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Evaluation of some Physicochemical Characteristics of Soil from Namtari, Yola South, Adamawa State, Nigeria

[*1]GARBA, A; [2]QADEER, MA; [3]KABIRU, I

*[*1]Department of Primary Education, School of Early Childhood Care & Primary Education, Federal College of Education, Yola, P.M.B. 2042, Yola Adamawa State, Nigeria*
[2]Department of Zoology, Faculty of Life Sciences, Modibbo Adama University, Yola, P.M.B. 2076, Yola, Adamawa State, Nigeria.
[3]Department of Agricultural Education, School of Vocational, Federal College of Education, Yola, P.M.B. 2042, Yola Adamawa State, Nigeria

**Corresponding Author: Email: Garbaa@fceyola.edu.ng*
ORCID ID: https://orcid.org/0009-0005-6734-8436
Tel: +234(0)8060546276

Co-Authors Email: Maqadeeri@yahoo.com; Idris.kabiru@fceyola.edu.ng

ABSTRACT: The objective of this paper is to evaluate some physicochemical characteristics of soil from Namtari Ward, Yola South LGA, Adamawa State, Nigeria using appropriate standard procedures. Data obtained shows that: Soil pH ranged from slightly acidic (7.04 ± 0.35) to slightly alkaline (7.37 ± 0.55), while organic matter content varied from 2.53 ± 0.28% (Karlahe) to 6.17 ± 0.67% (Changala). Nitrogen levels ranged from 0.126 ± 0.01 gkg^{-1} (Dadi) to 0.316 ± 0.02 gkg^{-1} (Changala), and phosphorus levels from 15.03 ± 1.5 gkg^{-1} (Karlahe) to 18.91 ± 1.116 gkg^{-1} (Dadi). Potassium levels spanned 0.73 ± 0.07 $cmolkg^{-1}$ (Dadi) to 1.956 ± 0.69 $cmolkg^{-1}$ (Changala), and moisture content was highest in Karlahe (61.16 ± 3.403%) and lowest in Changala (48.16 ± 7.42%). The results indicate significant changes in soil parameters, particularly a reduction in organic matter and moisture content, and slight changes in pH due to climate factors. These findings suggest that climate change contributes to soil degradation, with potential implications for agricultural productivity and ecosystem health. Practices like crop diversification, conservation tillage, and agroforestry were recommended to lessen the impact of climate variability on soil health and crop productivity. Providing farmers with training and resources will aid their shift toward these sustainable methods.

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Climate change is a global phenomenon with significant implications for environmental and ecological systems, notably soil health. Changes in temperature, precipitation patterns, and the frequency of extreme weather events have led to substantial alterations in soil parameters, which are critical for agricultural productivity and ecosystem sustainability. Research has shown that climate change can cause increased soil erosion, nutrient depletion, and shifts in soil microbial activity, further degrading soil quality (Abiodun *et al*., 2013; Amos *et al*., 2015). Globally, the detrimental effects on soil health are well-documented, reflecting a pressing concern for sustainable agriculture, food security, and environmental stability (Lal, 2004; Amundson *et al.*, 2015). In Northern Nigeria, agriculture is the backbone of the economy, and the impacts of climate change on soil health are particularly concerning. The region is experiencing shifts in temperature and rainfall patterns, which are critical in determining soil

**Corresponding Author: Email: Garbaa@fceyola.edu.ng*
ORCID ID: https://orcid.org/0009-0005-6734-8436
Tel: +234(0)8060546276

