers to employ rubber rollers, cost-sharing arrangements will be implemented.
4. To encourage the development of contemporary abattoirs, which will also serve as the hub for by-products like skins and hides, a similar cost-sharing scheme will be used. We'll reassess the present restriction on killing female cattle and buffaloes.
5. Since there is a shortage of bull calves needed to upgrade the cattle and the National Livestock Development Board is unable to provide them. To satisfy the demand, a cattle breeding facility will be set up to increase the number of bull calves. Also, this station will increase the number of better-quality draught animals for sale to farmer's cooperatives and individual cow breeders who will obtain loans, land, etc. to support such endeavors.

Selected natural pasturelands will be developed into pastures using the following methods:

Private business owners are tasked with management and subsidies programs

High-quality research animals and young does that may be used for both goat and sheep husbandry will be made available. The provincial government will set up a livestock farm for the breeding of better stock, distributing it to breeders, and providing management and disease prevention training. To disseminate better animals on a larger scale, a buy back mechanism will be implemented. The provincial animal production and health service will execute joint crop and livestock integration programs that combine the efforts of its extension personnel and crop extension workers. The veterinary medical system will be improved. Within the Department, a specialized division will be established to distribute loans to co-ops and farmers in order to help with the import and distribution of premium animals and any equipment [10].

The private sector will act as the primary driving force behind the growth of poultry, and it will be helped to establish hatcheries, make and sell feeds, and organize farmers to market eggs and meat. Self-employment endeavors, especially those of women, will get encouragement. The provincial government will provide funding to the province's institutions to help them establish illness investigation labs and conduct study on breeding, feeds, and other topics. To simplify sales and control market prices, regular livestock marketplaces will be set up. The necessary legislation will be passed to create laws that will enforce quality control, specified sanitary standards for goods, internal quarantine, and animal mobility. A disease monitoring program will be implemented, and measures to reduce illness-related losses will be conducted.

Financial Promotion

The government has already implemented a considerable number of programs to encourage investment in the nation, but they have not yet reached the North East Province. These Schemes work best in places with established infrastructure, amenities, and other favorable conditions for attracting investment. The key goal for the North East Province will be to deploy all national incentive programs and schemes for the benefit of the province in a manner that is successfully integrated with other strategic measures suggested in this study. In order to do this, a system will be created by the Provincial Planning Committee.

Environment

The primary goal of the development plans created will be to transition the province's traditional agriculture into commercial agriculture and agrobased enterprises that are focused on exports. Traditional fish harvesting will give way to fish culture, processing, and aquaculture for export in the fisheries industry. The environment is probably harmed in some way by these actions. Environmental protection will be addressed with a focus on public engagement to counteract this. With the help of the community and the Central Environmental Agency, a strategy for environmental protection will be created and put into action. The strategy chosen to protect the environment will be centered on expanding agro-forestry and social forestry activities through mass mobilization and free plant distribution, increasing the use of organic manure and thereby reducing the use of fertilizers, especially in areas where nitrate pollution of ground water is a problem, introducing integrated pest management practices, and Programs for coastal conservation will also be implemented [11].

Energy conservation methods will be used in agriculture as a result of rising energy costs. The amount of energy used for lift irrigation will be significantly reduced with careful irrigation management. Chemical pesticides will be used less often thanks to pest management techniques based on real pest level monitoring. Intelligent fertilizer application scheduling based on soil nutrient status and complementing usage of organic manure will lessen the demand for energy-intensive fertilizers that must be bought. Tractor use will decline if more small farms or draft animals are used for power. There will be action taken to stop the environmental harm already caused by the extraction of clay and limestone. To stop the environmental catastrophe in the area, all forms of clay and lime stone exploitation will be outlawed. In general, the community will be involved in the selection and adoption of environmental protection measures. The appropriate laws will be passed by the provincial council, and the environmental plan will be put into action. The local bodies will get the support they need to enact legislation requiring the adoption of recognized standards for environmental protection. To raise public understanding of the need of environmental preservation, a massive awareness campaign will be launched [12].

CONCLUSION

Farmers, anglers, and livestock breeders would all benefit from the successful implementation of insurance plans to lower producer risks. The effectiveness of such a plan will be increased by adding a monitoring system. For some agricultural and animal products, a guaranteed pricing plan will be implemented in order to safeguard farmers against prices that are lower than their costs of production. There will be an efficient market intelligence service.

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CHAPTER 19
IMPLEMENTING TECHNOLOGIES FOR SUITABLE AGRICULTURAL SYSTEMS

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ABSTRACT:

Reduces the use of chemicals in agricultural farming. Effective use of water resources. Disseminates state-of-the-art agricultural techniques to enhance quality, quantity and profitability of production. Changes in the socioeconomic status of farmers Robots, temperature and moisture sensors, aerial photographs, and GPS technology are frequently used in modern agriculture. Businesses can become more successful, productive, safer and more environmentally friendly thanks to these state-of-the-art equipment, robotic systems and precision farming techniques.

KEYWORDS:

Agriculture, Environment, Farming Techniques, Genetic Modified Crops, Management.

INTRODUCTION

During the last fifty years, agriculture has seen a significant transition. It has been successful in bringing down food prices, feeding an expanding population, relieving labor from the farm, and giving customers an ever-greater variety of food throughout the year. These advances have been greatly influenced by technology, which is also now tackling social and environmental issues in an integrated manner. Agriculture must also be seen in the perspective of other global economic changes. Agriculture is impacted by trade liberalization, agricultural policy change, and globalization. The way we approach agriculture is also influenced by increased public awareness and the focus on sustainable development. In all the OECD nations, interactions between agriculture and the environment are now important factors influencing agrofood policy. Upstream and downstream activities are having an increasing impact on agriculture. Farmers need the proper incentives, education, and technological advancements to guarantee that agriculture provides enough food while maintaining environmental standards. It also implies that cohesive policies must be in place, particularly in the areas of agriculture, the environment, commerce, and research and development. It is crucial to base policy decisions on solid, accepted scientific standards so that the choices are supported and can be defended to all relevant parties [1].

The next debates on international commerce in agriculture will also touch on the linkages between agriculture and the environment. Without undermining the commitment of the OECD and the WTO to a freer, more open system of agricultural commerce, additional goals and concerns must be taken into consideration when discussing international trade. The difficulty is in identifying win-win solutions. When we talk about adopting technology for sustainable farming systems, we're talking about both new or in-development technologies as well as ones that are well-established and already accessible but aren't used by all farmers. Let me elaborate on the latter and the issue of how these new technologies affect the environment. Several nations agree that new biotechnologies must be evaluated in the context of sustainable agriculture, which takes into account resource and economic sustainability. The advantages of biotechnology and genetically modified crops, both now and in the future, have been the subject of extensive controversy [2]. Scientific research and anecdotal evidence both support and cast doubt on the advantages in terms of yields, expenses, and environmental effects. Producer groups typically report positive outcomes, although it is still early and there hasn't been much practice. Local climate factors might have an impact. Organic farmers, who make up a tiny but constantly expanding portion of the agricultural industry, voice worries about the harm that GM crops might do to nearby farms and highlight issues with liability and protective measures. Farmers' organizations believe that laws should shield them from being held responsible for any harm caused by Genetic Modified (GM) crops [3].

In terms of giving direct, quick, and global access to information, we now recognize the great promise of modern information technologies, particularly the Internet. Farmers and decision-makers are investigating the reach of online communication as a way to deal with the lack of public support for information dissemination or development activities. Nevertheless, this progress is accompanied with the need to make sure that information can be transformed into knowledge that is relevant to end users and accessible. There are several instances of researchers interacting with various customer groups on the Internet. The agriculture industry, which is sometimes plagued by issues with farms being geographically far from markets, has a plethora of opportunities to use e-commerce to gather information, sell their goods, and promote other non-food outputs. Why is technology adoption important? Up until recently, farmers' ability to choose among a variety of technologies was mostly influenced by the desire to boost output, profitability, and productivity.

The primary obstacles were a lack of finance, a lack of technical expertise, and market dangers, which in many nations were protected by government regulations. As the goal of agricultural policies was to boost productivity in agriculture, "good policy practices" in the past were quite clear and mostly related to improving production. For instance, agricultural research and extension services could focus on raising small farms' output. Agriculture must now accomplish a variety of aims, including being globally competitive, producing high-quality agricultural goods, and achieving environmental goals. Agricultural producers want quick access to innovative technology in order to stay competitive. Farmers now have a lot more possibilities as well as much more restrictions. They must cope with direct and indirect customer demands, lobby group pressures, environmental standards and regulations, and be profitable in addition to doing so. A deluge of information from multiple government and business sources may also make it more challenging for them to choose the best technology. In response to agricultural policies that take into account environmental circumstances, farmers also need to alter their production and management methods [4].

DISCUSSION

Technology that aims illnesses and pests more accurately. Nonetheless, the necessity for medications and pesticides in agriculture is unlikely to go away very soon. It is anticipated that pest control technology will continue to develop chemical control agents that, over time, are at least as efficient at eradicating pests as the ones they replace while also being less harmful, persistent, and soil mobile. Farmers should be able to use pest control agents, especially insecticides, more economically by applying them only when and where they are needed rather than in accordance with predetermined dosages and schedules thanks to the increased use of monitoring and knowledge-based systems and the lower cost of electronic sensors and computers. Technologies for more effective nutrition administration. Manuring and burning have historically been the two major methods used by farmers to give nutrients to root zones. With the use of inorganic fertilizers, crop production and animal husbandry could be separated, exhausted soils could be made fertile again, and grain and other feed components could be used to produce cattle. More carefully prepared fertilizers and feeds have been developed throughout the years as a result of research into the unique requirements of various crop-soil combinations and animals. It is anticipated that wider use of technology that only apply fertilizers when and in the quantities required would boost crop yields while lowering nutrient leaching and runoff. Technologies for more effective water administration. Several of the methods of agricultural irrigation now in use date back to the dawn of civilization [5]. The issue is that moving water via open channels and furrows is inefficient since most of the water evaporates before it reaches the root zone, much as it did in ancient Mesopotamia. A large portion of the water used in agriculture in OECD nations is transported to fields via pipes, but technical efficiency could still be increased through increased application of technologies like precision fertilization, which combine means to deliver water more precisely and in more precise dosages with means to measure actual crop needs with greater accuracy.

Technologies that minimize waste after harvest

A derived demand, the demand for basic agricultural products is influenced by wastage between producers and consumers. Technology used in OECD countries to collect, transport, store, process, and distribute agricultural products are already quite efficient and produce considerably less waste than in nations where the necessary infrastructure and money are much harder to come by. Almost every crop and animal component is retrieved for some kind of commercial purpose, even if it's only for feed, fertilizer, or energy. While post-harvest losses may be reduced further, the point of ultimate consumption is when the majority of waste occurs. Technologies for knowledge dissemination. In the past, farmers adopted "excellent agricultural methods" based on their own and their neighbors' experiences. Environmental implications are becoming more and more the focus of advice and information from publically supported organizations and the agri-food sectors. The transmission of knowledge about sustainable technology has advanced thanks to the Internet [6].

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Technologies for more Effective Nutrition Administration

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CONCLUSION

In conclusion, everyone of us must consider what we must do to be "sustainable" in a world that is undergoing fast and profound change. Governments must assess the "sustainability" of their own policies, programs, and organizational structures, just as farmers must assess how "sustainable" their own agricultural operations are. Governments cannot claim to wish to maintain small-scale agriculture, wildlife-friendly hedges, beautiful landscapes, etc. without also providing the appropriate legislative framework and funding to enable it. Liberalized market dynamics will produce the exact opposite outcome. In the end, agriculture can only be sustained if it can continually reinvent itself by luring new generations of farmers into the industry. In order to maintain an economically viable agriculture and a thriving rural economy, this calls for the adoption of suitable technology for sustainable agricultural systems as well as adequate incentives and a framework for appropriate policies.

