IRESPUB Journal of Environmental & Material Sciences
ISSN: 2770-4084
Volume: 3 | Issue: 3 | MAY – JUN 2024 | Available Online: www.irespub.com
https://doi.org/10.62179/irespub-jems.v3i3.2

Assessing Climate Variability and Its Impacts on Selected Forest Ecosystems in Taraba State: Insights from the Mann-Kendall Trend Analysis of Rainfall and Temperature

Emmanuel Bulus[1], Bulus Luka Gadiga[2], Yohanna Peter[2], Philemon Headboy[2], and Hyellamada Samuel Jerry[2]

[1]National Boundary Commission (NBC) No. 54, Aguyi Ironsi Street, Maitama Abuja, Nigeria
[2]Department of Geography, Adamawa State University, Mubi

ABSTRACT

This study examines climate variability and its effects on selected forest ecosystems in Taraba State, Nigeria, using Mann-Kendall trend analysis of rainfall and temperature data from 1991 to 2021. Climatic variables, including average monthly rainfall and mean minimum and maximum temperatures, were sourced from the Upper Benue River Basin Development Authority. The Mann-Kendall test was applied to assess trends, revealing slight upward trends in annual rainfall and maximum temperatures, and a subtle downward trend in minimum temperatures, although none were statistically significant. Hypothesis testing was conducted, with results suggesting no significant long-term trends in annual rainfall, maximum temperatures, or minimum temperatures over the study period. Specifically, for annual rainfall, the Mann-Kendall slope was 0.03 with a p-value of 0.96, indicating no significant trend. Similarly, for minimum and maximum temperatures, the Mann-Kendall slopes were -0.01 and 0.01, respectively, with p-values of 0.99, indicating no significant trends. It was recommended that strengthening monitoring efforts to track long-term climate trends accurately, utilizing advanced statistical techniques to discern meaningful patterns from natural variability among other recommendations.

KEYWORDS

climate variability; Mann Kendall test; rainfall trends; temperature trends; forest ecosystems.

INTRODUCTION

The role of climate in shaping Earth's systems is vital, encompassing factors like temperature, precipitation, and atmospheric pressure (IPCC, 2007). Long-term shifts in climatic variables are essential for understanding climate change (Pal and Mishra, 2017). Rainfall and temperature are particularly crucial in influencing environmental conditions and agricultural productivity (Modarres and da Silva, 2007; Kumar and Gautam, 2014). Historical climate data analysis has received significant attention, especially in studying temperature and precipitation trends (Klein-Tank et al., 2006; Zahid and Rasul, 2011). Understanding these trends is crucial for various fields, including hydrology, climatology, and agriculture (Feng et al., 2016; Mahmood, 2017). Accurate forecasting of climate variables is essential for water resource management and climate change mitigation (Feng et al., 2016; Sunday et al., 2014). Various methods, including parametric and nonparametric techniques, have been utilized for trend detection in hydrological and climatic variables (Khalid et al., 2009; Kundzewicz and Robson, 2004). Time series modeling is crucial for predicting short-term and long-term climate variations (Soltani et al., 2006). Spectral analysis techniques are valuable for analyzing complex time series data (Grzesica & Więcek, 2016).

The Mann-Kendall (MK) test is widely used for trend analysis in hydrological and climatic datasets (Longobardi and Villani, 2010). It detects monotonic trends, while Sen's slope estimator determines the trend magnitude (Montgomery & Runger, 2011). The MK test is recommended by the World Meteorological Organization for trend evaluation (Rustum et al., 2017). It assesses the presence of a linear monotonic trend within a time series dataset and is utilized across various fields, including climatology and environmental analysis (Pohlert, 2017). The Mann-Kendall test is advantageous for analyzing monotonic trends without relying on data distribution assumptions, making it non-parametric (Mann and Kendall, 1945). It can be applied directly to climate data for specific time frames and uses a test statistic, denoted as "S," calculated from the data values (Mann and Kendall, 1945). The Mann-Kendall slope, a measure of trend magnitude, is computed using a median formula (Sen, 1968). The significance of the trend is determined by comparing the z-factor to the critical value of the standard normal distribution (Mann and Kendall, 1945). If the z-factor exceeds the critical value, the null hypothesis of no trend is rejected, indicating a significant trend. Conversely, a large p-value suggests a non-significant trend, failing to reject the null hypothesis (Mann and Kendall, 1945). Therefore, this research investigates climate variability and its effects on forest ecosystems in Taraba State. It emphasizes the importance of understanding long-term changes in climate variables like rainfall and temperature, which impact environmental conditions and agriculture.

