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Discovery Nature

Analysis of soil and ambient air temperature: Implication for sustainable agricultural practice in Lapai Town, Niger State, Nigeria

Liman HM*, Nwaerema P, Dangana K

To Cite:
Liman HM, Nwaerema P, Dangana K. Analysis of soil and ambient air temperature: Implication for sustainable agricultural practice in Lapai Town, Niger State, Nigeria. *Discovery Nature* 2024; 1: e8dn1033
doi: https://doi.org/10.54905/disssi.v1i2.e8dn1033

Author Affiliation:
Department of Geography, Ibrahim Badamasi Babangida University in Lapai, Niger State, Nigeria

***Corresponding Author**
Department of Geography, Ibrahim Badamasi Babangida University in Lapai, Niger State,
Nigeria
Email: pnwaerema486@gmail.com

Peer-Review History
Received: 25 August 2024
Reviewed & Revised: 29/August/2024 to 18/November/2024
Accepted: 21 November 2024
Published: 25 November 2024

Peer-Review Model
External peer-review was done through double-blind method.

Discovery Nature
pISSN 2319-5703; eISSN 2319-5711

ABSTRACT

This study analyzed soil and ambient air temperature as it applies to sustainable agricultural practice in Lapai Town, Niger State, Nigeria. The data for the study were generated from Ibrahim Badamsi Bangida University meteorological station hosted by the Department of Geography. The study data were collected from January to December in the year 2023. Thus, five (5) sets of automatic soil thermometer were laid at various depths of 5cm, 10cm, 15cm, 20cm and 40cm to capture soil temperature. Ambient air temperature data were generated using the automated air temperature thermometer. Results showed that the month with highest air temperature record was March with the value of 40.60C and soil temperature of 29.30C with a difference of 11.30C. This was seconded by April having air temperature of 38.80C and soil temperature of 29.30C having a difference of 9.50C. The month with least air temperature was September having the value of 29.60C and soil temperature of 29.60C with a difference of 00C. November had the highest of soil temperature record with the value of 29.80C. This was seconded by September and October (29.60C) and thirdly by August and December (29.50C) respectively. The test hypothesis showed that there was no significant difference in soil temperature across the various depths of the soil and that soil and air temperature from January to December do not differ significantly. This study has recommended that warm-weather thriving plants such as millet, guinea corn, maize, wheat, rice, beans should be commercially farmed in Lapai town, Niger State, Nigeria.

Keywords: Agriculture, Ambient, Soil, Sustainability, Temperature

1. INTRODUCTION

Soil moisture is a critical factor in agriculture, influencing various aspects of plant growth and crop production. Adequate soil moisture is linked directly to crop yield. Insufficient moisture can lead to stress on plants, resulting in reduced growth, lower yields and poor-quality produce. Conversely, optimal moisture levels can enhance crop productivity (Achieng and Nyamori, 2022). Soil moisture acts as a reservoir that

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supplies water to crops during dry periods. Thus, good management of soil moisture will bring about continues availability and reduce scarcity and drought. Proper management of soil moist will make farmers to make good decisions on irrigation. Adequate soil moisture promotes use of water, decrease water waste and reduce cost of irrigation thereby improving crop health (Moazzam et al., 2024). Good soil moisture will contributed to healthy ecosystem and function optimization.

This will aid the huge availability of microbial activities, and rise in earthworm population which is very important in nutrient cycling, soil structure and function. However, moist soil is less susceptible to erosion than dry soil, therefore, by proper moisture management, farmers will reduce soil erosion, improve the productivity of land decline environmental effects (Thais et al., 2024). Soil moisture influences local climate conditions around crops. Adequate moisture levels can help moderate temperature extremes, contributing to a more favorable growing environment. It can affect weed growth and pest populations. Maintaining optimal moisture can help suppress weeds and manage pests more effectively contributing to better crop management (Iqbal et al., 2020). With changing climate conditions, effective soil moisture management strategies help agriculture adapt to extreme weather events, such as prolonged droughts or heavy rainfall, thus ensuring food security (Ahmed et al., 2024).