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CHAPTER 20
MEASURING ECOLOGICAL, ECONOMIC AND SOCIAL IMPACTS WHILE EVALUATING TECHNOLOGICAL SOLUTIONS IN DEVELOPING NATIONS

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ABSTRACT:

It is possible to assess the creation, diffusion, and uptake of sustainable agricultural technology in the Third World from both a public and a private standpoint. The impact of sustainable land use technologies on factor production and the environment will be evaluated using a variety of criteria in this section. Distributional implications and external consequences will also be considered. In order to guarantee acceptable profits on innovative technology for sustainable agricultural intensification, appropriate markets and institutional frameworks are necessary. We come to the conclusion that an effective framework for ensuring fair and sustainable growth may be achieved by combining selective dependence on external inputs with well-targeted public investment, further market development, and better integrated agricultural methods.

KEYWORDS:

Agricultural Technology, Agroecological, Environment, Management, Sustainable Land.

INTRODUCTION

In recent decades, the production of food has increased in many portions of the developing globe at a never-before-seen rate. Famines in that region have been avoided, hunger and malnutrition are on the decline, and many nations are essentially self-sufficient as a result of the development of Green Revolution technologies and the widespread adoption of high-yielding varieties of staple foods by, for instance, Asian farmers. Benefits to the environment are also significant; consistent yield gains have avoided over-exploitation of marginal land and decreased the rate of deforestation. But, there are still a few issues. In Sub-Saharan Africa, where hunger is on the rise, the latest agricultural technology are scarcely effective. Around one billion people are still affected by significant pockets of poverty in regions with rain-fed agriculture or delicate soils.

Significant environmental issues have surfaced, yield increase in high-external input systems is slowing down, and further development of irrigated agriculture is constrained by both land and water limits. As a consequence, many high potential locations exhibit diminishing marginal returns from additional intensification as compared to the potential returns from developing more vulnerable land. The development of technology and practices that allow continuous agricultural expansion to meet the rising demand for food and feed is a significant challenge for the next decades. The agricultural development process must be fair, planned to preserve the natural resource base and prevent pollution in order to alleviate rural poverty and hunger. This style of agricultural growth, according to Hazell and Lutz, is broad-based, market-oriented, participatory, and decentralized, and it is fueled by innovative methods of agricultural innovation that increase factor productivity and protect the resource base [1].

There is rising interest in agroecological techniques, which concentrate on providing favorable circumstances for plants and animals to develop as parts of a broader ecosystem, in order to lessen over-dependence on external inputs. The biological management of pests and diseases, interaction between agricultural, livestock, and forestry activities, and control of soil erosion and nutrient depletion are important features of the latter system. The majority of ways that alternative systems are beneficial are biophysical. The welfare consequences in terms of farm family income, consumption, and labor usage are given significantly less consideration. To conserve soil nutrient balances and land productivity, as well as effective combinations of production elements that increase farm family income, including returns to labor, we propose the idea of sustainable agricultural intensification. We concentrate on "win-win" solutions that permit a simultaneous improvement on both scores since trade-offs between agroecological and welfare criteria are likely to develop.

Yet, not all farm families are expected to benefit equally from these advances. Different households have varying access to resources, markets, expertise, and information, and various households adopt technology at different rates, which may be problematic from an economic and social standpoint. In the context of emerging economies, this section examines the evaluation of the environmental, economic, and social effects of more sustainable technology. We restrict ourselves to the ex-ante evaluation and potential policy implications of new SAI techniques since the empirical information on sustainable agricultural systems is currently few and sometimes insufficient. Following some broad conclusions on increasing agricultural output and sustainable land use, five evaluation standards for SAI systems are put forward. We briefly look at how the effect of such new technologies may be monitored. Next, we discuss how to implement policies that will facilitate the rapid adoption of innovative sustainable agricultural practices [2].

DISCUSSION

Sustainability and Productivity

Productivity increases

A fascinating and seemingly counterintuitive function for agriculture in the process of development. Low levels of per capita income need a quick rise in productivity in order to boost rural incomes, sustain the food supply for the urban population, provide raw materials for agroindustrial growth, and produce enough cash crops to pay taxes and export revenues. These contributions of agriculture to economic growth need for a well-crafted regulatory framework that provides farmers with the proper incentives to increase output in a sustainable way while lowering historical demands on public spending. Consumption expenditures migrate steadily away from food as income levels rise, indicating increased factor productivity. While farming productivity continues to rise significantly, the pace of growth in agricultural production is often lower than for the majority of other economic activities. As a consequence, statistics show that agriculture's contribution to the macroeconomy is decreasing, and this process is sped up by the quick uptake of more productive technology. For policy-makers, the simultaneous expansion in agricultural output and relative size fall has often proven to be a cause of misunderstanding.

Supply response analysis is a key component of the analytics used to determine how the agricultural industry will react to policy changes. A supply response may take the form of crop substitution, technological advancement, or geographical expansion, each having somewhat different effects on resource allocation and the environment. Different sorts of rural families will respond differently, and as a consequence of varying expectations and adjustment costs, responses may lag. Hence, household diversity, particularly in terms of access to markets, expertise, and information, is a significant factor in the variation in technology adoption and income-generating possibilities [3].

Use of sustainable land

There is no clear consensus from empirical research on how agricultural policy and structural adjustment affect the sustainability of land usage. Although some writers contend that pricing changes would promote soil erosion, others assert that they will have a favorable impact on farmers' investments in soil conservation practices. These divergent viewpoints on the connection between pricing and soil deterioration result from variations in the definition of discount rates and in individuals' levels of risk aversion. Moreover, market flaws might prevent increasing production prices from reaching farm family levels. The analysis of supply response responses to shifting relative prices often takes the position that fertilizers will be used to make up for the decreased availability of nutrients from natural sources owing to soil loss. Other methods see labor and/or financial investments in conservation efforts as a function of natural soil fertility. Particularly in African agriculture, these resources are often in short supply. The practice of soil mining seems to be a recurring issue, necessitating contrasting tactics for selective intensification and productivity-boosting soil conservation measures in order to promote sustainable land use.

It is still unclear how agricultural policy, farmer supply, and the consequences for sustainable land use are related to one another. Deforestation, overgrazing, erosion, and sedimentation are all predicted environmental repercussions when greater agricultural supply results from area expansion. According to Binswanger et al., an increase in output prices results in a comparable rise in area but only a modest rise in yields. If changes in farming activities also take place, expanding the area might be compatible with better land use, with the ultimate result depending on how negatively cropping activities affect resource quality. The consequences of complementary input utilization on chemical or physical soil qualities are often not taken into account. As a result, expenditures in soil conservation or changes in input efficiency linked to soil organic matter concentrations are not fully recorded. A more thorough framework built on connections between welfare and sustainability consequences is needed for further exploration of these problems [4].

Only when farmers have access to greater and more consistent levels of income and consumption possibilities can we anticipate the adoption of sustainable agriculture technology and practices. Effective market outlets and favorable output/input price ratios are both necessary for profitability. The incentives for investing in activities that conserve soil are diminished by market distortions or ineffective trade networks. When farmers continue to subsistence agriculture and depend nearly entirely on locally available resources, agricultural intensification may become unsustainable. Farmers are likely to use yield-increasing and sustainability-enhancing inputs for economically driven agricultural operations, contrary to what is often thought. Chemical fertilizers, agricultural waste, and animal manure are often utilized in the cotton belts of southern Mali and Burkina Faso to grow cash crops that are guaranteed to provide enough income to cover these expenditures. Similar to this, when used on more fertile areas where commercial crops are cultivated, animal traction and enhanced tillage provide greater returns. Crop residue mulching only seems to be beneficial in the Central Chiapas area of Mexico when used in conjunction with animal traction on fields used for intense market-oriented cropping operations.

Efficiency of Input

The potential for increasing input efficiency, such as the marginal returns from adding an extra unit of inputs, is what determines whether agricultural intensification can be done sustainably. Productive ecology techniques draw attention to the fact that the availability of complementing micro- and macronutrients, particularly soil organic matter and phosphorus, determines nutrient efficiency. Alternatives to chemical fertilizers often have a poor recovery percentage because nutrients are immobilized and organic matter decomposes slowly. Using soil and water conservation techniques that lower the soil's ability to retain nutrients and via frequent nutrient treatments based on scheduling of activities in accordance with the crop development phase, nutrient recovery and uptake efficiency may be improved. Both tasks require a lot of labor, yet neither can really be automated. Therefore, nitrogen release from the soil is only accelerated by mechanical or animal tillage. Availability of input combinations that guarantee appropriate synergy effects based on precise complementarities between various growth-enhancing inputs is the only way to boost agricultural yields, which are dependent on the most restricting factor.

In studies on input efficiency, functional relationships between soil carbon content and organic nitrogen supply are mentioned in order to prevent the immobilization of nutrients, as well as the proportional relationship between nitrogen and phosphorus in order to ensure a sufficient rate of organic matter decomposition. This suggests that when complementary inputs are not accessible at the appropriate time or in adequate quantities, input efficiency is likely to be poor. Farmers have often mastered the art of fusing several producing endeavors to produce advantageous synergistic results. The greatest outcomes often come from combining locally accessible resources with well-chosen foreign inputs since organic and chemical inputs cannot completely replace each other. Since it allows for better scheduling of operations, lowers the need for labor during crucial times, and helps to a better look of the food in the marketplace, farmers often hesitate to entirely forego the use of bought inputs. Chemical fertilizers cannot entirely replace organically generated fertilizers because to the poor nutrient content and delayed nutrient availability. As organic matter breakdown takes time, best results are obtained when chemical fertilizer treatments are progressively decreased until they are at their lowest possible level [5].

Management of risk

Farmers with limited resources are more likely to depend on reasonably diverse activity patterns to guarantee adequate levels of risk management. By processes of nutrient recycling, biodiversity management, and integrated pest and disease control, crop and livestock diversification and integration with forestry, aquaculture, and better fallow practices might strengthen the resilience of agricultural systems. As a result, yield levels are often more consistent and reliance on bought inputs may be reduced. Yet it's becoming more widely acknowledged that participating in off-farm and non-farm activities may also help farmers manage risk. These activities' income sources are far less reliant on changing weather, which serves as appropriate protection against covariate shocks. Diversification into non-agricultural enterprises may also be seen as a viable risk management strategy in addition to cropping system diversity. When the need for labor for agricultural operations can be decreased and family members have the necessary skills and knowledge for wage work or self-employment, reliance on this technique becomes practical.

The ability of farmers to modify input consumption in response to shifting weather or environmental circumstances is another concern in the context of short-term risk management. Adaptive behavior is largely dependent on the ability for learning that permits quick responses to unforeseen occurrences. While the majority of agroecological practices have been created via participatory and horizontal extension techniques, the dynamics of production systems are only vaguely understood. A case in point is Honduras' failure to implement maize-cover crop systems, which may be attributed to a failure to adequately combat weed invasion and the consequent abandonment of "companion technologies" including living barriers, contours, and crop residue recycling, and reseeding.

The efficient mobilization of land, labor, and capital resources is another implication of agricultural intensification. To make sure that small farmers can benefit from new and better technology, concerted work in these areas is essential. A crucial prerequisite for increasing farmers' willingness to invest is the possession of secure and recognized land rights. Farmers are able to engage in land upgrades and the acquisition of inputs thanks to well defined land ownership, use, and transfer rights, which also serve as an appropriate collateral for loans. Secure land rights may also be obtained under common property regimes, even if private ownership offers the majority of direct incentives. To enable farmers to borrow for investments, input purchases, and insurance reasons, rural financial infrastructures are necessary. Although conventional banks are often less likely to lend to smallholders, regional credit and savings programs might significantly lower the costs and hazards associated with rural investment. Farmers are likely to expand their involvement in off-farm jobs as a way to acquire investment money when access to rural banking institutions is limited. Mobilizing investment capital seems to be entirely justified given the profitability of sustainable farming technology and practices. Agriculture technology development is significantly impacted by the characteristics of rural labor markets. Agricultural intensification is more likely to occur when labor is in short supply and employment opportunities are excellent. In response to increasing market prospects, the labor supply for intense commercial agricultural operations can only be expanded. As a standard practice for portfolio and risk management, labor diversification in non-farm businesses enables farmers to finance the purchase of inputs. In these situations, land use innovations that reduce the need for wage labor and increase the marginal productivity of family labor are necessary [6].