moisture content, nutrient availability, and organic matter decomposition (Akinsanola and Ogunjobi, 2014; Ibrahim *et al.*, 2020). These climatic changes directly affect soil fertility and structure, influencing crop productivity and threatening food security. How climate change alters soil parameters in this area is vital for formulating adaptive strategies that ensure sustainable agricultural practices and ecosystem services (Ebele and Emodi, 2016; Berkes, 2017). Namtari, located in Yola South Local Government Area (LGA) of Adamawa State, Nigeria, faces significant challenges due to climate change. The region has experienced notable shifts in temperature and rainfall patterns, which have led to visible changes in soil characteristics. These changes, primarily driven by climate-induced factors, threaten local agricultural activities by reducing crop yields and degrading soil fertility (Ladan, 2014; Ikehi *et al*., 2014). Despite these visible impacts, there is a lack of comprehensive studies in Namtari that examine the specific effects of climatic variables on soil parameters. This knowledge gap limits the development of informed strategies to combat soil degradation and adapt to changing climate conditions (Dasgupta *et al*., 2015; Danjuma, 2021). Understanding how climate change affects soil health in this region is essential; therefore, it is crucial to determine shifts in soil parameters and analyse the relationship between climatic variables (temperature, rainfall, relative humidity) and soil indicators (pH, organic matter, nitrogen, phosphorus, potassium, moisture content) to promote sustainable agricultural practices. Understanding the impact of climate change on soil parameters is crucial for ensuring the sustainability of agriculture in Namtari and similar regions. Soil health is directly linked to crop productivity, food security, livelihoods, and economic stability. By examining how climate variables such as temperature and rainfall affect soil characteristics, this study aims to provide valuable insights that can inform the development of adaptive agricultural practices and effective soil management strategies. These strategies are essential for mitigating soil degradation, maintaining soil fertility, and improving agricultural resilience to climate variability (Onyeneke *et al*., 2019; Abah, 2014). Furthermore, this research aims to add to the broader discourse on climate change adaptation by offering Localized data that policymakers and stakeholders can use to implement interventions to protect soil health. The study's findings will help inform agricultural and environmental policies, ensuring agricultural production and ecosystem services. The knowledge generated from this research will benefit the local community in Namtari and serve as a reference for other regions facing similar climatic challenges, fostering resilience against climate change impacts on soil health (Dasgupta *et al.*, 2015).

MATERIALS AND METHODS

Study Area: The study was conducted in selected communities within Namtari Ward, Yola South Local Government Area (LGA) of Adamawa State, Nigeria. The climate of Namtari is semi-arid, with distinct wet and dry seasons. The region typically experiences annual rainfall between 800 mm and 1,000 mm, between May and October. Temperatures in the area vary significantly throughout the year, with mean daily temperatures ranging from 25°C to 40°C. The topography of Namtari is predominantly flat to gently undulating, with elevations ranging from 150 to 200 meters above sea level. The land use in this area is primarily agricultural, with smallholder farmers cultivating crops such as Rice, Maize, millet, groundnuts, and vegetables. The soils in Namtari are generally sandy loam, which is prone to erosion and degradation, particularly under the influence of climatic changes and unsustainable land management practices.

Sampling and Sampling Process: The soil sampling process involved selecting representative sites within the selected communities of Namtari Ward. Four communities were chosen based on their geographical spread and agricultural activities: Changala, Karlahe, Dadi, and Dolabi. In each community, soil samples were collected from multiple locations, representing different land-use types (e.g., farmlands, fallow lands, and grazing areas). A total of 20 composite soil samples were taken from the topsoil (0-20 cm depth) using a soil auger. Each composite sample consisted of five subsamples collected from different points within a 10-meter radius and mixed thoroughly to ensure homogeneity. The soil samples were then air-dried, sieved through a 2 mm mesh, and stored in labelled polythene bags for laboratory analysis.

Climate data collection: historical and current climate data for the study area were collected from multiple sources, including the Nigerian Meteorological Agency (NiMet) and local weather stations. The data include monthly temperature, precipitation, and relative humidity over the past 30 years, focusing on the most recent decade to capture recent climatic trends. Furthermore, data on extreme weather events, such as droughts and floods, were also gathered to understand their potential impacts on soil parameters. The collected climate data were then cross-referenced with local observations from farmers and community members to ensure accuracy and relevance.

*Laboratory Analysis***:** The soil samples were Analyzed in the laboratory to determine key soil parameters that are influenced by climate change. The following techniques were employed:

Soil Texture: The particle size distribution was determined using the hydrometer method, which classifies soil particles into sand, silt, and clay fractions.

Soil pH: was measured using a pH meter in a 1:2.5 soil-to-water suspension.

Organic Matter Content: The Walkley-Black method was employed to determine soil organic matter content Oxidizing organic carbon with potassium dichromate and titrating it with ferrous ammonium sulfate.

Nitrogen Content: The Kjeldahl method was employed to determine the total nitrogen content in the soil samples.

Phosphorus Content: Available phosphorus was extracted using the Bray-1 method and quantified by calorimetry.

Potassium Content: Exchangeable potassium was measured using a flame photometer after extraction with ammonium acetate.
Soil moisture content was measured using the gravimetric method, which involved weighing the soil samples before and after drying them in an oven at 105°C.