Adequate management of soil moisture will continue to enhance sustainable agricultural practices. This can be achieved through the proper use of soil health and reducing the environmental consequences associated with excessive irrigation and fertilizer use (Sharma et al., 2024). Soil moisture is integral to both the physiological needs of plants and the practice of sustainable agriculture (Hou et al., 2020). On the other hand, the phenomenon of ambient air temperature has to be properly taken care of as it plays critical role in influencing the physiological health condition of the plants. This air temperature has the tendency to affect condition of soil, diseases and pests and the general crop productivity. Thus, ambient air temperature is linked to the process of photosynthesis which plants use the available heat manufacture their own food.

However, optimal ambient air regime will encourage plant growth and excessive ambient air temperature will hinder plant growth (Moore et al., 2021). It is obvious, that various plants have their required temperature for their germination, hence, inadequate temperature will impact plant growth and productivity. Temperature influences flowering time, fruit set and maturity periods. Crops may require specific temperature ranges for optimal reproductive success. The temperature of the air directly affects soil temperature, which in turn influences microbial activity, nutrient availability, and root growth. Warmer soils can enhance microbial processes leading to improved nutrient cycle (Qu et al., 2023). Ambient temperatures dictate the growth stages of plants (phenology), affecting planting and harvest timings. Changes in temperature patterns can shift these timings, potentially impacting yields and quality (Springate and Kover, 2014).

Whenever the heat is in excess, this can result to heat stress to plants thereby impacting crop productivity and quality of yield. Though, some crops and plants are very sensitive to excessive temperature which can lead to their low productivity. Therefore, temperature has the capacity to affect evaporation, transpiration and water availability. Thus, higher temperature will warrant excessive evaporation and transpiration thereby promoting high irrigation cost (Puértolas and Dodd, 2022). Excessive temperature can make crops more susceptible to infestations. Some pests thrive in higher temperatures, which can lead to increased crop damage. As global temperatures increase, understanding and adapting to changes in ambient temperature will be essential for sustainable agriculture.

Farmers may need to adjust planting schedules, crop varieties and management practices to mitigate the impact of temperature changes (Gurdeep et al., 2021). Temperature variations through seasons (wet and dry seasons) impact agricultural practices. Understanding seasonal temperature patterns can aid in planning for planting and harvest times. Overall, ambient air temperature is a fundamental factor that affects multiple aspects of agriculture. Farmers, agronomists and researchers must consider temperature variations and trends to optimize agricultural productivity and sustainability in the face of evolving climatic conditions (Gornall et al., 2010).

2. METHODS

Lapia is located within latitude 902’30”N and 904’10”N and longitude 6032’30”E and 6034’10”E of the GMT (Figure 1). Temperature in Lapai town typically ranges between 25°C and 42°C throughout the year (Olujimi, 2009). The average annual rainfall in Niger State ranges from approximately 900mm to 1,400mm, with variations across different parts of the state (Ejaro and Abdullah, 2023). The geology of the area is primarily composed of sedimentary rocks, including shale, sandstone, limestone and conglomerates, which were formed during various geological periods. Common soil types found in the area include sandy soils, loamy soils, and clayey soils, each with its own properties and agricultural suitability. The population of Lapai town is projected to 30,501 persons at 3.5% growth rate. Data for this study were collected from meteorological station in the Department of Geography, Ibrahim Badamasi Babangida University, Niger State, Nigeria.