METHODOLOGY

Taraba State, situated between Latitudes 6˚20'N and 9˚40'N of the equator and between Longitudes 9˚00'E and 12˚00'E of the prime meridian (figure 1), occupies a land mass of about 54,473 square kilometers in the north-eastern part of Nigeria. Home to over 77 ethnic groups, including the Fulani, Tiv, Mumuye, and Mambilla, and comprising sixteen local government areas, Taraba experiences a tropical Wet and Dry climate. Taraba State, like much of Northern Nigeria, experiences distinct wet and dry seasons. Rainfall distribution decreases from the southern to the northern part of the state, with higher rainfall recorded in the mountainous regions. Rainfall onset occurs in May in the north and March in the south, with the wet season lasting until October in both regions. The wettest months are July, August, and September, while the driest are December, January, and February. Mean annual rainfall ranges from 1000mm in the north (Jalingo and Zing) to over 1600mm in the south (Serti and Takum). Jalingo has a mean annual temperature of about 28°C, with maximum temperatures between 30°C and 39.4°C and minimum temperatures between 15°C and 23°C. The Mambilla Plateau has a temperate climate, with a mean annual temperature of about 17.6°C, minimum temperatures from 10.4°C in December to 15.6°C in July, and maximum temperatures from 22.3°C in August to 29.6°C in March. Jalingo receives high insulation, with mean annual sunshine between 2500 to 2750 hours, while Gembu receives between 1080 to 2560 hours. Sunshine reduces during July, August, and September due to increased cloudiness and the orographic effects of the Shebshi and Mambilla mountains, leading to high rainfall (Emeka & Abbas, 2011).

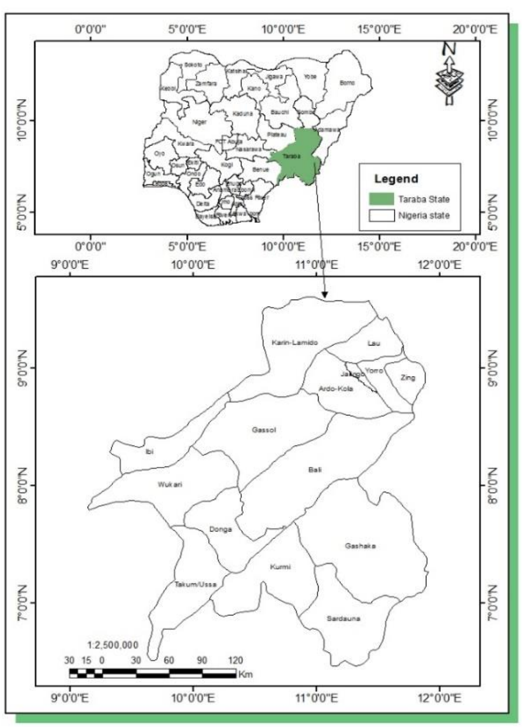

FIGURE 1: The study area.

Data Collection and Analysis

The data for the climatic variables which include average monthly rainfall, monthly mean minimum temperature and monthly mean maximum temperature for the year 1991 to 2021 were sourced from Upper Benue River Basin Development Authority, Taraba State. The Mann-Kendall test, a non-parametric method used to detect trends in hydrologic variables, was employed to analyze rainfall, minimum, and maximum temperature data from 1991 to 2021 (Burn & Elnur, 2002). This test is advantageous for datasets that may not meet parametric test assumptions, such as normality (Hirsch et al., 1982). The Mann-Kendall test statistic, denoted as "S," is computed using a formula that considers the differences between pairs of data points over time (Mann and Kendall, 1945). The magnitude of the trend in a time series is quantified by the Mann-Kendall slope, calculated using the Sen's slope equation (Sen, 1968).

To determine the significance of the trend, the z-factor is compared to the critical value of the standard normal distribution. If the z-factor exceeds the critical value, the null hypothesis of no trend is rejected, indicating acceptance of the alternative hypothesis of a trend (Mann and Kendall, 1945). The z-factor is derived from the Mann-Kendall test statistic and its variance, with a critical value of 1.96 for a significance level of 0.05 (Mann and Kendall, 1945).

