An Assessment of Land Management Practices for Sustainable Irrigation Farming in Numan Local Government Area, Adamawa State

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Abstract

Irrigated agriculture is a critical strategy for enhancing food security in Nigeria, particularly in semi-arid regions where rainfall is unreliable. However, the sustainability of irrigation farming depends on the interaction between land management practices, soil–water chemistry, and crop productivity. This study assessed the sustainability of irrigation farming in Numan Local Government Area, Adamawa State, by examining farmers' land management practices, the chemical properties of soil and water, and their relationship with crop yields. A mixed-methods approach was employed, combining field surveys, laboratory analyses, and statistical techniques. Data were collected through 384 questionnaires administered to farmers, alongside 30 soil samples and 30 water samples, obtained across six wards. Laboratory tests assessed soil pH, electrical conductivity, organic carbon, nitrogen, phosphorus, and exchangeable bases, while water samples were analysed for salinity, turbidity, and nutrient content. Results showed that 57% of farmers were small-scale producers cultivating 1-2 hectares, with 93% relying on flood irrigation, a method noted for inefficiency and soil degradation risks. Adoption of soil and water management practices was high, with mulching (59.9%) and crop rotation (36.5%) being the most common erosion control measures. Correlation analysis revealed that crop yields were positively and significantly associated with essential nutrients such as nitrate, potassium, phosphorus, organic carbon, and effective cation exchange capacity. Conversely, excess sodium, calcium, chloride, iron, zinc, and heavy metals showed strong negative correlation on yield, underscoring the risks of salinity and contamination. The findings suggest that while farmers demonstrate awareness of basic soil conservation practices, gaps remain in the adoption of efficient irrigation technologies and balanced nutrient management. The study concludes that irrigation sustainability in Numan is threatened by reliance on flood irrigation, salinity build-up, and nutrient imbalances. It recommends targeted farmer training, promotion of water-efficient irrigation systems, regular soil and water testing, and integrated land management policies to enhance productivity and ensure long-term agricultural sustainability.

Keywords: *Flood Irrigation, Irrigation sustainability, Land management practices, Soil-water chemistry, Crop yield*

INTRODUCTION

Agriculture has always been the mainstay of Nigeria's economy, providing food, raw materials for industries, and employment opportunities for a large portion of the population. Despite its importance, the sector has struggled to meet the increasing food demands of a rapidly growing population. Nigeria's population is projected to surpass 400 million by 2050, and without significant improvements in agricultural productivity, the country risks greater dependence on food imports. To close this gap, irrigated agriculture has become essential, as it allows farmers to cultivate crops throughout the year, improve yields, and stabilize food supply. However, the effectiveness of irrigation depends largely on how land is managed, the chemical and physical condition of soils, and the quality of water used. These factors collectively determine whether irrigation practices are sustainable in the long run (Mohammed & Ali, 2021).

Soil and water resources are at the heart of successful farming. Soil provides the foundation for crop growth by anchoring roots, storing nutrients, and supporting microbial activities. Its fertility is influenced by properties such as texture, structure, organic matter content, and nutrient composition (Javed et al., 2022). Water, on the other hand, ensures that crops receive the moisture and dissolved nutrients necessary for growth and survival. In regions where rainfall is unreliable or insufficient, irrigation bridges the gap by supplying water directly to crops (Rockström, et al., 2013). The success of irrigation, however, is influenced by soil characteristics, such as porosity, infiltration rate, and moisture retention, and by the chemical balance of the soil-water system (Nasidi, 2016). When irrigation is poorly managed, it can create new problems rather than solve existing ones. Excessive irrigation often leads to waterlogging, while poor drainage can cause salt build-up in soils, reducing their productivity. Soil-water chemistry becomes particularly important in this context. For example, soil pH plays a key role in determining nutrient availability; an imbalanced pH can lock up essential elements, making them inaccessible to plants. Similarly, high salinity in irrigation water or soils can reduce crop yields by hindering root water uptake. Without careful management, these challenges can erode the benefits of irrigation and threaten the sustainability of agricultural systems (Wu & Ma, 2015).