Data Analysis: The relationship between climate data and changes in soil parameters was Analyzed using descriptive and inferential statistical methods. mean, and standard deviation were used to Summarize the soil and climatic data. Inferential statistics, including Pearson correlation analysis, were employed to assess the strength and direction of the relationships between climate variables.

RESULTS AND DISCUSSION

Table 1 presents the descriptive statistics for these parameters across the study locations. The pH values across the locations ranged from 7.04 to 7.37, indicating neutral to slightly alkaline soils. The organic matter content varied significantly, ranging from 2.53% to 6.17%, reflecting differences in soil fertility and land use practices. The nitrogen content was generally low, ranging from 0.126 g/kg to 0.316 g/kg, which may impact crop yields. Phosphorus levels ranged from 15.03 g/kg to 18.91 g/kg, with some variation across locations. The range of Potassium content was observed between 0.73 cmol/kg and 1.96 cmol/kg, a critical factor for plant health. Soil moisture content varied widely from 48.16% to 61.16%, reflecting the influence of local climatic conditions and soil properties. The F-test results (F calculated (3,6) = 2.47; P-value = 0.159) indicate that the differences in soil parameters across the locations were not statistically significant (P > 0.05).

Table 1: Soil Parameters in the Study Locations

Location	Soil pH	Organic Matter (%)	Nitrogen (gkg-1)	Phosphorus (gkg-1)	Potassium (cmolkg-)	Moisture Content (%)
Changala	7.33±0.12	6.17±0.67	0.316±0.02	18.24±0.69	1.956±0.69	48.16±7.42
Karlahe	7.37±0.55	2.53±0.28	0.183±0.11	15.03±1.5	1.03±0.64	61.16±3.403
Dadi	7.04±0.35	5.4733±0.43	0.126±0.01	18.91±1.116	0.73±0.07	59.83±8.51
Dolabi	7.26±0.26	5.05±0.321	0.156±0.06	17.29±0.38	1.59±0.421	51.33±7.094

F calculated (3,6) =2.47; P-value=0.159; P<0.05.

Table 2 highlights the significant correlations between climate variables such as temperature, rainfall, relative humidity, and key soil parameters, revealing how climate change has altered soil conditions in the study area. Temperature was found to have a significant negative correlation with soil pH (-0.844), indicating that increasing temperatures may contribute to soil acidification. This suggests that rising temperatures, often linked to climate change, could lead to more acidic soils, that affect nutrient availability and plant growth. Interestingly, temperature showed a strong positive correlation with phosphorus content (0.968**), suggesting that higher temperatures could enhance phosphorus availability. This may be due to the accelerated rate of organic matter decomposition and Mineralization processes under higher temperatures, which releases more phosphorus into the soil. Rainfall also affects soil parameters, a negative correlation between rainfall and nitrogen content (-0.989**) indicates that increased rainfall may lead to nitrogen losses, likely through leaching processes. Nitrogen, being highly mobile in the soil, is more prone to being washed away during heavy rainfall events, this reduces the presence of nitrogen in crops. Additionally, the negative correlation between rainfall and potassium (-0.824) suggests that excess rain might result in potassium leaching, further reducing soil fertility. Relative Humidity showed a strong positive correlation with soil pH (0.965**), indicating that higher humidity levels may help maintain or increase soil alkalinity. This might be due to reduced evaporation rates, which can slow the loss of basic cations such as calcium and magnesium, helping to maintain a higher pH. On the other hand, relative humidity negatively correlates with phosphorus content (-0.831), which could be due to decreased microbial activity under more humid conditions. This reduction in microbial activity might slow the Mineralization of organic phosphorus, leading to lower phosphorus availability in the soil. These findings illustrate the complex interactions between climate variables and soil properties, suggesting that ongoing climate change can significantly alter soil health and fertility. Understanding these relationships is crucial for developing adaptive strategies to mitigate the impacts on agriculture and ecosystems.