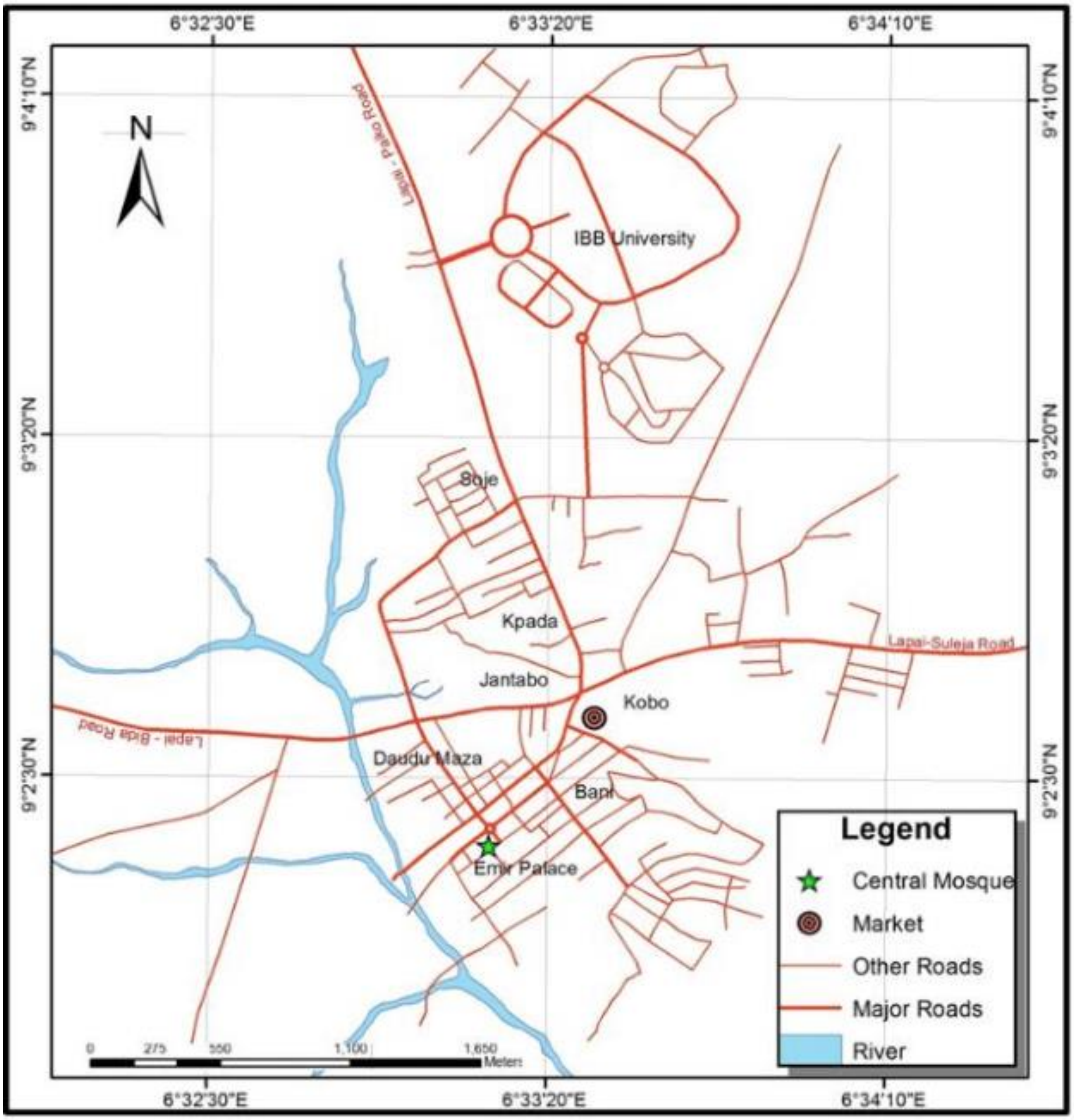

Figure 1 Lapai Study Area showing IBB University

The metrological station was an automated weather center. Thus, five (5) sets of automatic soil thermometer were laid at various depths of 5cm, 10cm, 15cm, 20cm and 40cm respectively to capture soil temperature. On the other hand, ambient air temperature data were generated using the automated air temperature thermometer. The records were transmitted to a computer logger and analyzed on the Microsoft Excel work sheet. The soil temperature and ambient air temperature data generated were for the twelve (12) months in the year 2023 beginning from January to December. Tables were created, mean data were established and represented in bar graphs.

The hypotheses guiding the study established that there is no significant difference in soil temperature across the various depths of the soil. Also, that there is no significant difference in soil temperature and ambient air temperature across the various months of the year. The Analysis of Variance (ANOVA) and student t-Test were the statistical tools used to test the hypotheses.