Land management practices also influence how effective irrigation is in boosting crop production. Sustainable practices such as mulching, crop rotation, cover cropping, and contour farming help conserve soil moisture, reduce erosion, and maintain soil fertility. In contrast, unsustainable practices, such as over-tillage, indiscriminate use of agrochemicals, or neglect of drainage systems, degrade soil quality and undermine irrigation outcomes. Integrated soil fertility management, which combines the use of organic and inorganic inputs, has been shown to improve soil-water interactions and crop yields. Therefore, land management is not just a supportive factor but a decisive one in determining whether irrigation practices are productive and sustainable (Lal, 2015). In Nigeria, irrigation has contributed significantly to food production, especially in the semi-arid northern states where rainfall is highly variable. Irrigation schemes enable the production of rice, maize, vegetables, and other crops even during the dry season, thereby stabilizing food supply and farmer incomes. Despite this potential, many irrigation schemes in the country are underperforming (Fanadzo et al., 2018), Bjornlund et al., 2020), Higginbottom, et al., 2021). Problems such as poor infrastructure maintenance, limited farmer participation, weak institutional support, and inefficient water distribution have reduced their effectiveness. Some irrigation projects have suffered from underfunding, while others were abandoned due to technical and managerial shortcomings. Irrigation cannot make its full contribution to food security and rural development when these issues are not addressed (Jibril et al., 2017).

In the Numan Local Government Area of Adamawa State, irrigation farming is a vital source of livelihood and food production. Yet, despite its importance, there is no formal system for tracking or documenting trends in soil conditions, crop yields, or irrigation practices. Local farmers have repeatedly expressed concern over declining crop yields and noticeable changes in soil quality, including reduced fertility, compaction, and altered moisture retention. These problems are widely linked to unsustainable soil and water management practices, such as inadequate fertilisation, over-irrigation, poor drainage, and insufficient soil amendments. If left unaddressed, these practices threaten the long-term sustainability of irrigation farming by degrading soil structure, increasing salinity or alkalinity, and reducing water-use efficiency. Such deterioration could further reduce productivity, undermine household incomes, and jeopardise food security in the area.

There is therefore an urgent need for a comprehensive assessment of the chemical and physical properties of both soil and water used for irrigation. Relevant national standards and internationally recognized guidelines for irrigation-water quality (FAO/WHO) standards for irrigation quality, identify the risks of soil degradation or water contamination, and reveal how they interact with crop performance. At the same time, it is crucial to examine the current land management practices of irrigation farmers such as fertiliser application, drainage, crop rotation, or erosion control, to determine which are sustainable and which may be contributing to soil and water quality problems. In addition, identifying areas with the potential for irrigation expansion and investment can increase productive land, boost agricultural output, create jobs, and enhance long-term sustainability.

Literature Review

One of the fundamental aspects of land management practices is erosion control. Soil erosion not only leads to the loss of fertile topsoil but also poses a significant threat to water quality and aquatic ecosystems (Feeney *et al*., 2023). Soil sustainability and erosion control are critical components of land management practices, with significant implications for the overall health and productivity of agricultural ecosystems. Soil erosion, the process by which soil is displaced from its original location, poses a severe threat to sustainable land use. This phenomenon is particularly pronounced in areas with intensive agricultural activities, deforestation, or improper land management practices. Evaluating the effectiveness of conservation tillage, cover cropping, and agroforestry in preventing soil erosion is essential for maintaining soil health and sustainable agricultural productivity (Du *et al*., 2022).

Land management practices significantly influence soil fertility and nutrient cycling. The sustainability of soil fertility is intricately linked to effective nutrient management practices. Nutrients are vital for plant growth, and their availability in the soil directly influences agricultural productivity. Unbalanced nutrient management can lead to soil degradation, nutrient runoff, and environmental pollution. Therefore, evaluating and optimizing nutrient management practices is crucial for maintaining soil fertility and ensuring sustainable agricultural systems. Sustainable nutrient management involves optimizing the use of fertilizers, incorporating organic amendments, and adopting precision agriculture techniques (Lowenberg-DeBoer & Erickson, 2019). Assessing the impact of different nutrient management strategies on soil health is crucial for minimizing nutrient runoff, enhancing crop productivity, and mitigating environmental impacts.