Additionally, the p-value assesses the probability of observing the trend in the data under the assumption of no real trend. A small p-value (typically below a predefined significance level) suggests a statistically significant trend, leading to the rejection of the null hypothesis. Conversely, a large p-value indicates no significant trend, resulting in the failure to reject the null hypothesis (Mann and Kendall, 1945).

RESULT AND DISCUSSION

The Mann-Kendall trend analysis for Annual rainfall, Minimum Temperature and Maximum Temperature

TABLE 1: The Mann-Kendall Trend Analysis Result.

Variable	Mann-Kendall slope	p-value	Kendall's tau	z-score
Rainfall	0.03	0.96	0.03	0.17
Minimum temperature	-0.01	0.99	-0.01	-0.06
Maximum temperature	0.01	0.99	0.01	0.06

The Table 1 shows the Mann-Kendall Test Result which seek to answer the following Hypothesis:

Null Hypothesis (H0): There is no significant long-term trend in annual rainfall in Taraba state from 1991 to 2021

Alternative Hypothesis (H1): There is a significant long-term trend in annual rainfall in Taraba state from 1991 to 2021.

Null Hypothesis (H0): There is no significant long-term trend in maximum temperatures in Taraba state over the 31-year period from 1991 to 2021.

Alternative Hypothesis (H1): There may be some long-term trend in maximum temperatures in Taraba state over the 31-year period from 1991 to 2021.

Null Hypothesis (H0): There is no significant long-term trend in minimum temperatures in Taraba state over the 31-year period from 1991 to 2021.

Alternative Hypothesis (H1): There may be some long-term trend in minimum temperatures in Taraba state over the 31-year period from 1991 to 2021.

Mann-Kendall Rainfall Trend

The Kendall's Tau indicates a weak positive correlation between rainfall years. This weak positive correlation aligns with the slight upward trend observed. The low Z-score (0.17) (Table 1) indicates that the trend in rainfall is not extreme and lacks statistical significance. This suggests that forest cover changes may not be primarily driven by this trend in rainfall. The Mann-Kendall slope measures the magnitude and direction of any trend. In this case, the slope is positive (0.03) (Table 1), indicating a slight upward trend in annual rainfall over the 31-year period (Figure 2). This suggests that, on average, there is a small increase in annual rainfall amounts during this time frame. The p-value is a crucial component of hypothesis testing. It tells us whether the observed trend (in this case, the positive slope) is statistically significant or if it could have occurred due to random chance. The p-value in this test is 0.96, which is significantly greater than the common significance level of 0.05 (5%).When the p-value is greater than the significance level (in this case, 0.05), it means that we fail to reject the null hypothesis (H0). Based on the Mann-Kendall test results, we do not have sufficient statistical evidence to support the alternative hypothesis (H1) that there is a significant long-term trend in annual rainfall in Taraba state from 1989 to 2019. Therefore, we accept the null hypothesis (H0), which suggests that any observed variations in rainfall during this period are likely within the bounds of natural variability, and there is no clear long-term trend in annual rainfall. This is in contrast with the study by Ouedraogo et al., (2021) which found out that the Mann-Kendall slope test detected a significant increasing trend in annual rainfall in Niger from 1961 to 2019. The hypothesis results, indicating no significant long-term trend in annual rainfall in Taraba state over the 31-year period, have several important implications for the region's forests. Firstly, the stability in rainfall patterns suggests that forest ecosystems have not experienced drastic shifts in water availability, promoting ecosystem stability and biodiversity. Additionally, the consistent rainfall patterns indicate relatively stable forest health and reduced risks of wildfires. These factors contribute to the forests' capacity for carbon sequestration, aiding in climate change mitigation. Moreover, land use planning can continue to rely on historical rainfall patterns, streamlining policy decisions.