Sustainability problems in low-external-input agriculture, which is particularly practiced in the poorest regions of developing countries, center primarily on the depletion of the natural resource base owing to rising strain on land. This paper's discussion of sustainability emphasizes a mix of more prudent use of outside inputs and improved agricultural techniques. Farmers must do this by increasing their participation in the market economy and by selling some of their produce in order to raise money for input purchases. A key component of this approach is the creation of efficient marketplaces and a transportation infrastructure. In-depth knowledge of production methods and decisions made at the home level is necessary for the identification and selection of sustainable and successful agricultural techniques. The main challenge is to distill this in-depth information into a set of basic best agricultural practices and disseminate it to a sizable number of farmers. The availability of such information may be improved via instruction, research, and extension. Fairs, marketplaces, co-ops, and farmer organizations all contribute significantly to the sharing of knowledge and information in rural communities.

Sustainability concerns are quite different in high-external-input agriculture, which is practiced in the majority of developed countries, and they primarily center on the negative externalities of agricultural production, loss of genetic diversity and nature, and standards related to food safety and animal welfare. The institutional framework under which these issues may be resolved as well as the difficulties at hand are different. Markets, auxiliary services, platforms for exchanging knowledge and information, and legal systems are all quite advanced. Governments in this situation often work to eliminate harmful externalities of agricultural output via law and diplomacy. There are deadlines established to phase out unfavorable farming techniques like the usage of certain herbicides or techniques for producing cattle. Establishing such goals often entails a lot of political wrangling, including heated discussions over the scientific evidence governments use to justify imposing stricter regulations. Given the still-large number of farms, implementing such law once it has been adopted by parliament may sometimes be challenging [7].

Consumers are increasingly able to impose restrictions on agricultural production techniques in addition to governments. Their tolerance threshold might be far lower than the government's at times, and consumer organizations and market channels are the best places for them to voice their concerns. The availability of technology alternatives heavily influences the capacity to phase out undesired manufacturing methods. Governments in underdeveloped nations often are unable to provide substantial financial incentives, and the economic viability of more sustainable practices continues to be a key barrier to their adoption. Returns need to be enticing enough in comparison to income from non-farm work, and sustainably produced goods finally need to be competitive in the market. Farmers carefully examine additional elements and dangers even when cost-benefit analyses provide favorable findings. Returns to land and labor must rise at the same time since most agroecological approaches need a lot of labor and because factor substitution is currently constrained. Hence, increasing the amount of dependence on bought inputs may be the ideal method for preserving farmer incomes and enhancing the chances for food security. However, for SAI to be effective in increasing family incomes as well as agricultural production, at least three other requirements must be met. Secondly, when public funds and services are made accessible to farmers in distant areas, the economic feasibility of more sustainable methods may be significantly increased. Without such initiatives, low-input farming methods are often limited to medium-sized farmers who participate only little in market trade. The most crucial prerequisites for agricultural intensification are the growth of the market and a decline in transportation costs, since trade relations favor access to complementary inputs and encourage investment [8].

CONCLUSION

Consequently, increasing the access of underprivileged farmers to physical infrastructure is a crucial need for equitable and long-term rural development. Second, to minimize uncertainty and allow adaptable responses to shifting production and exchange situations, sustainable intensification needs increased access to factor and commodity markets. The only way to significantly boost agricultural output is to combine home resources from the farm with well chosen outside inputs. Given the demands for factor substitution and input efficiency, the potential for overcoming important input limits has a significant impact on agricultural production. Thus, it is necessary to have access to complementary inputs and a labor supply to ensure their timely use. Finally, legislative measures that allow farmers to allocate resources to more effective integrated agricultural systems are crucial for the adoption and sustainability of sustainable production systems. The availability of financial services, marketing outlets, and off-farm employment opportunities are equally crucial from the perspective of reducing poverty, even though land and water conservation practices, improved tillage systems, and better nutrient management offer wide prospects for enhancing productivity. While market prices were usually improved by structural adjustment programs, input costs remained high and the delivery system was ineffective. Access to inputs turns out to be highly influenced by personal traits and social networks. The adoption of sustainable behaviors and technology may thus be accelerated by investments in both human and social capital.

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CHAPTER 21

STIMULATING INNOVATION AND TECHNOLOGY UPGRADE FOR SUITABLE AGRICULTURAL SYSTEMS

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ABSTRACT:

The idea that traditional intensive farming systems might be just as sustainable as any other kind of agricultural system is examined in this essay, along with its viability and ramifications. It covers the European policy climate within which industry is developing cutting-edge agricultural technology, in particular pesticides, GM crops, and seeds, based on the findings of an EC-funded experiment. At both the national and international levels, important policies and regulations include those that support trade liberalization, including revision of the Common Agricultural Policy, as well as technical innovation, environmental protection, and biodiversity. Although certain policy efforts are promoting the development of new technologies by the sector, it is more typical to discover that policies coming from several government departments conflict and provide less than ideal results. Policymakers must be more integrated across functional domains and better knowledgeable outside of their own specialized field.

KEYWORDS:

Agriculture, Environment, Fertilizers, GM Crops, Natural Resource, Management.

INTRODUCTION

A societal idea related to the management of a natural resource for human use is called sustainable development. Hence, depending on the interests and values that drive that aim, it is subject to many interpretations. Farrell and Hart provide two opposing perspectives on sustainability. The Critical Limits perspective emphasizes the necessity to protect natural resources in order to continue providing the services that the human population depends on for existence as well as worries about the earth's carrying capacity and resource constraints. The Competing Goals perspective on sustainability focuses on striking a balance between social, economic, and ecological objectives and seeks to satisfy a variety of human needs, including a healthy natural environment, political freedom, literacy, and other purely material need.

It has been passionately argued that organic and intensive systems are more sustainable than each other, but more often than not, the critical limits perspective is used to support the idea that organic agriculture is the only form of agriculture that is truly sustainable, and that society must accept the restrictions this would place on the number of people in the world and the lifestyle they can lead. It prioritizes the one goal of environmental sustainability, which is presumed to trump the interests of all other stakeholders and to favor a cautious response to environmental concerns connected to agricultural systems. Hence, the theory goes, our lives and consumption habits will need to be drastically altered in order to feed the world's population utilizing organic agricultural practices. The conflicting aims viewpoint on agricultural systems, on the other hand, would agree that compromises are necessary between a broad varieties of objectives in order to serve a complex array of human demands. It aims to strike a balance between long-term agricultural land use and economic sustainability, environmental protection, meeting public demand for food, and delivering the landscape advantages associated with agriculture [1].

The pertinent question thus becomes: to what extent can we reconcile divergent stakeholder interests in any given agricultural system? This point of view enables the interests of all key stakeholders in any development or activity to be balanced in the context of overarching policy considerations, but it runs the danger of allowing trade-offs that allow eventually unsustainable behaviors to continue unchecked. Whose understanding of sustainable development planners, policy makers, and their advisors choose will determine how future agricultural systems are designed and developed, among other things. The decision will be influenced by personalities, values, and self-interest in addition to scientific data, as is the case in the majority of human endeavors. While seeming to be based on science and economics on the surface, discussions on the relative benefits of various agricultural methods are unavoidably emotive. With a few noteworthy exceptions, intensive or traditional high yielding farming systems on rich soils are often robust to disruption and have seemed to be sustainable in strictly agricultural terms for at least 50 years.

In terms of competing objectives, these are the farming systems that must continue to be viable from an agricultural and economic standpoint if we are to be able to feed the world's population. Some would also argue that they are necessary if we are to keep some arable land so that we can give biodiversity and landscape objectives a higher priority. While intensive farming practices could seem viable from the viewpoint of the farm alone, they might have effects on the larger environment that are seen as inappropriate or unsustainable at the very least. Extensive farming systems predominantly based on organic or comparable technologies may have lasted for millennia at low levels of production in more unstable agricultural settings, such as on marginal land, steep slopes, poor soils, or regions with little rainfall. When techniques are altered in an effort to increase yields, such as via incorrect cultivation or irrigation, the use of chemical inputs, or overgrazing, they often become manifestly unsustainable. Although the sustainability of such extensive farming systems is frequently crucial to the subsistence farming communities that depend on them, they are unlikely to significantly contribute to the world's food supply, and technological innovation's role in the sustainable improvement of yields in such areas is likely to be localized and context-specific [2].

The degree to which agricultural systems can maintain a significant level of wildlife biodiversity on farms is a major point of contention in the argument concerning their sustainability. There is a significant difference between the presence of wildlife on the cropped area of the farm and alternatively in field margins and non-cropped regions. Various kinds of farming systems will unavoidably have a variety of diverse consequences on wildlife biodiversity. The increased biodiversity on the farmed lands is sometimes cited as evidence for the improved sustainability of organic farming methods, however it is seldom feasible to promote solely species that have no bearing on crop output.

The majority of commercial farmers believe that having wildlife on their harvested land would lower output. It is more reasonable for policymakers to expect that farmers who want to remain competitive are unlikely to have biodiversity encouragement as one of their top priorities for the farm's cultivated areas. By effectively using "clean technology," it should be feasible to reduce the influence of the agricultural system on wildlife biodiversity on field margins and other non-cropped areas. So long as the biodiversity of the cultivated area is taken into account, traditional farming techniques need not have a detrimental influence on the environment from the standpoint of "competing aims".

To fulfill conflicting productivity, environmental, biodiversity, and aesthetic objectives, a mosaic of crop production systems using a combination of integrated, organic, and conventional cropping systems would likely be necessary to attain maximum biodiversity at a regional level. Key caveats include the need to prevent unwarranted agricultural system expansion in more vulnerable places and excessive use of technical inputs like pesticides or fertilizers everywhere. The balance of agronomic, landscape, and biodiversity-related demands, as well as the varying ability of the land area to meet those needs, will determine the appropriate proportions of various cropping systems in a region. The Organic Food and Farming Targets Bill, supported by the WorldWide Fund for Nature, UK, for instance, sets a target of 30% of UK farmland being organic or in conversion by 2010. However, even if this target is met, it is unlikely that organic farming systems will be evenly distributed across the country's farmed land areas [3], [4].

DISCUSSION

Technologies to increase the sustainability of agricultural systems. Most agricultural policy makers neglect the requirements of conventional farming systems on the most fertile agricultural land in favor of focusing on organic and related integrated farming systems as the path to sustainability. Scottish Natural Heritage took up this task a few years ago and launched a study to look at the many technical possibilities that may assist such systems to become more ecologically sustainable without compromising their ability to compete economically. More recently, a project funded by the European Commission has been looking into how national and international policy environments affect the innovation strategies of businesses creating pesticides, biotechnology, and seed products that may lessen the environmental impact of all farming systems, including conventional and intensive ones.

The scales stand in for contemporary enlightened philosophy, which embraces scientific rationality and related technical approaches to problem-solving. The yin/yang sign alludes to an earlier time when people lived in peace with nature and rejected "technical remedies" as a cure for agricultural issues. It is a representation of post-modern philosophy. In contrast to any underlying facts about the nature of agricultural policy, this sociopolitical viewpoint reflects the character of the disputes contending for influence on those policies. Organic farming methods are on the right side of this spectrum, whereas conventional or intensive farming systems are on the left. The term "integrated farming systems" is used by both sides of the argument to describe a middle ground that uses natural controls, crop rotation, and a variety of agronomic practices to encourage pest predators, reduce the incidence of diseases, and reduce the need for chemical or biotechnological inputs.