Land use change, such as deforestation, urbanization, and conversion of natural ecosystems to agriculture, has profound implications for soil structure. Soil structure, encompassing properties like aggregation, porosity, and compaction, directly influences water infiltration, nutrient cycling, and overall ecosystem health. Understanding how different land use changes affect soil structure is crucial for sustainable land management and environmental conservation. The impact of these changes on soil physical properties, including porosity, permeability, and water retention, is vital for predicting the resilience of ecosystems to climate change (Fan *et al*., 2019). Evaluating the effectiveness of land-use planning and conservation measures in preserving soil structure is crucial for sustainable land management.

Land management practices influence soil biodiversity and microbial communities, which play a pivotal role in nutrient cycling, disease suppression, and overall ecosystem functioning (Saccá *et al*., 2017). The intricate interplay between biodiversity and soil microbial communities is a critical aspect of ecosystem functioning. Soil microorganisms, including bacteria, fungi, and archaea, are essential for nutrient cycling, organic matter decomposition, and overall soil health. Biodiversity, both aboveground and belowground, influences the composition and activity of soil microbial communities, and understanding this relationship is fundamental for sustainable land management and conservation. Assessing the impact of land management on soil microbial diversity and activity provides insights into the resilience and adaptability of soils to changing environmental conditions.

Soils are significant carbon sinks, and land management practices can either enhance or deplete soil organic carbon. As global concerns over climate change intensify, the role of soil in mitigating greenhouse gas emissions, particularly carbon dioxide (CO_2), has gained prominence. Carbon sequestration in soils, through various land management practices, has the potential to offset emissions, contribute to climate change mitigation, and enhance the overall sustainability of ecosystems. Evaluating the effectiveness of practices such as agroforestry, cover cropping, and reduced tillage in carbon sequestration is essential for climate change mitigation (Tan & Kuebbing, 2023). Understanding the potential of different land management strategies to sequester carbon contributes to both soil sustainability and global efforts to reduce greenhouse gas emissions. Irrigated agriculture has played a crucial role in human civilization for centuries, enabling the sustained production of food and the development of complex societies. Throughout history, the management of land in irrigated agricultural systems has evolved in response to changing environmental, technological, and socio-economic factors. Historically, the earliest known irrigation systems date back to ancient civilizations such as the Mesopotamians, Egyptians, and the Indus Valley. These societies relied on complex networks of canals, ditches, and levees to divert and distribute water to their agricultural lands (Adams, 1981). Irrigation was fundamental to food security, and its success depended on effective land management practices, including soil preparation, crop rotation, and water allocation.

Ancient irrigated agriculture developed around major river systems: Mesopotamia used canals and dikes fed by the Euphrates and Tigris, while Ancient Egypt relied on Nile inundation managed through ditches and basins to support crops such as wheat, barley, and flax (Yannopoulos et al., 2015). Over time, irrigation technology advanced from earlier methods to water wheels and later steam and electric pumps, improving water distribution and expanding irrigated land, and by the 20th century sprinkler and drip systems further increased water-use efficiency (Yannopoulos et al., 2015).

Socio-economic arrangements also shaped land management throughout history. In medieval Europe, the feudal system controlled land tenure, with serfs working the lands of lords and religious institutions, influencing both water allocation and crop patterns, whereas in parts of Asia communal systems emerged where villagers collectively managed water and land resources (Postel, 1992; Tian, 2015). These differences reflected how local governance and power structures determined access to irrigation and agricultural decisions.

As environmental effects became clearer, land management shifted toward sustainability. In the 20th century, increased awareness of irrigation-driven challenges such as soil salinization and waterlogging supported the development of sustainable practices, including integrated water resource management and soil conservation measures intended to balance productivity with environmental protection (Singh, 2021; Cowie et al., 2018).