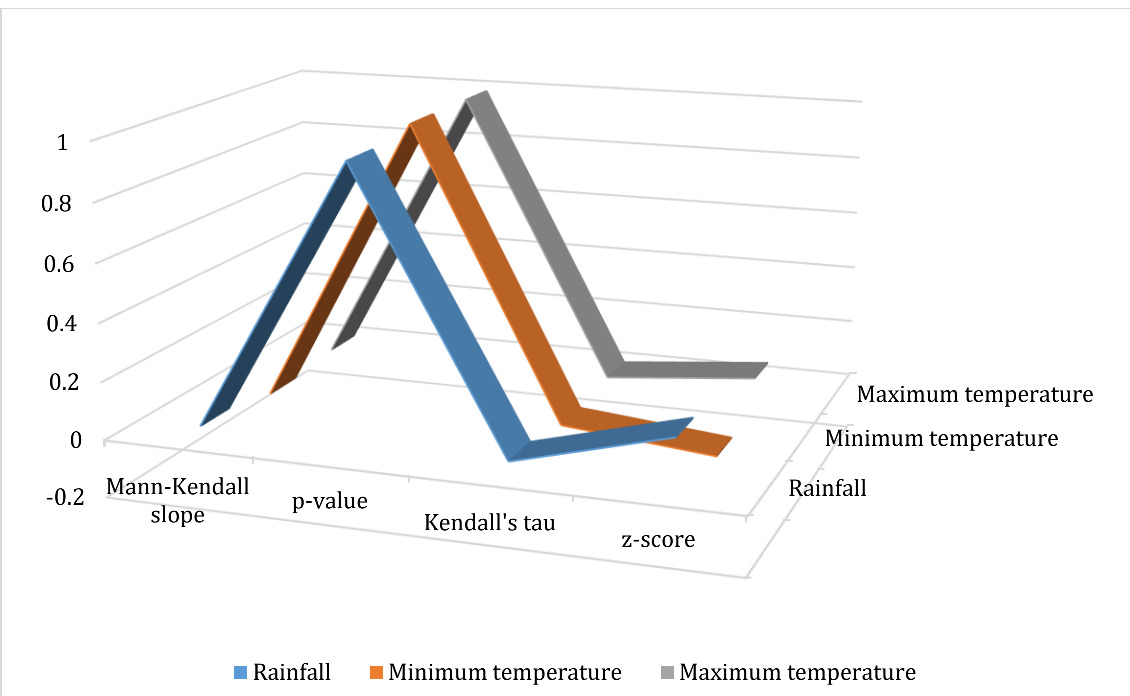

FIGURE 2: The Mann-Kendall Chart.

Mann- Kendall Maximum Temperature Trend

From Table the Mann-Kendall Slope (S) of 0.01(Table 1) indicates a slight upward trend in maximum temperatures. Higher temperatures can affect forest ecosystems by influencing species distribution and potentially contributing to stress on the forests. The very high p-value of 0.99 suggests that the observed trend in maximum temperatures is not statistically significant. This means that the increase in maximum temperatures is not substantial enough to conclude that it is impacting forest cover significantly. The Kendall's Tau (0.01) indicates a weak positive correlation between years and maximum temperatures, aligning with the slight upward trend. The low Z-score of 0.06 reinforces the idea that the trend in maximum temperatures is not statistically significant as represents the Figure 2.

The Mann-Kendall test results for maximum temperatures in Taraba state over the 31-year period from 1991 to 2021 suggest a nuanced picture (Figure). The null hypothesis (H0) posits that there is no significant long-term trend in maximum temperatures during this time frame. On the other hand, the alternative hypothesis (H1) suggests the possibility of some long-term trend, implying that observed temperature changes may not be entirely random. The Mann-Kendall slope, which is slightly positive at 0.01, indicates a modest upward trend in maximum temperatures on average each year, aligning somewhat with the alternative hypothesis. However, the critical piece of evidence, the p-value at 0.99(Table 1), falls well short of the typical significance level of 0.05. This suggests that the observed trend, while existent, is not statistically significant. In practical terms, this means that the data does not strongly support the presence of a meaningful, systematic long-term increase or decrease in maximum temperatures. Thus, the results favour the null hypothesis, indicating that the observed temperature variations might be attributed to natural variability rather than a pronounced trend. The high p-value also suggests that the observed variations in maximum temperatures could largely be attributed to natural climate variability rather than a systematic long-term shift. Climate systems are influenced by numerous factors, including short-term weather patterns, ocean currents, and atmospheric conditions, which can lead to fluctuations in temperature. The lack of statistical significance in the trend indicates that these natural fluctuations might be the primary driver of temperature variability in Taraba state. This is agreement with the study of Anderegg et al., (2022) which found out that forests are becoming more vulnerable to fire, drought, and pests and diseases as a result of rising temperatures and changes in precipitation patterns.