Table 1: Interaction Between Soil Parameters and Climate Indicators

	Soil pH	Organic Matter (%)	Nitrogen (gkg-1)	Phosphorus (gkg-1)	Potassium (cmolkg-1)	Moisture Content (%)	Temperature	Rainfall
Organic Matter (%)	-0.435							
Nitrogen (gkg-1)	0.596	0.344						
Phosphorus (gkg-1)	-0.722	0.932	0.070					
Potassium (cmolkg-1)	0.583	0.460	0.799	0.107				
Moisture Content (%)	-0.301	-0.696	-0.683	-0.390	-0.950**			
Temperature	-0.844	0.846	-0.177	0.968**	-0.059	-0.251		
Rainfall	-0.493	-0.478	-0.989**	-0.208	-0.824	0.752	0.036	
Relative Humidity	0.965 **	-0.614	0.497	-0.831	0.365	-0.054	-0.939	-0.371

*Note: **=significant at a 5% level of Significance*

The findings from this study revealed significant concerns for agricultural sustainability in Namtari and similar regions in Northern Nigeria. The altered temperature and precipitation patterns due to climate change might affect soil health and agricultural productivity (Onyeneke *et al.,* 2019; Ebele and Emodi, 2016). The rising temperature in this region has been linked to accelerated organic matter decomposition and subsequent reductions in soil organic carbon stocks, components for maintaining soil fertility and structure (Akamigbo and Nnaji, 2011; Lal, 2009). This phenomenon threatens soil health, as lower organic carbon levels can lead to diminished nutrient availability and affect microbial activity essential for soil functions (Abiodun *et al.,* 2013). Studies indicate that these temperature increases, coupled with changing precipitation patterns, exacerbate the vulnerability of soils, particularly in arid and semi-arid regions like Northern Nigeria (Akinsanola and Ogunjobi, 2014; Ibrahim *et al.,* 2020).

Changes in precipitation have profound implications for soil moisture levels and nutrient dynamics. Increased rainfall can lead to higher erosion rates and nutrient leaching, resulting in significant soil degradation (Dasgupta *et al.,* 2015; Kehinde *et al.,* 2014). The findings are consistent with the observations of Akande (2021), who noted that variability in rainfall patterns significantly influences soil quality and, consequently, agricultural outputs. In Namtari, these effects are evident as farmers report declining crop yields attributed to altered soil characteristics, necessitating adaptive measures to manage soil health under changing climatic conditions (Lal, 2016). The impacts of climate change on soil health extend beyond the environmental sphere, affecting the socioeconomic fabric of communities reliant on agriculture. As highlighted by Elum *et al.* (2017), the degradation of soil resources Jeopardizes food security, undermining livelihoods and economic stability in rural areas. The findings of this study align with those of Amundson *et al.* (2015), Emphasizing the interdependence between soil health and human security in the face of climate variability. Therefore, understanding these complex interactions is essential for developing strategies beyond soil health preservation, and enhancing community resilience to climate change (Akinyemi, 2019; Børgesen and Olesen, 2011).

In light of these findings, there is an urgent need for adaptive management practices to mitigate climate-induced soil changes. Strategies involving improved irrigation techniques, soil conservation practices, and Fertilizer usage responsive to changing climate conditions are critical (Amos *et al.,* 2015; Akimigbo and Nnaji, 2011). Furthermore, engaging local communities for implementation strategies can enhance their effectiveness and ensure sustainable agricultural practices that align with local needs (Ladan, 2014; Biswas *et al.,* 2019). the study highlights the significant impacts of climate change on soil parameters in Namtari, stressing the need for a concerted effort to address these challenges through adaptive management and policy interventions. Continued research and collaboration among stakeholders will be crucial in fostering resilience against the adverse effects of climate change on soil health and agricultural productivity.

Conclusion: The study reveals significant correlations between climate change variables (temperature, rainfall, humidity) and key soil parameters (pH, organic matter, nutrients) in Namtari, underscoring the detrimental effects of climate change on soil health. Rising temperatures contribute to soil acidification, while increased rainfall leads to nutrient leaching. These changes, coupled with potential impacts on soil structure, microbiome, and carbon sequestration capacity, may threaten crop productivity, food security, and broader ecosystem services. However, to mitigate these impacts, the study recommends implementing sustainable soil management practices, improving irrigation, adopting climate-resilient crops, and strengthening policy support for research, extension services, and nutrition. Additionally, community engagement, policy and institutional support, and international cooperation are crucial to developing and implementing effective adaptation strategies. Further research is necessary to understand the long-term impacts of climate change on soil health and to identify localized adaptation strategies.

Conflict of Interest: The authors declare no conflict of interest.

Data Availability Statement: Data will aways be available upon request from the first author.

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