Meanwhile, irrigation agriculture continued to evolve from traditional subsistence systems into more specialized, market-oriented production. This transformation included mechanization, growth in cash-crop production, and greater use of agrochemicals, often driven by government policies, market forces, and globalization (Drechsel et al., 2001; Pender et al., 2006). Key historical shifts such as the agricultural revolution and the 19th-century expansion of irrigation projects improved productivity through innovations like crop rotations and irrigation infrastructure, while the Green Revolution increased yields via high-yield varieties and greater fertilizer and pesticide use—despite raising sustainability concerns.

Finally, the introduction of agricultural machinery (such as tractors and combine harvesters) and wider agrochemical use further altered land management by increasing efficiency and reducing labor requirements. Overall, the historical progression shows irrigated land management adapting to changing technological, economic, environmental, and institutional conditions (Drechsel et al., 2001; Pender et al., 2006; Singh, 2021; Cowie et al., 2018).

MATERIALS AND METHODS

Study Area

Numan Local Government Area (LGA) is located in the southern part of Adamawa State, northeastern Nigeria. It lies approximately between latitude 9°28'N and 9°33'N and longitude 12°02'E and 12°07'E. The area serves as one of the major agricultural and administrative centers in the region and is characterized by a tropical climate with distinct wet and dry seasons. Rainfall usually ranges between 800 mm and 1,200 mm annually, while average temperature fluctuates between 25°C and 35°C throughout the year. The topography of Numan LGA is generally low-lying, forming part of the Benue River floodplain. The terrain is largely flat to gently undulating, with elevation ranging between 150 and 250 meters above sea level. The land slopes gradually toward the Benue River, which forms the southern boundary of the area. During the rainy season, some parts of the lowlands are prone to flooding, especially in communities close to the river and its tributaries. The gently sloping upland areas are suitable for farming and settlement, while the floodplains support wet-season rice cultivation and fishing activities. The soils of Numan LGA are largely influenced by the hydrological and geological characteristics of the Benue River basin. (Terrumun, 2025). Based on field samples and observations across the six wards, the major soil types identified include: Alluvial Soils: These soils are predominant along the riverbanks and low-lying floodplains. They are deep, poorly drained, and rich in organic matter due to periodic flooding and sediment deposition. Alluvial soils are suitable for crops such as rice, sugarcane, and vegetables. Sandy Loam Soils: Found mainly in the upland areas, sandy loam soils in Numan are well-drained, moderately fertile, and easy to cultivate. They support crops like maize, sorghum, groundnut, and millet. However, their low water-holding capacity makes them susceptible to drought during dry spells. Clayey Soils: In certain depressions and valley bottoms, clayey soils occur as a result of sediment accumulation and limited drainage. These soils retain moisture for longer periods, making them favorable for wet-season crops but less ideal for dry-season farming without proper drainage. Lateritic Soils: In isolated upland ridges, lateritic soils (reddish-brown and iron-rich) are common. They are relatively less fertile due to leaching but are stable and suitable for construction and roadworks (Terrumun, 2025).

Methodology

This study combined both fieldwork and desk research. Primary data were gathered directly from farmers through questionnaires and interviews, as well as from soil and water samples taken across six wards in Numan Local Government Area where irrigation farming is widely practiced. A total of 384 farmers were selected at random from Numan, and 384 questionnaires were shared among these farmers, while thirty soil samples and thirty water samples were collected for laboratory analysis. Soil samples were taken at surface depth (0–15 cm) using auger and grid sampling techniques, while water samples were drawn from irrigation points into clean plastic containers. In the laboratory, soils were tested for pH, electrical conductivity, organic carbon, nitrogen, phosphorus, and exchangeable bases such as calcium, magnesium, potassium, and sodium. Water samples were examined for their chemical properties to determine their suitability for irrigation. The questionnaires focused on farmers' land management practices, use of irrigation, and crop yield outcomes. Data collected were analyzed using descriptive and statistical methods to establish the relationship between land management practices, soil–water chemistry, and crop yield, with the overall aim of assessing the sustainability of irrigation farming in the study area.