On the one hand, the agrochemical industry uses the term to refer to the use of technological options to reduce dependence on pesticides and fertilizers. Often, organic farming methods are presented as comprehensive and sustainable, whereas conventional farming methods are seen as the reverse. According to the thesis of this essay, there is no reason why either cannot be equally sustainable, and both are unquestionably equally holistic in that they behave as structured systems of interconnected parts, and that the behavior of the system will change if components are added or removed, possibly dramatically. The challenges farmers have when crossing the main split between conventionally based and organically based systems and the relative ease with which they may migrate in either direction to or from that border are evidence of this systemic structure in both situations [5].

Through a variety of innovations in engineering, information technology, pesticides, and biotechnology, reducing the load of known toxins, substituting safer alternatives, protecting ground or surface waters, protecting natural habitats, reducing nutrient loads in soils, reducing gaseous nitrogen loss, or reducing the amount of non-renewable energy used, technological innovation has a potentially significant role to play in improving the sustainability of these farming systems. In this volatile physical and legislative climate, we will be dependent on European intensive/conventional agricultural methods on the most productive soils to feed a rising global population. It is possible that farmers will become more risk averse as a result of the increased commercial pressure brought on by the globalization of food production systems and market liberalization. In years when crop prices are high, farmers who provide commodities to markets will be under pressure to ensure they have a good crop in terms of quality and quantity. However, they will have to make decisions about the use of fertilisers and pest control inputs before they have information on pertinent market prices. As a result, companies will be more inclined than ever to employ inputs as insurance, but they will also want to keep the cost of this insurance as low as possible, which can drive them to utilize older, non-patent, and perhaps more ecologically harmful technologies. The use of new technology is more likely than any other presently available alternative to be more acceptable to these farmers and to have a greater and faster effect on the sustainability of European agricultural systems [6].

Policy's effect on industry strategy

On the whole, industry will be deterred from investing in innovation if the market for new technology is unclear and regulatory structures are in flux. Nevertheless, given that corporations are accustomed to working with lead periods of 15-20 years, notably in the case of pesticides and genetically modified crops, this impact is likely to be delayed and that short-term market and policy shifts are less significant to their choices. After the policy study, top managers from businesses that produce pesticides, biotechnology, and seeds were interviewed for a number of hours as part of the PITA project's second step. While the analysis of these data is still ongoing, some early conclusions that are pertinent to the question of overall agricultural sustainability are starting to emerge, for instance regarding the creation, manufacture, and usage of pesticides as well as the future of GM crops [7], [8].

From the perspective of the industry, European biotechnology legislation was considered as possibly having a significant influence on the R&D strategy of businesses, especially those with their primary R&D facilities in Europe. While the regulatory uncertainty may force businesses to go elsewhere, it is unlikely to have an impact on business decisions in international markets where GM crops are still seen as having huge promise for improving the sustainability of agricultural systems. Only a few instances would be: "Low phytate" animal feeds and feeds adapted to the nutritional requirements of various species would lessen the environmental impact of animal husbandry systems; GM crops with insect and disease resistance would lessen, but not completely eliminate, the need for pesticide applications; and if fewer pesticides are used, the number of chemical factories can be decreased and there will be less waste of fossil fuels in the transport and application of chemicals. Industry experts believe that GM crops might have a far bigger and faster effect on pesticide consumption rates in agriculture than any legislative or regulatory action that could ever be considered. Nonetheless, there is growing agreement among policymakers that the introduction of GM crops was done too quickly and possibly didn't pay enough attention to the need for public choice and confidence. To provide governments a state-of-the-art evaluation of scientific knowledge and to place it in the perspective of society's larger concerns, a worldwide forum modeled after the Intergovernmental Panel on Climate Change has been suggested [9]–[11].

CONCLUSION

This paper has provided an overview of one area of the present legislative and policy landscape where innovative methods for the creation of agricultural technology are developing. It only covers a small portion of a very broad region, but some key elements are already starting to become apparent. There are governmental and regulatory measures that may have a significant and immediate impact on the innovation processes pertinent to sustainable agricultural systems, but they are rare, and it's possible that their importance and worth are not acknowledged. It is increasingly common to discover that laws and rules created in one policy area have unintended consequences in other areas or are offset by previously unrecognized restrictions. The best way for public arena decision-makers to achieve their goals is to concentrate on creating a policy and regulatory climate that is facilitating rather than constrictive and restrictive. Policy makers need to be more educated and more integrated in order to deal with multinational enterprises, internationally coordinated environmental and other public pressure organizations, and quick information flows utilizing the internet. This will entail constructing on fresh national and global transboundary regulatory frameworks and cultivating a group of policymakers with cutting-edge, multidisciplinary expertise.

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CHAPTER 22

IMPROVING DISSEMINATION OF TECHNOLOGICAL INFORMATION TO FARMERS

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ABSTRACT:

In order for farmers to produce, they need knowledge on the newest varieties, shifting weather patterns, crop production methods, and enhanced agronomic practices. Regardless of their agro ecological region, information technology is essential in ensuring that farmers have access to this information. African farmers have access to information about what farmers across the world are doing because to ICT. As a consequence of this information gathered, farmers are able to better their agricultural practices, which leads to higher yields.

KEYWORDS:

Agriculture, Agronomic, Environment, Fertilizers, GM Crops, Natural Resource, Management.

INTRODUCTION

Improving the dissemination of technological information to farmers is a challenging task; how this task will be accomplished will depend on the country and the farming system in question. This workshop provides an opportunity to relate my experiences in Denmark in comparison to experiences found in other countries. In order to improve farmers' access to and their use of new technologies in sustainable farming, we need solutions that are well targeted to a specific country and farming system [1].

Sustainable Agriculture

The great majority of farmers manage their land in a responsible and sustainable manner and their management practices are generally in line with the traditional notion of sustainability. That is, farmers want to pass on the farmland to the next generation in the same — or preferably, in a better state than they received it. There is no consensus about the definition of sustainable agriculture, even in a small country such as Denmark. The range of views is wide with some people considering only organic farming to be truly sustainable. I do not share this view. Agriculture can remain sustainable through the judicious use of fertilisers and pesticides. Farming will always have an influence on the landscape and the environment, but land can be farmed without degrading soil resources or causing excessive nutrient run-off to the environment. This can be achieved by combining experience and common sense with the application of new technology and research results. Countries have different ways of defining "sustainable agriculture". In Denmark, farmer organisations have developed guidelines on how to achieve environmental sustainability at the farm level while maintaining economic sustainability. Codes of good agricultural practice provide practical guidelines to farmers. The main objectives for codes of good agricultural practice are: [2]–[4]

- To produce high quality food and fibre.
- To use sustainable and profitable production methods,
- To reduce adverse effects on the environment,

- To use ethically justifiable production methods.

The purpose of the guidelines, disseminated through extension services, is to help set standards for individual farmer's management practices. In addition to the codes of good agricultural practice, these practices are also influenced by various government regulations on sustainable farm management. Adopting sustainable farm management practices often requires farmers to make investments. In some cases, these investment costs can be covered through higher prices for their products at the market, but this can occur only if the consumer is aware of the shift to a more sustainable production method and is willing to pay a premium for such products. Farmers, however, are still not successful at getting this information across to consumers. When farmers do a good job in improving their farm management practices, they should inform the public about it. So it is important to improve communication [5].

New technologies available to farmers

Farming methods are undergoing significant technological changes. New government regulations and the demand for more advanced and labour-saving technological solutions are among the driving forces behind the change. To give a practical example, some of the important changes on my own farm in the past ten years include:

- Animal waste storage capacity increased to one year,
- Manure spread while crops growing and better spreading equipment used.
- Total plant nutrient balance calculated.
- Nitrogen and phosphorous content in animal feed minimized.
- Pesticide use optimized with help of a computer programme.
- Pesticides sprayed at the optimal time
- Better spraying equipment used and spraying equipment cleaned in a safe place.

The choice of farming technologies will continue to increase in the future. One problem, however, is the price of new technology, which is often high. Adopting new technologies can thus require making significant investments and farmers are only willing to invest money when it is profitable for them to do so. This can require expanding the scale of the farm operation through buying more farmland or livestock. Thus new technologies are a major driving force behind structural change resulting in fewer and larger farms, more machinery used on farms, and less manpower needed to run the farm [6], [7].

DISCUSSION

How to improve the dissemination of information we have now at our disposal excellent means of compiling and disseminating information. Satellite communication, computer technology and the Internet are examples of information dissemination tools. New technologies and opportunities are developing so quickly that we can be sure of only one thing: that tomorrow there will be still more information technology available. About 50% of Danish farmers are currently connected to the Internet. This share is increasing rapidly and in the future nearly all farmers will be connected [8], [9]. This development is about to revolutionise the traditional dissemination of information as most farmers will be able to obtain information through the Internet. For example, farmers will be able to look up information on new legislation and regulations, engage in professional debates with other farmers and advisers, participate in electronic conferences and discussion groups, and fill in applications and requests on-line.

These new developments do not necessarily make it easier for the advisory service to help farmers as it is not just the quantity of information that matters. Farmers can be flooded with information that is biased, irrelevant or motivated by commercial interests, creating confusion as they try to find the "right" information. The main challenge is the transformation of information into relevant and practical know-how. First, farmers must receive a good basic education that enables them to ask the right questions and search for answers in the right places; − second, we need independent research institutes to develop and test new technologies; − third, the advisory service network must remain as an independent and credible source of guidance and information for individual farmers. Some farmers will certainly use the Internet actively to build their personal networks by, for example, joining discussion groups that include farmers in other countries. In the coming years, however, most farmers will continue to prefer human contact because that is the easiest and most pleasant way to convert basic information into practical know-how [10]–[12].

CONCLUSION

Sustainable agriculture implies that all farmers understand what sustainable agricultural practices are and that they apply them. Although the trend is increasingly towards commercialization of dissemination of information, farmer organizations and governments continue to have the biggest responsibility for helping farmers choose appropriate farming practices. Appropriate farming practices are those which at once contribute towards making the agriculture industry more sustainable as well as contributing to the farmer's personal success that is his income and working conditions. In a world where government and the general public have placed so many demands and restrictions on farmers, government must take an interest in and financially support an efficient information service geared to the farmers

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CHAPTER 23
SUSTAINABLE AGRICULTURAL PRODUCTION SS BEING IMPLEMENTED

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ABSTRACT:

The United States Department of Agriculture Area Studies Project was created to assess the factors that influence adoption for a wide range of management strategies across various natural resource regions and to characterize the extent of adoption of sustainable nutrient, pest, soil, and water management practices. The research included administering a thorough field-level survey to farmers in 12 U.S. watersheds to collect information on farming techniques, input use, and the characteristics of the natural resources used in farming. Certain regions were chosen for examination in addition to the combined-areas analysis to highlight how the outcomes of the aggregate and area-specific models varied. The value of field-level natural resource data for assessing adoption at both the aggregate and watershed levels was explored using the survey's distinctive sample design.

KEYWORDS:

Agriculture, Environment, Fertilizers, GM Crops, Natural Resource, Management.

INTRODUCTION

Several initiatives from the US Department of Agriculture promote the adoption of methods and tools that save resources and lessen the flow of potentially hazardous chemicals into the environment. The majority of initiatives depend on voluntary methods to encourage the adoption of sustainable agriculture techniques, including technical support, teaching, demonstration, and cost sharing. These efforts have had varying degrees of success in influencing the spread of the targeted technology. This study details an attempt by the USDA Economic Research Service to identify the environmental, human, and policy variables that impact the adoption of sustainable technologies and how these influences vary among cropping systems, geographical areas, and technology types.