3. RESULTS AND DISCUSSION

Table 1 and Figure 2 showed soil temperature across various depths and air temperature variability in Lapai town. The month with highest air temperature record was March with the value of 40.60C and soil temperature of 29.30C with a difference of 11.30C. This was seconded by April having air temperature of 38.80C and soil temperature of 29.30C having a difference of 9.50C. The third highest air temperature was recorded in February, having air temperature of 36.60C and soil temperature of 29.30C showing a difference of 7.10C. The month with least air temperature was September having the value of 29.60C and soil temperature of 29.60C with a difference of 00C. The mean annual air temperature during the period under study was 39.90C and mean soil temperature was 29.40C having a mean difference of 4.50C showing that Lapai town is located at warm temperature region of Guinea Savanna that can support warm-weather thriving crops such as millet, guinea corn, wheat, maize, etc.

Soil depth at 5cm and 15cm had the highest temperature of 29.50C respectively. This was followed by 10cm having soil temperature of 29.4cm and the least soil temperature depth was 20cm. There was alternate variation of soil temperature from the top to the bottom soil of (5cm to 40cm). Figure 3 showed that November had the highest of soil temperature record with the value of 29.80C. This was seconded by September and October (29.60C) and thirdly by August and December (29.50C) respectively. The month with the least soil temperature was recorded in January having the value of 29.20C. There was moderate increment of soil moisture from January to July and a sharp rise from August to November and a drastic drop in December. This showed that wet season condition affected soil moisture from July to November thereby allowing crops to thrive better during the wet season.

Table 1 Soil Temperature across Various Depths and Air Temperature Variability

Month /Temp. (oC)	**Soil Temp. (5cm)**	**Soil Temp. (10cm)**	**Soil Temp. (15cm)**	**Soil Temp. (20cm)**	**Soil Temp. (40cm)**	**Mean Soil Temp.**	**Mean Air Temp.**	**Difference Between Soil and Air Temps.**
Jan	29.3	29	29.2	29.1	29.2	29.2	34.1	5
Feb	29.4	29.2	29.3	29.2	29.2	29.3	36.6	7.1
March	29.4	29.2	29.4	29.2	29.2	29.3	40.6	11.3
April	29.4	29.2	29.3	29.2	29.2	29.3	38.8	9.5
May	29.6	29.3	29.5	29.3	29.3	29.4	34.6	5.2
June	29.6	29.3	29.5	29.4	29.3	29.4	32.3	2.9
July	29.5	29.2	29.4	29.3	29.3	29.3	31.2	1.9
Aug	29.7	29.4	29.6	29.4	29.3	29.5	31.6	2.1
Sept	29.8	29.5	29.7	29.5	29.4	29.6	29.6	0
Oct	29.8	29.6	29.7	29.5	29.5	29.6	31.4	1.8
Nov	30.0	29.7	29.9	29.7	29.6	29.8	33.4	3.6
Dec	28.7	29.6	29.8	29.6	29.6	29.5	33.6	4.1
Mean	29.5	29.4	29.5	29.1	29.3	29.4	39.9	4.5

The first null hypothesis (HO1) that guided this study seeks to establish that there is no significant difference in soil temperature across the various depths of the soil (Table 2). Soil moisture has P-value of 0.107476 with 4 and 50 Degrees of Freedom (D.F) in a two-tailed at 0.05 Significant Levels (SL). The computation shows that P-value of 1.107478 is greater than 0.05, therefore the hypothesis that there is no significant difference in soil temperature across the various depths of the soil is accepted. This exposes the fact that soil temperature from 5cm to 40cm does not differ significantly.