RESULTS AND DISCUSSION

Table 1 Farm Size

Farm Size	Frequency	Percentage (%)
Small–scale farmer (1-2 hectares)	219	57.0
Medium-scale farmer (3-4) hectares	139	36.2
Large-scale farmer (5-8) hectares	26	6.8
Total	**384**	**100**

The result presented in Table 1 on farm size under cultivation in the study area revealed that the majority of respondents (57%) are small-scale farmers, cultivating between 1 to 2 hectares of land. Medium-scale farmers, cultivating (3-4 hectares), account for 36.2% of the respondents, while a smaller proportion, 6.8%, are large-scale farmers, managing (5-8 hectares) of farmland. The predominance of small-scale farmers highlights the reliance on limited land resources for agricultural production in the study area. Small-scale farming, typically characterized by lower levels of mechanization and input use, may present challenges related to resource constraints, such as access to quality seeds, fertilizers, and irrigation facilities. These farmers may also face limitations in adopting advanced soil and water management practices due to financial constraints or limited knowledge. Medium-scale farmers, representing 36.2% of the respondents, likely have more resources and capacity than their small-scale counterparts. This group may be more capable of adopting new agricultural practices or investing in better soil and water management techniques, such as drip irrigation or improved fertilization methods. Large-scale farmers, though a minority at 6.8%, play a vital role in the agricultural landscape of the study area. These farmers manage substantial plots of land (5-8 hectares) and are likely to have more access to capital, technology, and infrastructure, enabling them to implement more advanced farming practices. Their capacity to adopt improved irrigation methods, invest in soil management, and utilize modern agricultural equipment can contribute significantly to overall agricultural productivity. However, their larger environmental footprint also means they need to adopt sustainable practices to mitigate negative environmental impacts.

Extent of Adopting Soil and Water Management Practices

The data from Table 1 showed that a significant majority of farmers 330 (86%) in the study area strongly agreed to adopting soil and water management practices. This is followed by a smaller proportion of farmers, 52 (13.5%), who "agreed" to adopting these practices. Only a minimal percentage (0.5%) disagreed, and none strongly disagreed, indicating that there are an overwhelming acceptance and practice of soil and water management techniques among the farmers.

Table 2 Farmers' Extent of Adopting Soil and Water Management Practices

Extent	Frequency	Percentage%
Agreed	51	13.5
Strongly agreed	330	86.0
Disagreed	3	0.5
Strongly disagreed	0	0
Total	384	100

The high percentage (86%) of farmers who have " strongly agreed that they adopted soil and water management practices reflects a strong awareness of the importance of these practices in sustainable agriculture. This could be attributed to effective agricultural extension services, awareness campaigns, or training programs that emphasize the benefits of such practices in improving soil fertility, conserving water, and increasing crop yields. The significant level of agreement suggests that farmers recognize the importance of these practices in mitigating soil degradation, managing water resources efficiently, and enhancing agricultural productivity. For example, they may be using techniques such as drip irrigation, mulching, or contour farming, which help conserve water, reduce evaporation, and improve water infiltration and retention in the soil. This high adoption rate also implies that these farmers are more likely to understand the importance of managing soil quality to prevent waterlogging or salinization, which can be detrimental to crops. A smaller proportion of farmers (13.5%) "agreed" to adopting soil and water management practices, which indicates that while they may practice some form of management, they might not be fully committed or might face certain constraints. These could include limited access to resources such as fertilizers, organic matter, or irrigation equipment, or they may lack the technical knowledge required for advanced management practices. The minimal percentage (0.5%) of farmers who "disagreed" with adopting soil and water management practices suggests that there are few farmers who do not see the relevance or benefits of these practices. This small minority could be due to lack of awareness, resistance to change, or challenges specific to their farming operations that make adoption difficult. However, the lack of any farmers "strongly disagreeing" further underscores the general acceptance and positive attitude towards these practices among the majority of farmers.