The USDA Area Studies Project included administering a thorough field-level survey to farmers in certain American watersheds to collect information on farming techniques, input use, and the features of the natural resources used in farming. In Caswell et al., the project is fully discussed. Ten of these watersheds were chosen because they had enough data to provide statistically accurate estimates and were thought to have potential issues with water quality brought on by agriculture. The goal of the ERS analysis was to apply an uniform methodological framework and the whole collection of data to examine the barriers to the adoption of certain agricultural techniques that might prevent or lessen environmental harm.

Moreover, the survey's distinctive sample design was utilized to investigate the significance of field-level data on natural resources for assessing adoption at both the aggregate and watershed levels. We analyzed the adoption of technology and practices in four important management categories: nutrients, pests, soil, and water, using the same unified econometric methodology and set of core variables [1], [2].

DISCUSSION

Adoption Behavior Theory

On the economic theory of technology adoption, there is a wealth of literature. The development of pollution-reducing devices requires a knowledge of the factors that influence acceptance since the location and timing of usage will determine how successful the technology is. In addition to the use of conventional inputs like agricultural fertilizers and chemicals, the adoption of technology for natural resource management and conservation is taken into consideration. Examples include soil conservation, integrated pest management, soil nutrient testing, and irrigation management. The choice to accept new technology marks a substantial change in a farmer's production plan, while choices about how much traditional input to use are made on a seasonal or yearly basis. Adopting new technology is similar to making an investment choice. Although the option may have significant upfront fixed costs, the advantages will be seen over time. The initial expenditures can include the cost of investing in new equipment and learning the best methods for using technology on the farm. The non-financial costs of change could seem quite large to a producer. A person's opinion of a new technology is subjective, and it may evolve when a farmer learns more about it via the media, the extension agency, or neighbors who have already embraced it. When a new technology first becomes available, there is sometimes a lot of ambiguity about how well it will work in a given environment. Before the technology works successfully in the local manufacturing context, significant customization may be required. The risk and expense associated with adoption decrease over time when certain local farmers use the new technology and acquire expertise. If they find that the technology simply does not perform effectively given their resource constraints, or if the scale or nature of their farm business is incompatible with the technology, some farmers may decide not to implement it at all [3], [4].

A new innovation or technology will alter the marginal rate of input substitution in a manufacturing process. These modifications could seem significant to a prospective adopter. Early adoption studies were predicated on the idea that people were reluctant to change and that opposition needed to be overcome. But, the distinction between a producer who is unable to adopt and one who is reluctant to adopt is clear. In other words, nonadopters can be divided into two categories: those for whom adopting a new technology would not be more profitable than continuing with their current methods, and those for whom adopting a new technology would be more profitable but who decide against doing so due to other obstacles. For these two populations, distinct adoption-promoting policies would need to be developed. The current economic theory of adoption is predicated on the idea that a prospective adopter would choose based on how to maximize predicted utility while taking into account pricing, regulations, individual traits, and natural resource assets.

A certain technological decision is taken, which results in a degree of input utilization and profit. Producers would not be required to take into account advantages that flow mostly outside of the farm when deciding whether or not to implement a conservation technique. Instead than boosting production on-site, many of the techniques that are suggested aim to lessen environmental problems that occur off-site. If the profits are not seen by the farmer who suffers the expenses, the voluntary adoption of preferred technologies may not take place even though the overall benefits of switching to these technologies considerably exceed the costs. As no two farms or farmers are the same, there will be variations in whether or when a certain technology is implemented. The quality of the land that farmers own and their capacity to comprehend and adopt new ideas will vary. The farmer is aware of these elements and makes an assessment of the anticipated benefits of adoption using this information. The pattern of practice adoption will be determined by the distribution of the underlying diverse elements.

The adoption trend might be localized when one of the heterogeneous elements is connected to features of natural resources.

Understanding how farmers choose their production methods can help policymakers enhance water quality or other environmental assets by encouraging the use of conservation technology and sustainable management techniques [5], [6]. The Area Studies Project was created with the purpose of characterizing the level of adoption of techniques for managing nutrients, pests, soil, and water as well as evaluating the variables that influence adoption for a variety of management methods across various natural resource areas.

The Area Studies survey instrument was created to gather comprehensive data on cropping systems, agricultural production technology, and chemical usage on individual fields as well as whole farms. The owner of the property was spoken to personally. On the scale of the enterprise as well as the crops and animals produced, information was collected. The survey year's cropping and tillage techniques, as well as those from the two years before, were covered in the questions. Data on the different soil conservation techniques used throughout the three years was also gathered. Farmers were questioned about their involvement in government programs and if they had crop insurance.

The management of fertilizers, pests, soil, and water was covered in a broad variety of questions posed to farm owners. Information was acquired on soil tests, manure applications, the source of the fertiliser, and the quantity of fertiliser used. On their employment of biological and chemical pest management techniques, farmers were questioned. The survey's irrigation and drainage part included questions on the irrigation technology employed, the water supply, the drainage systems, and who gave the operator irrigation timing advice. The farm owner's age, education, years of experience, tenure status, and the number of days worked off the farm were all recorded as demographic data. Just experience was employed in the study since age and experience were closely associated. Yet, since we were unable to collect information on costs and pricing, the economic analysis was severely hampered.

The main goal of the econometric research was to pinpoint the main barriers to resource-conserving technologies' adoption in agriculture and to compare these barriers across various technologies, cropping systems, and geographical regions. If the usefulness or profitability of adopting the new technology outweighs the disadvantages, we anticipate that the farmer will do so. Most of the time, the choice to accept a new technology is a simple yes-or-no proposition. In these situations, we estimated the likelihood of adoption using a binomial logit model. We utilized a multinomial logit model when a farmer had to choose amongst numerous competing options. While we are aware that there are more complex empirical approaches available, none of them could be used to compare findings across technologies and fields, which was the main driving force for our work, owing to data restrictions.

The adoption of soil conservation techniques such as conservation tillage, crop residue use, chiselling and subsoiling, contour farming, conservation cover or green manure crops, rotational grass and legumes, strip cropping, terracing, grassed waterways, filter strips, grade stabilization structures, and critical area planting was examined. The pest management techniques that were investigated included the utilization of crop residue destruction, biological controls, pheromones, and professional scouting. In addition to the more conventional method of rotating legume planting, we added contemporary nutrient management techniques including N-testing, split nitrogen treatments, and micronutrient utilization. Both the choice of irrigation technology and the decision to irrigate were examined. In order to examine the impact of human capital, policy, farm, and natural resource features on the adoption of various management strategies, each adoption research employed the same fundamental set of variables. For each study, the data from all the watersheds were merged, and just a few specific locations were chosen to examine any possible aggregation bias [7], [8].

By increasing the effectiveness of chemical or mechanical inputs used in agricultural crop production, the Area Studies investigation focused on technologies that help preserve natural resources. Several of these environmentally friendly systems combine information technology and chemical inputs with more intensive management techniques. It could be able to lessen or minimize the negative environmental effects of agricultural production while simultaneously increasing farm productivity and profitability by using traditional inputs more wisely. All locations were merged to study each of the four key management categories, and just a few places were chosen to determine if combining all areas would overlook significant site-specific aspects. We evaluated a wide range of agricultural management approaches, and a number of characteristics emerged as significant determinants for the adoption of conservation technologies.

The premise that landowners would be more willing to invest in novel practices than renters led us to first predict that ownership of the surveyed field would have a greater influence on practice adoption. Yet, the majority of the activities examined in this research weren't structural. Renters were less likely to invest in irrigation systems than owners, despite the fact that these technologies had large upfront costs. A livestock-related firm was more likely to employ manure instead of information-intensive nutrient management techniques like soil testing, split nitrogen application, or micronutrient utilization. If livestock enterprises are compelled to follow nutrient-management plans that include limitations on applying manure to land, this anticipated outcome may alter in the future. All of the pest and nutrient management measures that we took into consideration were used much more often after irrigation investment.

The main means of transportation for chemicals that leave a root zone and go to ground or surface water is water. Thus, it is anticipated that water and chemical control would work well together. The adoption of chemical management tactics by such farms may be less successful than for farms that are irrigated since water management is less predictable for agricultural output that is rain-fed. Participation in government programs and the use of professional guidance both had significant beneficial effects on the uptake of almost all recommended soil, pest, and nutrient management methods. While a number of USDA programs required conservation compliance before recipients could get benefits, the Area Studies Survey was carried out. To be eligible for the programs, farms had to implement conservation techniques if their erosion potential was higher than a certain level. The choice to employ the collection of practices examined in this research seems to be significantly influenced by the availability and utilization of technical support [9].

A regional dummy performed as well as the more exact resource characteristics in the combined-area model for the majority of activities. The fact that dummies often absorb numerous indistinguishable effects should be anticipated to explain why their larger relevance in the combined-area model. Nonetheless, the resource factors were often major adoption drivers in the single-area models, supporting the notion that site-specific data is essential for modeling and explaining resource-conserving initiatives. The key resource features anticipated to affect the adoption of all technologies in all watersheds may not have been reflected by the resource metrics we selected. We didn't anticipate that the general resource attributes we employed would have a significant impact on the pest-management technique a farmer chooses. In this scenario, a crucial resource attribute is an estimate of insect infestation. Nevertheless, we had anticipated that creating site-specific indices would enhance the overall modeling of adoption for techniques related to managing soil, nutrients, and water.

We come to the conclusion that the modeling efforts at the single-area or watershed level benefit from the use of field-level resource data. In addition, rather than being a universal index, the selected index should take into account the local environmental conditions as well as technology. For instance, slope, a single variable, has more explanatory power than the index of soil productivity when modeling the choice to irrigate. The Area Studies Survey included site-specific resource information for a number of reasons, one of which was to evaluate the impact of resource features on adoption. These facts were collected in order to establish a connection between the economic, physical, and transport destiny models. It is still unclear if the micro data are helpful to evaluate aggregate models since that study has not been finished. The watershed level site-specific resource data is crucial for both production-impact and environmental-impact assessments.

The aggregation across several watersheds is represented by the combined-area models. These findings can be deceptive from a policy standpoint. In the Susquehanna River Basin, for instance, a farmer's experience and whether he or she works off-farm have large positive impacts on the adoption of soil-conserving methods, while the findings of the aggregate model reveal no significant benefits of these characteristics. Based on site-specific data, a policy choice to promote the use of conservation technology in Susquehanna would be more effective. On the other hand, sometimes a single region predominates in the combined-area model findings. The information enables reasonably accurate environmental policy modeling to be used for targeting. The unified modeling technique we utilized demonstrates that crucial information might be lost during the aggregation phase. It's possible that incentives created to address elements in the aggregate model are only useful in one area and harmful in another. We acknowledge that all policies have this averaging difficulty to some degree. Yet, the size of the disparities across the Area Studies areas was made clear by our comparison of the combined-area and single-area models [10]–[12].

CONCLUSION

The data set from the Area Studies Survey provided a rare chance to evaluate the value of performing a field-level survey connected to site-specific resource features. A variety of studies were possible due to the data set's richness. Nevertheless, the analysis was severely limited by the absence of cost and pricing information. An Area Studies survey based on field-level features could be most useful in helping to resolve a topic particular to a certain watershed. In order to compare the findings of aggregate and regional investigations, a common modeling framework was used. Resource features have a significant role in producers' choices. Site-specific resource data will also help assessments of agricultural systems. The data generated by the survey may be used to help both physical and economic modeling initiatives. Problems with agricultural water quality are always site-specific. Surveys that aim to obtain national averages are less helpful for analysis than those that sample widely within a particular field. Where feasible, evaluations of environmental issues should be carried out at a scale that is appropriate to that region. The Area Studies Project was successful in creating and carrying out a survey that has improved our comprehension of the adoption of agricultural practices and survey design.