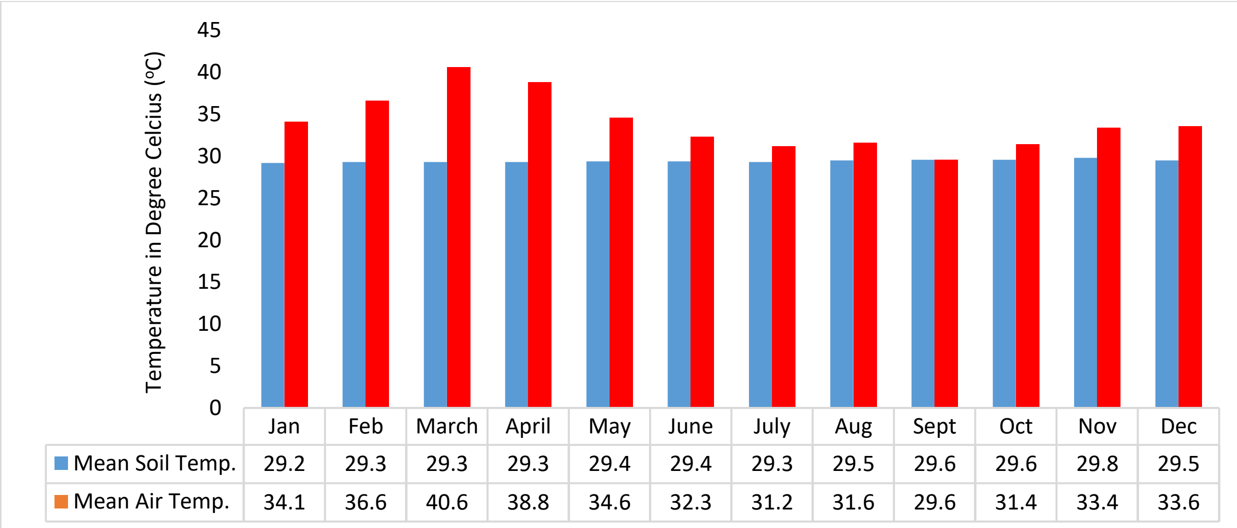

Figure 2 Mean Soil and Ambient Air Temperatures across different Months of the Year

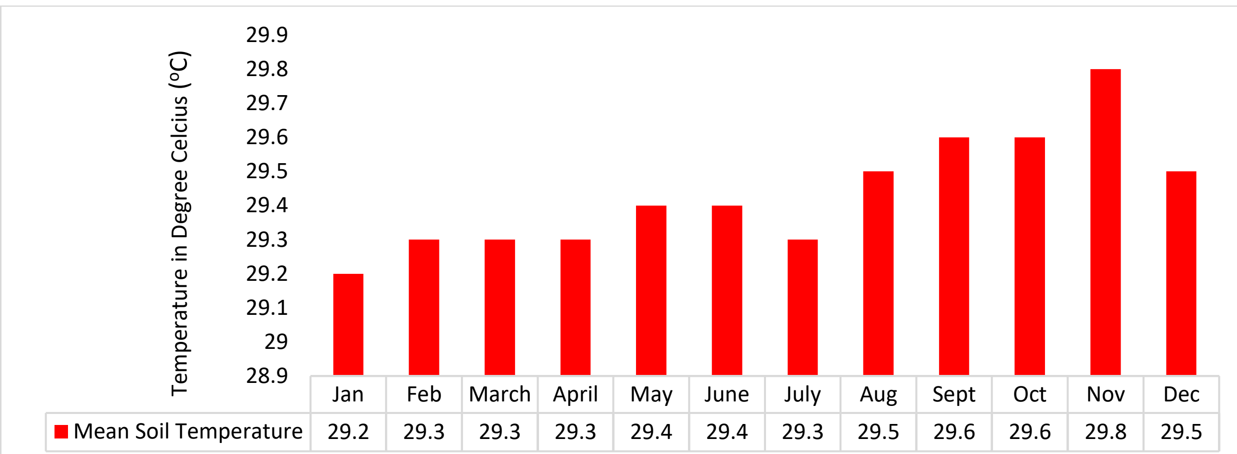

Figure 3 Soil Temperature across different Months of the Year

Table 2 ANOVA Test Explaining significant in soil temperature across the various depths of the soil

SUMMARY						
Groups	*Count*	*Sum*	*Average*	*Variance*		
29.3	11	324.9	29.53636	0.114545		
29	11	323.2	29.38182	0.035636		
29.2	11	325.1	29.55455	0.040727		
29.1	11	323.3	29.39091	0.028909		
29.2	11	322.9	29.35455	0.022727		
ANOVA						
Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	0.389818	4	0.097455	2.008996	0.107476	2.557179
Within Groups	2.425455	50	0.048509	-	-	-
Total	2.815273	54	-	-	-	-

The second null hypothesis (HO2) that guided this study considers that there is no significant difference in soil temperature and ambient air temperature across the various months of the year (Table 3). The computation shows that soil temperature and ambient air temperature have P-value of 0.001637 with 10 Degrees of Freedom (D.F) in a two-tailed at 0.05 Significant Levels (SL). The record shows that that P-value of 0.001637 is lesser than 0.05, therefore the hypothesis that there is no significant difference in soil temperature and ambient air temperature across the various months of the year is rejected. This exposes the fact that soil temperature and air temperature from January to December does differ significantly.