Land Management Practices

Table 3 presents data on respondents' adoption of measures to prevent soil erosion and methods of irrigation within a sample of 384 individuals. In terms of soil erosion prevention, mulching is the most widely adopted measure, with 59.9% of respondents utilizing this technique. Crop rotation follows with 36.5%, while windbreaks and other methods are less commonly employed, with only 2.6% and 1.0% of respondents, respectively. The high adoption rate of mulching (59.9%) and crop rotation (36.5%) suggests that many farmers are recognizing the benefits of these practices for soil health and long-term productivity. Mulching, in particular, plays a crucial role in preventing soil erosion, conserving moisture, and improving soil fertility, which are all essential components of sustainable farming. Crop rotation contributes to maintaining soil health by disrupting pest cycles and enhancing nutrient availability, further supporting sustainable agricultural outcomes. However, the data also reveals significant gaps, particularly in the adoption of other soil erosion prevention methods like wind breaks (2.6%) and alternative techniques (1.0%). The low usage of these practices may indicate a lack of awareness or resources among farmers, suggesting the need for increased education, training, and support to encourage the adoption of a broader range of sustainable soil management practices.

Table 3 Farmers' Lang Management Practices

Variable	No. of Respondents	% respondent
	Measures to prevent soil erosion	
Crop rotation	140	36.5
Wind break	10	2.6
Mulching	230	59.9
Others	4	1.0
Total	**384**	**100**
	Method of Irrigation	
Drip	8	2.1
Sprinkler	10	2.6
Flood irrigation	357	93
Others	11	2.9
Total	**384**	**100**

Regarding irrigation methods, flood irrigation is the predominant choice, used by 93% of the respondents. Drip irrigation and sprinkler systems are less prevalent, with only 2.1% and 2.6%

adoption rates, respectively. The minimal use of advanced irrigation methods such as drip or sprinkler systems, coupled with the high reliance on flood irrigation, may suggest opportunities for promoting more water-efficient practices. The irrigation data raises concerns about the sustainability of current water use practices in agriculture. With 93% of respondents relying on flood irrigation—a method known for its inefficiency and high water consumption—the environmental impact on water resources is considerable. The minimal use of more sustainable irrigation methods, such as drip (2.1%) and sprinkler systems (2.6%), underscores a significant challenge in transitioning to water-efficient practices. Drip and sprinkler irrigation are known to reduce water wastage, improve crop yields, and enhance the overall sustainability of agricultural operations. The low adoption rates of these methods suggest that barriers such as cost, accessibility, or knowledge may be preventing wider implementation. The data imply that while there is some progress in adopting sustainable practices, there is a critical need for enhanced support and resources to promote the broader implementation of sustainable techniques, particularly in areas like water management and diversified soil conservation strategies.

The practices mentioned, particularly in how they manage water flow and soil stability, have implications for fluvial processes, which involve the movement of water and sediment in rivers and streams. For example, minimizing soil erosion through mulching and crop rotation reduces the amount of sediment that reaches waterways, thereby decreasing sediment load and the potential for riverbank erosion, channel migration, or sediment deposition that could alter riverine landforms. Furthermore, by alternating crops with different root structures and growth habits, crop rotation helps maintain soil structure and reduce the risk of erosion. Certain crops, like legumes, improve soil cohesion and reduce the vulnerability of the soil to erosive forces. This practice helps stabilize landforms by preventing excessive soil loss and maintaining soil fertility, which is critical for sustainable agriculture. In contrast, this traditional method involves spreading water over the land surface, which can lead to significant runoff and erosion if not managed properly. Over time, the geomorphological impact of flood irrigation can include changes in soil structure, compaction, and even the formation of new channels or erosion features, particularly in areas with poorly drained soils.

Relationship between Chemical Properties of Water/Soil and Crop Yield in the Study Area.