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CHAPTER 24
INTERACTIONS BETWEEN POLICY AND TECHNOLOGY FOR INTENSIVE FARMING SYSTEMS

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ABSTRACT:

The Netherlands has embraced several technical innovations during the last 10 years to fulfill the demands of intensive agricultural systems with regard to the environment. In order to satisfy environmental policy goals for crop protection goods and greenhouse energy efficiency, this research focuses on the arable sector and offers factual facts on the adoption of innovative technology by Dutch agriculture.

Such technologies are essential for achieving sustainable agricultural production practices and increasingly strict environmental policy goals via intensive farming systems. Public policies, which are often backed by market efforts, are the major factors behind the development of incentives for such technology. Regarding the use of crop protection products in arable agriculture and increasing the efficiency of energy use by greenhouses, public initiatives have helped to achieve significant environmental gains.

KEYWORDS:

Greenhouse, Technology, Energy, Crop Protection, Agricultural Productivity.

INTRODUCTION

This section, which follows a basic review of Dutch agriculture and the environment, is divided into two parts: the arable sector and greenhouses. The first case study looks at how rules to limit the use of crop protection agents have affected arable productivity. It looks at how the agriculture industry responded to fulfilling the demands of the Multi-Year Crop Protection Plan. Links are shown between the adoption of more sustainable agricultural techniques and governmental policy.

The use of existing technology has helped policy goals be achieved. In the second case study, greenhouse horticulture output is analyzed, along with the adoption of technology to increase energy efficiency in this very energy-reliant industry. These innovations demonstrate how crucial it is to increase energy efficiency in order to fulfill the obligations set out in the MultiYear Agreement on Energy in Horticulture under Glass.

A few conclusions are then reached in relation to methods for creating and implementing innovations in intensive agricultural systems. Moreover, pertinent information and indications about the effectiveness of the inputs utilized in intensive farming systems are included. An effective instrument for accomplishing policy goals is seen to be a collection of agri-environmental indicators, which might track advancements in the use of more sustainable technology in agriculture. The emphasis of the workshop is on environmental issues that would necessitate the adoption of technology since the workshop's concentration is on technologies for sustainable agricultural systems. As they are less reliant on technical advancements and primarily depend on the adoption of well-targeted public policies that represent society preferences, other problems are not fully investigated [1].

Environment and agriculture in The Netherlands

The Netherlands is one of the smaller nations in the EU; it is larger than Belgium and Luxembourg but somewhat smaller than Denmark. The nation has a total area of 41 026 km2, and over half of it is utilized for agriculture. With 15.6 million people, it is one of the most densely inhabited countries in the world [2]. Almost 80% of the land area and about 40% of the inhabitants are in the rural countryside. Land is a finite resource utilized for a variety of competing purposes, including agriculture, housing, infrastructure, industry, and services. It is also used for leisure, nature preservation, and industry and services. Due to increased competition among these alternative uses, the price of agricultural land is typically rising and now surpasses NLG 50 000 to 60 000 per hectare in much of the nation. Prices rose in the 1990s mostly due to the increasing demand from non-agricultural activities and the need for agricultural land to satisfy nitrogen control measures. In terms of agricultural export surplus, the Netherlands is second only to the United States; around 80% of exports are made to other EU members. With one of the highest production levels and one of the most intensive farming practices, it uses a lot of agrochemicals.

This tendency is a result of internal and external factors. The limitations on the amount of agricultural land available on a national level have provided incentives to gradually improve the intensity of agricultural output. The Common Market has further facilitated unrestricted internal commerce inside the European Union and given incentives to boost manufacturing in areas with a competitive edge. High input utilization is a frequent characteristic of intensive agricultural systems with high levels of output. A high level of production is produced for each unit of labor given when land, labor, and capital resources are utilised intensively. In these situations, technology is essential for overcoming environmental restrictions. Over 2 million acres of land are used for farming by about 100 000 farms. Around NLG 35 billion worth of agricultural produce are gross each year. The main industry, horticultural production, now accounts for 40% of total gross production value, followed by intensive livestock production and cattle farming, all of which contribute around 25% to total gross production value. A little under 8% of output is on arable land [3], [4].

DISCUSSION

Nitrate and phosphate pollution of groundwater, surface water, and coastal waterways. Over 20% of observations at sandy soils used for agriculture show that the concentration of nitrate in the groundwater surpasses 50 mg per litre; emissions of ammonia and their effects on the acidification of soils, water, natural areas, and forests. Ammonia emissions have decreased significantly throughout the 1990s, mostly as a result of the requirement that manure be applied in a low-emission manner; crop protection product impacts on soil and water quality. The pesticide standards are exceeded in certain pumping stations for some pesticides; emissions of greenhouse gases and potential consequences on global warming. The horticulture industry utilizes roughly 80% of the total energy required by the agricultural industry while occupying less than 1% of the area utilized for agriculture.

Nowadays, agriculture is responsible for 4.5% of all CO_2 emissions, accounting for nearly 11% of all greenhouse gas emissions. The shares for the other emission categories are much bigger. Desiccation of natural regions due to excessive use of groundwater resources, drainage projects, and land consolidation programs. The relative shares for CH4 and N2O are 41% and 33%, respectively. Groundwater levels in the eastern and southern parts of the nation have dropped by up to 40–120 cm as a result of previous land consolidation initiatives; biodiversity and landscape issues, which primarily affect important bird habitats, semi-natural grasslands, and areas with a lot of natural features. The other environmental themes also have an influence on farms or nearby natural areas, even if direct management problems for biodiversity and landscape are not covered here. In the 1960s, for instance, the use of crop protection agents significantly impacted raptors and water birds, but things have since improved [5], [6].

Since the late 1980s, there has been an increase in public awareness of environmental challenges, and legislation has been passed to encourage sustainable manufacturing practices. In the 1990s, environmental management measures were implemented. Examples are sectoral programs to increase the efficiency of energy usage and the Multi-Year Crop Protection Strategy to mitigate the negative environmental consequences of crop protection products. the sector's usage of crop protection products and the gross value added of arable output since 1990. Crop protection products were used much less often, but the gross value added of agricultural output mostly fluctuated from year to year as a result of changes in the price of agricultural commodities. In addition, the quantity of energy used in this industry and the total value gained from greenhouses since 1985. At this time, greenhouses' gross value added rose by more than 50% but their energy use climbed at a slower rate [7].

Use of Crop Protection Technologies

In the Multi-Year Crop Protection Plan from 1991, the goals of crop protection policy were created. Reduced reliance on crop protection agents in agriculture and horticulture, together with the eradication of negative external impacts brought on by their usage, was the key accomplishment for the years 1991 to 2000. There are three quantifiable goals. First, the plan contains a long-term, multi-objective focused strategy to lower consumption levels, with a decrease in total crop protection product use from 1984 to 1988 to be attained by the year 2000. Next, emissions must be decreased. Reduce dependency on the usage of crop protection agents is the third and final goal. It's important to keep in mind the following: − By 2000, the usage of crop protection products must be much lower than it was during 1984 to 1988. Crop protection product usage reduction policies are developed based on product group. There has to be a 56% reduction in the overall use of crop protection agents. More precisely, a collection of active substances has created the reduction objectives. Nematicides demand the biggest reductions. There has to be a 40% reduction in the usage of herbicides, insecticides, fungicides, and other active agents. For each agriculture industry, reduction goals are established. − Crop protection product usage reduction goals must be combined with lowering the products' environmental impact. Reduced dependency on the use of crop protection products; reduction of air emissions by 50%; reduction of emissions to soils and groundwater by 75%; and reduction of emissions to surface water by 90%. For this item, no precise reduction objectives are established [8].

Increasing greenhouse energy efficiency

Strong output growth over the last several decades has led to a rise in greenhouse energy usage, which now accounts for nearly 60% of all agricultural energy use in the Netherlands. It accounts for more than 85% of all natural gas used in agriculture. Natural gas used in greenhouses costs around 26 cents per cubic foot. Charges associated with the energy strategy directed for greenhouses are included in this pricing. Prices, however, are less than what consumers pay since significant customers, such as the chemical sector, the manufacturing of aluminum, and greenhouses, are given a reduction. The industry of greenhouses is regarded as a significant consumer of natural gas. The evolution of fuel oil prices on the global market has an impact on price development throughout time. Any assets that use more natural gas than 30 000 m3 are subject to the lower gas costs. In greenhouses, energy expenditures make up a significant portion of overall expenses, ranging from around 18% to 13%. The amount of energy consumed per unit of agricultural product is examined in this section together with changes in greenhouse energy consumption, carbon dioxide emissions, and greenhouse gas emissions. This will aid in looking at technological ways to increase energy efficiency, which relates to how much energy is used to generate one unit of a product. Hence, both the amount of output and the consumption of energy have an impact on this statistic. The major goal of policies concerning greenhouse energy usage is to increase the energy-efficiency of horticultural product production. For greenhouse gas emissions, there is no clear reduction goal in place. The Dutch government's energy strategy has been influenced by a Multi-Year Accord on Energy in Horticulture under Glass. The goal of this agreement was to increase energy efficiency by 40% in 1995 as compared to the reference year of 1980. Energy efficiency was predicted to have increased by 50% by 2000 compared to 1980. The industry has been successful in completing the 1995 intermediate goal. Between 1980 and 1995, energy consumption efficiency increased by 40%. The ensuing five years were to see an additional 10% increase in energy efficiency. The ultimate goal of 50% is unlikely to be attained. Meanwhile, it is anticipated that energy efficiency would increase by the year 2010. It ought to have advanced by 65% from the starting point year of 1980 by then [9]–[11].

CONCLUSION

The significance of recording the inputs that farmers employ in achieving policy goals is well supported by data. It raises consciousness about how agricultural methods affect the environment. Such records are seen as a crucial tool for influencing individual farmers' behavior and ultimately advancing sustainable farming techniques. Farmers looking for innovations to satisfy policy needs are given incentives by public policies. The main driver of crop protection product usage reduction in the Netherlands, for instance, has been mandatory national regulations with a wide range of reduction objectives. These policies have also helped to manage the use of crop protection goods. Advanced machinery has been purchased in order to apply crop protection agents and minimize drift. The authorization process changed the active component makeup of those accessible for agricultural use, hence reducing overall utilization. Yet, these technologies must be accessible, and private players are essential in ensuring their availability. New crop protection solutions, for instance, are provided by the chemical sector and enable for much more focused application at considerably lower doses. In greenhouses, similar findings have been observed. The implementation of public policy in this field has also benefited from the accessibility of technology. Innovations are also required for the delivery of technological tools to increase greenhouses' ability to consume less energy. − Indicators of efficiency are important when discussing the adoption of technology by intensive agricultural systems in an effort to achieve environmental policy objectives. Fundamentally, environmental policy guidelines may lead to an increase in production efficiency, for instance, a better use of energy and crop protection goods, thereby lowering costs and boosting gross margins. These metrics enable harmonizing environmental restrictions with individual producers' economic success. Incentives to raise the efficiency per unit of agricultural production, for instance, have been provided through policies to boost energy efficiency.

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CHAPTER 25
WATER'S CONTRIBUTION TO AGRICULTURAL DEVELOPMENT

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ABSTRACT:

Water is an essential component of agricultural productivity and is crucial to food security. Twenty percent of all farmed area is used for irrigation agriculture, which generates forty percent of all food produced globally. The primary source of revenue for the federal and state governments is agriculture. The country's government receives significant funding from increasing land income. Also, the transportation of agricultural products helps the Indian Railways make money, which aids the government in making money. In agricultural regions, too much water may hamper plant development, change how the soil works, and raise the danger of nutrient runoff. On the other hand, crops' capacity to absorb nutrients from the soil might suffer greatly from a lack of water.

KEYWORDS:

Agricultural, Agricultural Productivity, Crop, Development, Water.