Table 3 Student t-Test Explaining significant difference in soil temperature and ambient air temperature across the various months of the year

t-Test: Paired Two Sample for Means		
	29.2	*34.1*
Mean	29.45455	33.97273
Variance	0.026727	11.68418
Observations	11	11
Pearson Correlation	-0.54107	-
Hypothesized Mean Difference	0	-
df	10	-
t Stat	-4.27004	-
P(T<=t) one-tail	0.000818	-
t Critical one-tail	1.812461	-
P(T<=t) two-tail	0.001637	-
t Critical two-tail	2.228139	-

The high air temperatures of Lapai town could be influenced by a variety of natural and human-induced factors such as seasonal changes (wet and dry seasons). Seasonal transitions, particularly dry season, naturally lead to higher temperatures due to increased solar radiation. Thus, areas closer to the equator generally experience higher temperatures due to more direct sunlight year-round which Lapai town is one the towns. Also, lower altitudes tend to have warmer temperatures. Mountainous regions can experience cooler temperatures but valleys and lowlands may be warmer. Other factors that could result to high ambient air temperature of Lapai town could be urban heat island (UHI), climate change, industrial emissions, agricultural practices, land use change and air pollution. For the soil temperature of Lapai town could be influenced by climate and weather conditions, soil properties, moisture contents, vegetation cover, soil management practices, vegetation cover, seasonal changes and surface cover respectively.

This study showed that soil temperature did not significantly vary from top layer (5cm) to bottom layer (40cm). This is similar to the findings of Tang et al., (2022) who studied soil temperature variability under different land use types and depths. The findings unveiled that air temperature and humidity were the parameters determining the changes in soil temperature and moisture levels in the depth between 0–60cm of the soil. However, humidity and wind speed were the variables influencing soil temperature and moisture changes especially in maize terraced field and soil moisture; and soil temperature were all negatively correlated under the four studied land use types. Thus, air temperature had a high correlation with soil temperature in the 0–60 cm soil layer under the four sloping land use types.

Also, this study results show that soil temperature and ambient air temperature differ from January to December. This is similar to the findings of Reidsma et al., (2007) who revealed that ambient temperatures throughout the year influence agricultural yields, analyzing temperature data from January to December. It revealed that a 2°C local warming in the mid-latitudes could raise wheat production by nearly 10 per cent whereas at low latitudes the same amount of warming may reduce yields by nearly the same amount from January to December. Thus, different crops show different sensitivities to warming in different months of the year therefore reveled the uncertainties in crop yield changes for a given level of warming in various months of the year.

4. CONCLUSION

This study investigated soil and ambient air temperature, implication for sustainable agricultural practice in Lapai Town, Niger State, Nigeria. Soil temperature and ambient air temperature are critical factors for increased crop yield. However, increasing soil temperature can have both positive and negative effects on crop yields. Higher soil temperatures can enhance microbial activity and nutrient availability but may also lead to water stress and stress on crop plants if temperatures exceed optimal ranges.

Therefore, for farmers to increase crop yield in Lapai, there is need to associate farming with irrigation, mulching, soil management practices, crop variety selection, improve soil health, planting time adjustment, use of shade and windbreaks, fertility management, pest and disease management and research and extension services. By properly managing soil temperature and implementing these strategies, farmers can enhance agricultural productivity by adapting to the effects of climate change on crop growth. Thus, it is concluded that warm-weather thriving plants such as millet, guinea corn, maize, wheat, rice, beans etc should be commercially farmed in Lapai town, Niger State, Nigeria.

Acknowledgement

We thank the participants who contributed samples to the study.

Author Contributions

Liman HM develop the literature section of the study. Nwaerema P conducted the data analysis and Dangana K discussed the results. All authors conducted the internal review of the study.

Informed consent

Not applicable.

Ethical approval

Not applicable.

Conflicts of interests

The authors declare that there are no conflicts of interests.

Funding

The study has not received any external funding.

Data and materials availability

All data associated with this study are present in the paper.

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