The Pearson product-moment correlation in Table 4.5 showed that various degrees of correlation between the Yield of farmers and the chemical parameters of water. It can be seen that Nephelometric Turbidity Units (NTU) had a Correlation = -0.838 and Sig. = 0.037. This means NTU has a strong negative correlation with yield, meaning as turbidity increases, the yield decreases significantly. The p-value of 0.037 indicates that this relationship is statistically significant, suggesting that this variable is likely a critical factor in reducing yield. This could imply that high levels of turbidity, which often indicate the presence of suspended solids or pollutants in water, negatively affect the conditions needed for optimal crop growth, leading to lower yields. The correlation analysis revealed varying relationships between soil chemical properties and crop yield. Soil pH showed a moderate negative but non-significant correlation with yield, while electrical conductivity and total dissolved solids also displayed strong negative yet non-significant relationships, suggesting that high salinity may reduce yield but the effect was not statistically clear. Carbonate (CO_3) had a strong and significant negative effect on yield, and bicarbonate (HCO_3^{2-}) a moderate but non-significant negative effect. Magnesium showed a weak, non-significant positive relationship, whereas calcium exhibited a very strong and significant negative correlation, indicating that higher Ca^{2+} levels were linked with lower yields. Potassium showed a moderate and significant positive correlation, while iron had a very strong and significant negative effect. Nitrate displayed a strong and significant positive correlation with yield. Sodium also showed a strong and significant negative relationship with yield, consistent with the harmful effects of salinity. Manganese had a strong but borderline non-significant negative effect. Fluoride showed a moderate non-significant negative relationship, while chloride exhibited a very strong and significant negative correlation. Zinc and lead both showed strong, statistically significant negative correlations with yield, pointing to possible toxicity effects at high concentrations. In sum, nutrients such as nitrate and potassium were positively associated with yield, while high concentrations of salts and heavy metals (Ca^{2+}, Na^{+}, Fe^{2+}, Mn, Cl^{-}, Zn, Pb) were linked with reduced yields, some significantly.

Table 4 Pearson Correlation between Chemical Properties of Water and Crop Yield

Variable		Yield
Yield	Pearson Correlation	1
	Sig. (2-tailed)	
	N	6
NTU	Pearson Correlation	-.838*
	Sig. (2-tailed)	**.037**
	N	6
PH	Pearson Correlation	-.507
	Sig. (2-tailed)	.305
	N	6
EC	Pearson Correlation	-.751
	Sig. (2-tailed)	.085
	N	6
TDS	Pearson Correlation	-.744
	Sig. (2-tailed)	.090
	N	6
Co3	Pearson Correlation	-.847*
	Sig. (2-tailed)	**.033**
	N	6
HCO32	Pearson Correlation	-.563
	Sig. (2-tailed)	.245
	N	6
Mg2	Pearson Correlation	.241
	Sig. (2-tailed)	.645
	N	6
Ca2	Pearson Correlation	-.868*
	Sig. (2-tailed)	.025
	N	6
K	Pearson Correlation	.449
	Sig. (2-tailed)	**.037**
	N	6
Fe2	Pearson Correlation	-.879*
	Sig. (2-tailed)	.021
	N	6
NO32	Pearson Correlation	.858*
	Sig. (2-tailed)	**.029**
	N	6
Na	Pearson Correlation	-.828*
	Sig. (2-tailed)	**.042**
	N	6
Mn	Pearson Correlation	-.876
	Sig. (2-tailed)	.052
	N	5
F	Pearson Correlation	-.553
	Sig. (2-tailed)	.256
	N	6
Cl	Pearson Correlation	-.896*
	Sig. (2-tailed)	**.016**
	N	6
Zn	Pearson Correlation	-.876*
	Sig. (2-tailed)	**.022**
	N	6
Pb	Pearson Correlation	-.708
	Sig. (2-tailed)	0.11
	N	6

Relationship between Chemical Properties of Soil and Crop Yield in the Study Area

The analysis above table 4 showed different patterns of association between soil chemical properties and crop yield in the study area. Soil pH had a weak but significant negative relationship with yield, meaning that yields tended to fall slightly as pH increased.