INTRODUCTION

Perhaps, agriculture has done a great job of snatching up the majority of the world's usable water supplies. The socioeconomic and environmental justification for this sector's acquisition, nevertheless, is now under scrutiny. The framework and a collection of tools presented in this study may be used to analyze these problems and make their justifications clear and understandable. It is more of a "advocacy" brief than a field handbook. In order to question and alter the principles of the prevalent technocentric perspective of the utilization of water resources, it aims to combine economic and ecological data and arguments. If the world's population is to be sufficiently fed without further deterioration and loss of the planet's essential ecosystem functions, a new and more suited strategy to the distribution of water resources is required. Significant improvements must be made to water productivity, and price structures and economic cost-benefit analyses might be important in this process. These economic measures won't be enough on their own, though. In order to promote a more equal allocation of resources and to reduce possible international disputes across "shared" water basins, they will need to be supported by technology advancement and institutional improvements [1].

Due to its distinct qualities, water is allocated and used by agriculture as a resource in different ways. Water used for irrigation in agriculture is dependent on the availability of land resources. This is a summary of water's economic properties and their ramifications. The argument for better water distribution to the agricultural sector and for better distribution within the agricultural sector is then made. Reevaluation of sectoral water allocations is necessary due to the increasing water shortage and demand for non-agricultural uses of water. Irrigated agriculture makes a significant contribution to domestic food security and the reduction of poverty in emerging nations. Hence, ensuring that agriculture receives sufficient water allocations is necessary for the attainment of these goals. Irrigated agriculture must be a cost-effective method of fulfilling specified political or social goals, such as food security or poverty reduction, and all externalities must be taken into account in the pricing mechanism in order for such allocations to be justified. In order to utilize irrigation water and current irrigation infrastructure more effectively, the agricultural sectors of emerging nations need to better allocate irrigation water. Reallocation is also necessary to lessen the negative environmental effects of irrigation as well as waterlogging and salinization of irrigated land. The strategies for obtaining better allocation to and within the agricultural sector are described in the following chapters. Using a functional ecosystem viewpoint for water resources, which supports water resource management at least on a watershed size, is fundamental to the suggested strategy. This is seen at the chapter's conclusion.

ECONOMIC FACTORS RELATING TO WATER

Agriculture, industry, and household use water to produce commodities and services. The amount and quality of the water that is accessible affects how many of these products and services are provided. Water management and distribution include taking into account its special qualities as a resource. They are briefly covered below.

It is possible to pump water from underground reservoirs or to draw it from sources of surface water that have been stored, such as rivers. It is sprayed, dripped from nozzles, flooded into channels, or sprayed over crops. Precipitation provides water to crops as well. Water evaporates, permeates the earth, or flows off as surface water. Some of the water that percolates deeper into the soil and replenishes groundwater is absorbed by plants. Agrochemicals, salts leached from the soil, and effluent from animal feces may all contaminate this water. Yet, when water penetrates the ground, pollution may be reduced by sorption, ion exchange, filtration, precipitation, and biodegradation. Pollution may also come from aquifers. Pockets of impurities or organic materials inside the aquifer may leak pollutants into the groundwater. There is a two-way relationship between surface and groundwater resources when river levels are low and groundwater levels are high because groundwater may replenish river levels[2].

It is difficult to regulate or stop the usage of water. The removal of water from the hydrological system is a common practice. The majority of the water extracted is often not consumed. Consumption of water is limited in its application. Consumed water cannot be used for other purposes since it is held in plants, animals, or industrial items. Nevertheless, the majority of the water extracted is not used right away; instead, it is returned to the water system for later use in another place. Water in return flows may evaporate and return to the hydrological system as gas, percolate into aquifers, or rejoin the surface water system farther downstream. Hence, only within a limited geographic and temporal context are water withdrawals exclusive within a comprehensive view on water consumption. Moreover, water may be utilized in-stream without being taken out of the hydrological system. These applications often involve little to no water consumption, but they do influence where and when water is accessible to other users.

A "bulky" resource is water. This indicates that it has a generally low economic worth per unit of weight or volume. As a result, unless a high marginal value can be produced, its transportation involves a high cost per unit of volume and is often not economically feasible across large distances. As compared to the little economic value put on using an extra unit of water, the expenses of abstraction, storage, and any kind of transportation are often significant. This may lead to the creation of location-specific water values. Water also has the additional quality that its supply cannot be easily predicted; it is governed by a number of processes, including water flow, surface evaporation, and ground percolation. The supply of surface water is greatly influenced by the climate. As a result, the supply is unpredictable and inconsistent. This may prevent certain water usage and reduce the value of water in other applications. Some applications may be prohibited by water quality, while others may not be impacted at all.

Demand for water for irrigation has characteristics that relate to amount, location, timing, and quality. Large quantities of often poor-quality water are typically needed for irrigation. Contrastingly, home usage of water, for instance, only needs small amounts of high-quality water. Large amounts of water that are needed for irrigation must often be delivered a fair distance to the field. Canals and pipelines may be used to transport surface water, whereas tubewells are used to draw groundwater. When it comes to scheduling, the need for irrigation water may continue into the dry season for repeated cropping when sufficient supplies are available throughout the growing season. Peak surface water flows do not often correspond with peak irrigation water demand. This necessitates the requirement for storage capacity, which may be provided by naturally existing waterbodies or specifically built dams. Despite the poor quality of water needed for irrigation, it cannot be used due to excessive saline levels, and tainted sources may lower the quality of the crop. Agriculture is connected to problems with water quality. Leaching of animal waste effluent, particularly from extensive livestock agriculture, may seriously threaten water quality. Both irrigation water runoff and precipitation runoff from arable land have the potential to contaminate surface waters with nutrients, pesticides, herbicides, and salts that have leached from the soil.

THE OVERPOWERING USE OF AGRICULTURAL WATER

For the agricultural productivity of many emerging nations, irrigation is essential. In developing nations, irrigated land produced two-fifths of the crops grown between 1997 and 1999, and it made up roughly one-fifth of the total area under cultivation. This data' discrepancy is due to the large agricultural yields and repeated cropping made possible by irrigation. Irrigation is especially important to developing nations since, between 1997 and 1999, 59 percent of their grain output was done thus. To meet the needs of a growing population and rising income, food production is rising in emerging nations. Increased imports and higher productivity of rainfed agriculture will both contribute to meeting part of this need, but irrigated agriculture will contribute significantly.

Except for Europe and North America, agriculture is the major use of water worldwide. 70% of water withdrawals and 93% of global water consumption in 2000 were attributed to agriculture, where consumption is defined as withdrawals less returns flows and evaporation. Contrast this with industry, which in 2000 accounted for 20% of withdrawals and 4% of global consumption, and home usage, which accounted for 10% of withdrawals and 3% of global consumption (FAO, 2002b). Compared to water demands for other human needs, agriculture has a high water need. The average person need 3 liters of water every day.

It is often argued that the prices charged for irrigation water do not adequately inform farmers of the resource's limited availability. Due to entrenched interests, political obstacles to pricing reform, practical challenges in measuring and monitoring water consumption, and societal conventions, such as the belief that access to water is a fundamental human right, this scenario may continue. The efficiency of irrigation systems and water utilization may suffer as a result of these cheap prices. As a consequence, there is water waste at the farm level, limited capacity for upgrades or investment in new infrastructure, and inefficient operation of the current irrigation systems. Additionally, it is said that subsidies for irrigation water favor the rich and increase disparities in rural regions' access to resources and income distribution [3].

Surface water or groundwater are the sources of irrigation water. The expansion of the irrigated area beyond what surface water alone can sustain is made possible by the use of groundwater for irrigation. Moreover, it helps the soil to drain. At times of low flow, groundwater may augment surface water, allowing surface water to be used for other purposes. Also, it serves as the only water supply for agriculture. For instance, in India, one-third of the nation's food output comes from the more than half of irrigated land that is supplied by groundwater. Groundwater has many advantages over surface water, including the ability to be stored in aquifers for years with little to no evaporative loss, the ability to be withdrawn close to the point of use, and the ability to be made instantly available on demand, which enables more timely irrigation water applications. Nevertheless, dissolved salts in groundwater may be hazardous to plants and cause salinization of the soil. Salt concentrations may be diluted to levels appropriate for use in irrigation by mixing groundwater and surface water. Surface water for irrigation is kept in either natural or artificial reservoirs made via the building of dams. Dams are often built to store water for flood control, hydroelectric power production, agriculture, or any combination of these. Conflicts may, however, occur when dual-purpose dams are built to store water for both hydroelectric power production and irrigation, since the demand for irrigation water rises during the dry season beyond the need for electricity. The definition of the necessary storage capacity and the timing of water discharges become challenging as a result. For dams that are also intended to defend against flooding, the issue is much more complicated. Effective flood management requires that storage capacity be left empty, yet efficient water storage for irrigation and the production of hydroelectric power demands that storage capacity be maintained as full as feasible. Despite the possibility of conflict, providing storage space for irrigation in addition to other applications might be beneficial. Making major dam constructions economically feasible may need the combined value of storage capacity for a variety of uses. Also, the availability of storage space for non-agricultural applications may act as a backup plan in the event that irrigation projects don't provide the anticipated levels of uptake and financial returns, for example, by opening up the possibility of expanding power generation capacity [4].

Engineers and agronomists have historically been in charge of designing and carrying out irrigation projects. A wider interdisciplinary view on irrigation is developing in response to a commitment to a more sophisticated approach to water management. This strategy takes into account the larger economic, social, cultural, and environmental effects of irrigation projects. Yet, putting this concept into practice in the creation and administration of irrigation projects and programs continues to be difficult. Yet, by properly implementing the functional approach to water management that is here proposed, this difficulty may start to be solved.

The demand for water for non-agricultural uses is rising as a result of economic growth, population growth, and increased urbanization. The supply of bulk water for irrigation is under pressure from the demands of other water-using sectors, restrictions on further water resource development, and poor maintenance of existing irrigation infrastructure. Growing urban water needs represent a particular danger to agriculture since, in cases of potential conflict, urban demands take precedence over rural ones. This is due to the fact that new urban supplies must originate from more far-off sources, current urban supplies are often contaminated, and urban water supplies have greater economic advantages than rural ones. Water withdrawals for domestic and industrial usage tripled globally between 1950 and 1995, while those for irrigation only increased by half during that time. Between 1995 and 2025, the demand for water in emerging nations is expected to climb by 100% in the non-agricultural sector, but only by 12% in the agricultural sector. It is the "first time in global history," according to Rosegrant, Cai, and Cline, that the absolute rise in non-agricultural demand for water would outpace that of agricultural consumption. As a consequence, agriculture's proportion of total water use in developing nations will decline from 86 percent in 1995 to 76 percent in 2025.

As non-agricultural water use rises, the ability to create new water sources is being constrained. These two causes are working together to make water more scarce, and as a consequence, water will unavoidably move from agricultural usage to higher-value domestic and industrial applications. The depletion and contamination of surface water resources utilized by farmers and rural families occur when urban regions appropriate water supplies from rural areas. In parts of India and the Philippines, water supplies have been permanently or seasonally diverted from huge irrigated regions to fulfill urban demand without paying farmers compensation for the agricultural production losses that resulted. It is anticipated that the demand for water from households and industries would rise, making irrigation water more scarce.

DISCUSSION

Objectives for Irrigation and Agricultural Development

Water distribution to agriculture has historically been justified by governments and donors on the basis of food security and rural development. After a quick summary of pertinent components of the global consensus that has developed in water management policy, they are addressed in the sections that follow.