Table 5: Pearson Correlation between Chemical Properties of Soil and Crop Yield

Variable		Yield
Yield	Pearson Correlation	1
	Sig. (2-tailed)	
	N	6
pH	Pearson Correlation	-.175
	Sig. (2-tailed)	**.040**
	N	6
EC	Pearson Correlation	-.181
	Sig. (2-tailed)	.732
	N	6
Org.c	Pearson Correlation	.355
	Sig. (2-tailed)	**.03**
	N	6
AvN	Pearson Correlation	.894
	Sig. (2-tailed)	**.004**
	N	6
AvP	Pearson Correlation	.587
	Sig. (2-tailed)	**.048**
	N	6
Ca	Pearson Correlation	-.050
	Sig. (2-tailed)	.926
	N	6
Mg	Pearson Correlation	-.285
	Sig. (2-tailed)	.585
	N	6
Na	Pearson Correlation	-.813*
	Sig. (2-tailed)	**.049**
	N	6
K	Pearson Correlation	.738
	Sig. (2-tailed)	**.002**
	N	6
	N	6
ECEC	Pearson Correlation	.460
	Sig. (2-tailed)	.019
	N	6
PBS	Pearson Correlation	-.384
	Sig. (2-tailed)	.453
	N	6
ESP	Pearson Correlation	-.315
	Sig. (2-tailed)	**.043**
	N	6

Electrical conductivity also showed a weak negative relationship, but it was not significant. Organic carbon displayed a moderate and significant positive relationship with yield, indicating that higher organic matter improved productivity. Available nitrogen showed a very strong and significant positive relationship with yield, underlining its importance for crop growth, while available phosphorus showed a moderate and significant positive effect. Calcium and magnesium were both weakly and negatively related to yield, and neither was significant. Sodium showed a strong and significant negative relationship with yield, suggesting that high sodium levels reduced productivity, probably because of salinity effects. Potassium showed a strong and significant positive relationship with yield, confirming its role in plant growth. Effective Cation Exchange Capacity (ECEC) also had a moderate and significant positive effect on yield, reflecting better nutrient retention and soil fertility. Exchangeable Sodium Percentage (ESP) showed a weak but significant negative effect on yield, while Percent Base Saturation (PBS) showed a moderate negative relationship that was not significant. In general, nutrients such as nitrogen, potassium, phosphorus, organic carbon and ECEC were linked with higher yields, whereas high sodium levels and increased ESP tended to reduce yields. pH had a slight influence, while calcium, magnesium, EC and PBS had little or no meaningful effect.

CONCLUSION/RECOMMENDATIONS

This study has shown that the sustainability of irrigation farming in Numan Local Government Area is shaped by the interaction of farmers' land management practices, the chemical composition of soils and water, and the methods of irrigation employed. Although farmers demonstrated appreciable knowledge of basic conservation measures such as mulching and crop rotation, the overwhelming dependence on flood irrigation remains a serious limitation, as it encourages nutrient loss, salinity buildup, and long-term soil degradation. The analysis of soil and water chemistry further revealed a mixed outcome: while essential nutrients like nitrate, phosphorus, potassium, and organic carbon support higher yields, excessive sodium, chloride, and certain heavy metals exert negative effects, thereby threatening productivity. Farmers should ensure that crops receive adequate nitrate and potassium, as these nutrients have been positively correlated This study has shown that irrigation farming in Numan Local Government Area plays a vital role in food production and livelihoods, but its long-term sustainability is threatened by soil and water quality challenges as well as gaps in land management practices. The findings reveal that the majority of farmers are small-scale producers relying heavily on flood irrigation, a method that consumes large amounts of water and contributes to soil degradation. While most farmers reported adopting soil and water management practices such as mulching and crop rotation, the adoption of more advanced and efficient irrigation methods remains very low. The chemical analysis of soils and water indicated that crop yields are strongly influenced by their nutrient and salinity levels. Essential nutrients like nitrogen, potassium, phosphorus, organic carbon, and effective cation exchange capacity were positively linked with yields, whereas excess sodium, calcium, chloride, iron, and heavy metals were found to reduce productivity. Farmers should use fertilizers that are rich in these essential nutrients based on soil-testing results to enhance crop yields. They should also apply fertilizers in balanced amounts to avoid over-fertilization, which can lead to nutrient imbalances and environmental problems such as water pollution, eutrophication, nitrate contamination of groundwater, and soil degradation. Numan Local Government Authority should organize workshops and field days to train farmers in advanced soil and water management techniques and sustainable practices. Government at all levels should synergize to carry out detailed geomorphological

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