Food Safety

Compared to rainfed agriculture, irrigation allows for higher agricultural productivity. Irrigation increases agricultural output, which is crucial for both national and international food security in certain nations. It is possible to achieve national food security either by working toward food self-sufficiency or by combining local production with imports. Self-sufficiency in food was once a common goal, and some countries still strive for it. It generates foreign currency savings, shields local producers and consumers from market volatility, assures the availability of food in rural areas, and supports a political sense of national security. It does, however, have drawbacks. A self-sufficiency strategy may enhance water allocations to agriculture in dry regions at the cost of residential and industrial water consumption. This may result in over-extraction of groundwater resources. Moreover, because of the vulnerability of food supplies to inclement weather, any shortages must be filled via imports, using up scarce foreign currency resources. Several nations have moved toward an ideal of food security that is partially supported by imports in response to numerous challenges, such as growing water scarcity, decreased availability of agricultural land, and industrial expansion. To ensure that imports are made under fair trade conditions, proper regulation of the global food trade is necessary for the successful achievement of this goal [5].

As the world's population and standard of living both expand, so does the need for food. Demand pressure is mostly felt in emerging nations, where it is anticipated that from 1999 to 2030, global demand for agricultural goods would grow by an average of 2% year. A change in nutrition that is taking place in emerging nations as a consequence of rising income, urbanization, and shifting tastes has an impact on food demand as well. More fruit and vegetables, animal products, and less grain are typically consumed by populations in developing nations. The consumption of meat is expected to rise by 44% per person in emerging nations from 1997–1999 to 2030. This is leading to a rise in demand for cereals for animal feed, along with a general transition in animal agriculture from extensive to intensive systems and the poor efficiency of meat production. Half of the anticipated 70 percent increase in grain consumption in developing nations between 1997/99 and 2030 will be met by cereals used as animal feed. In order to grow grains, irrigation is crucial. For instance, irrigated land produced about 60% of the grain consumed in developing nations during the 1997–1999 period. It also helps to fulfill the rising demand for other meals, too.

To varying degrees, greater agricultural output will counter rising food demand at the national level in emerging nations. In the years 1997/99-2030, a 61-percent rise in yearly grain output is anticipated. The majority of this growth will come from irrigated agriculture, with the exception of sub-Saharan Africa and South America. Irrigated agriculture will provide 57 percent of the extra 256 million tonnes of wheat that will be produced in developing nations by 2025 compared to 1995. With both the extension of the cultivable area beyond what is achievable with rainfed agriculture and improved crop yields, irrigation boosts agricultural productivity. According to the FAO, increasing yields, crop area expansion, and cropping intensity will account for 70% of the rise in agricultural output that is expected to occur in developing countries between 2000 and 2030. The use of irrigation in conjunction with high yielding cultivars, fertilizers, and herbicides has complementing advantages that boost yields in addition to reducing or preventing crop water stress. In 1995, the combined yields of developing nations generated with irrigation outperformed those produced with rain by 115 percent, and by 150 percent in sub-Saharan Africa, West Asia, and North Africa. Even if yields for irrigated grain production are rising by 1.2 percent annually in developing nations, this is a slower pace than it was between 1982 and 1995 [6].

In developing nations, gains in grain yields from 1997/99 to 2030 are anticipated to be comparable in proportion to those from rainfed crops. Nevertheless, bigger absolute gains will occur during this time due to irrigated cereals' higher beginning yields. Between 1997/99 and 2030, developing country average weighted yields for irrigated cereal production are projected to rise by 1.4 tonnes/ha, compared to a rise of 0.5 tonnes/ha for rainfed cereals. So, it is anticipated that irrigated agriculture would greatly improve future food production via high and rising crop yields.

Irrigation not only boosts output but also makes it possible to expand the area under cultivation. Irrigation was employed on 21% of the total arable land in developing nations in 1997–1999, albeit there was significant regional variation. Just 2 and 9% of the fertile land in sub-Saharan Africa and Latin America, respectively, was irrigated, compared to 39 and 31% of the arable land in South and East Asia, 30% of the arable land in the Near East, and 40% of the arable land in North Africa. It is anticipated that emerging nations would see the most irrigation area expansion. The largest absolute gains in irrigated arable land are anticipated to occur in Asia from 1997 to 2030.

While these regions will see significant proportional increases, the growth of irrigated arable land is predicted to be modest in sub-Saharan Africa and South America. Between 1962 and 1998, developing nations had an average 2% annual growth in the area irrigated, bringing the total area under agriculture to 100 million hectares. Nevertheless, it is anticipated that from 2000 to 2030, the net growth in irrigated land in emerging nations would be 60% lower than the net increase seen from 1960 to 2000. The projected growth rate for the irrigated area is one-third of what was attained between 1960 and 2000. In emerging nations as a whole, the increase of arable land used for rain-fed agricultural production will somewhat offset the slowdown in the development of irrigated arable land. As a result, the proportion of the total cereal land that is irrigated in 2030 will be largely stable from 1997–1999. Irrigation will cover 22% of the total arable land in emerging nations.

Rising temperatures in dry places and increased climatic unpredictability are projected to have an impact on agricultural productivity in emerging nations. It will probably lead to more regional variations in crop output and food availability, which will have an impact on poor people's earnings and food supply in particular, as well as more national susceptibility to food insecurity. Even in the next several decades, the consequences could be seen strongly in certain areas. By 2020 or 2030, for instance, climate change may result in a 2% to 3% drop in grain output in Africa. The number of individuals at danger of starvation would rise by 10 million as long as other variables stay the same.

In many developing nations, imports of food are necessary to varied degrees in order to meet the demand for food. Production of cereals met 91% of the demand for cereals in developing nations between 1997 and 1999. This aggregate, nevertheless, masks regional extremes. 63 percent of the demand for grain in the Near East and North Africa was met by local production. It satisfied 82 and 88 percent of the demand in sub-Saharan Africa and Latin America, respectively, and 95 and 102 percent of the demand in East and South Asia. It is anticipated that import dependence would grow. Cereal imports made for 9% of total demand in emerging nations in 1997–1999; by 2030, they are expected to account for 14% of demand [7].

Reduction of Poverty

Investment in irrigation projects may reduce poverty both directly and indirectly by stimulating the rural economy under the right circumstances and with the right design. In fact, rather than focusing on generating immediate financial gains, many large-scale programs connected to the Green Revolution in Asia had more to do with tackling food security and poverty concerns. This belief and practice continue. With the necessary institutional and legislative framework, irrigation projects directly assist the poor, according to the IFAD's "Report on Rural Poverty 2001". Although while irrigation is not expressly intended to benefit the poor, it indirectly boosts the rural economy's agriculture sector by increasing the need for agricultural inputs and the sale of more output. Demand for non-agricultural products and services, many of which are sold only locally and may be provided by people with limited resources, can increase as farming communities' earnings rise. Long-term reduction of absolute poverty in rural regions and reduction of relative poverty are both possible with the consequent stimulation of non-farm earnings, provided that the current asset distribution is not overly skewed.

Improved food output from irrigated agriculture may assist farmers, their families, and the neighborhood's population nutritionally. Multiple cropping may be made possible by irrigation, which can help to mitigate seasonal food shortages and promote the growth of crops that provide variety and nutrition to diets. A better diet may raise quality of life, decrease disease, boost labor productivity, and boost academic achievement in kids. The urban poor may also profit from irrigated agriculture because it keeps food costs down despite rising demand from expanding populations. In fact, if the present fall in irrigation investment continues, food prices might ultimately rise, which would hurt the poor in particular since a major percentage of their income is spent on food.

Irrigation, however, may harm rural families' health by exposing them to parasite infections and illnesses spread by water-related vectors like malaria. However, the economic advantages of irrigation may be mostly enjoyed by affluent farmers in an unfavorable context, such as one where land is not allocated equally, which would exacerbate existing disparities in the allocation of income and resources. Whether irrigation benefits the lives of the poor, it depends critically on the institutional and policy contexts.

Water as an economic benefit is a global agreement in water policy

An worldwide agreement on water management has developed as a result of rising worries about the effectiveness of the use of resources provided by donors and the government, unsuccessful prior initiatives, and increased awareness of environmental problems. These worries are seen, for instance, in the European Community's water policy, which encourages the use of water pricing and charging as a way to improve the sustainability of water resources as well as the incorporation of economics into planning and decision-making. The development cooperation agenda's reorientation, which has led, among other things, to a stronger emphasis on institutional reform, participation, and engagement of civil society and the corporate sector, has also influenced the policy consensus [8].

The International Conference on Water and the Environment's key recommendations, Chapter 18 of Agenda 21, the action plan adopted at the 1992 Rio de Janeiro United Nations Conference on Environment and Development, which included adoption of the Dublin Principles for water resources management in rural contexts, and the World Summit on Sustainable Development form the basis of the current consensus on water policy.

The agreement embraces a multisectoral perspective of water usage at least on a watershed scale and an integrated strategy to managing water resources. The management of water is taken into account in connection to matters of sustainability, marginalized and impoverished people's needs, economic efficiency, and environmental preservation. The community's requirements should be taken into consideration while making decisions, and users, especially women, should be included. Investments in the water industry must be both financially viable and socially and economically acceptable. While there is agreement on water policy, there is significant disagreement about how such improvements should actually be put into practice. Reforms in the economic price of irrigation water, for instance, have been suggested; nevertheless, the political economy of pricing policy changes implies that a pretty complicated process is really in play. The "pragmatic but principled" approach, which respects the principles of efficiency, equity, and sustainability but acknowledges that water resources management is intensely political, is acknowledged as the main management challenge. Reform requires the articulation of prioritized, sequenced, practical, and patient interventions.

Sustainability is a crucial consideration in water management choices, as was already mentioned. Yet, there are several ways to define the phrase "sustainability," and all have an impact on how it might be put into practice. The distinctions are brought about by using a loose or strict definition of sustainability, referred to as weak or strong sustainability, respectively. In order to be sustainable, the amount of capital accessible to current and future generations must be equal. Capital in this context refers to the whole stock of resources, including knowledge, that is used to produce commodities and services that improve societal welfare. According on whether it is used up during the creation of products and services, capital may be categorized into the following categories:

a. Damage brought on by human activity. This may be raised or lowered at your choice.

b. Vital natural resources. Something is necessary for human existence and cannot be replaced or substituted with money created by humans.

c. Non-essential natural capital, which consists of a limited number of mineral resources and certain renewable natural resources. Human-induced capital may completely or partially replace or compensate for this.

Weak sustainability believes that natural and human-induced capital are interchangeable and calls for the maintenance of the overall stock of capital. When a natural resource is used up, its price rises, encouraging better resource management, product substitution, and technical development. Complete replacement, however, is not always feasible or practical, for instance because there aren't enough substitutes for certain types of capital. The complete pool of natural capital cannot be drained for strong sustainability. Both natural and human-induced capital must be kept in stock since they are seen as complements rather than alternatives. As a result, efforts are needed to preserve the ecosystem or to guarantee that any losses are completely made up for in physical terms by "shadow projects". As most development projects have some environmental impact, applying a strict sustainability criteria to them is likely to lead to their complete rejection. The use of project suites that are planned to include components that provide net environmental benefits, however, may overcome this rejection. Market-oriented decision-making may continue even in the face of strict sustainability regulations by using such an approach. Strong sustainability requirements may be seen in the United States of America's wetland mitigation policy. According to the policy, each wetland that is lost must be replaced with one of comparable physical quality. Nonetheless, there have been a few issues with the policy's implementation. Defining an appropriate metric for wetlands' physical quality is among them, as are concerns about the area and how wetlands interact with the landscape [9].

CONCLUSION

The new approach to water governance aims to embrace a more robust sustainability strategy, one that is governed by the stewardship, equality, and accountability principles. The eventual outcome will be to limit the mentality and market processes that see water as a commodity in its different applications and strive to create an effective distribution of water among competing end users. Efficiency is a necessary but not sufficient condition for sustainability, but it is still unclear from a scientific and policy perspective how restrictive sustainability requirements should be. The methodologies and strategies examined in this paper may serve as a decision-support toolkit to help with the issues and concerns of composite sustainability.

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