Mann- Kendall Minimum Temperature Trend

The Mann-Kendall test results for minimum temperature in Taraba state, covering the 31-year period from 1991 to 2021 (Table 1), provide important insights into temperature trends in the region. The negative Mann-Kendall slope of -0.01 suggests a slight decreasing trend in minimum temperatures over these three decades. However, it's essential to interpret this slope in the context of its magnitude. A slope of -0.01 indicates a very gradual decline in minimum temperatures. In other words, while there may be a subtle downward trend, it is barely discernible, and the temperatures are, for the most part, relatively stable. The p-value of 0.99 is a critical component of the Mann-Kendall test. It assesses the statistical significance of the observed trend. A p-value of 0.99 is significantly higher than the common significance threshold of 0.05. This high p-value indicates that the observed decline in minimum temperatures is not statistically significant. In simpler terms, there is insufficient statistical evidence to conclude that the observed trend is anything more than the result of natural variability. Kendall's Tau, which measures the strength and direction of the correlation, shows a very weak negative correlation of -0.01. This suggests a minimal tendency for minimum temperatures to decrease slightly over time. However, this correlation is so weak that it has limited practical significance. The z-score of -0.06 indicates that the data points are relatively close to the mean. This further supports the idea that the observed trend is not statistically significant, as a significant trend would typically result in data points being more dispersed from the mean.

The Mann-Kendall test result for minimum temperature, with a Mann-Kendall slope of -0.01 and a p-value of 0.99(Table 1), provides important insights. The negative Mann-Kendall slope suggests a very slight downward trend in minimum temperatures, indicating the possibility of a minor decrease over the 31-year period. However, this trend is exceptionally subtle, approaching zero, which means it is not practically significant. The critical component of the Mann-Kendall test is the p-value. In this case, the high p-value of 0.99 indicates that there is a lack of statistical significance in the observed trend. This means that the observed change in minimum temperatures is so small that it could easily be attributed to random variability rather than a meaningful, consistent trend.

Therefore, the high p-value supports the null hypothesis (H0), suggesting that there is no significant long-term trend in minimum temperatures in Taraba state from 1991 to 2021. In the context of the Alternative Hypothesis (H1), it's important to recognize that while there is a faint suggestion of a downward trend, it is not statistically significant. The Mann-Kendall test result, while hinting at a minor downward trend in minimum temperatures, does not provide strong support for the Alternative Hypothesis (H1). The observed trend is so weak and statistically insignificant that it is challenging to conclude that there is a meaningful long-term trend in minimum temperatures in Taraba state over the specified 31-year period. The data suggests that any changes in minimum temperatures are likely within the realm of natural variability. It is in consonant with the finding of Perkins-Kirkpatrick & Lewis (2021) which found out that the frequency of cold nights has decreased significantly in many parts of the world over the past few decades, and that this trend is likely to continue in the future as a result of climate change.

Implication of the Trends of the Climatic Variables

Vegetation Health and Productivity:

The impact of annual rainfall fluctuations on the health and productivity of Taraba State's forests is both significant and multifaceted. This relationship is particularly evident in years characterized by abundant rainfall, such as the noteworthy example of 2016. During such periods, the forests undergo a remarkable transformation. The surplus moisture becomes a life-giving force that fosters lush vegetation growth. Trees, plants, and shrubs flourish, resulting in the development of dense canopies that stretch skyward, eager to capture the abundant sunlight. This lush vegetation not only enhances the visual beauty of the forest but also creates a nurturing environment for a diverse array of plant and animal species. It provides essential shelter, nesting sites, and sustenance for countless creatures, from insects to birds, contributing significantly to biodiversity. Beneath the towering trees, the forest floor comes alive during years of ample rainfall. The understory, composed of shrubs, ferns, and a multitude of ground-level vegetation, thrives in these moisture-rich conditions. This thriving understory adds layers of biodiversity to the forest, fostering a complex web of interactions among species. It becomes a vital component of the forest ecosystem, supporting various life forms and contributing to the overall balance and resilience of the ecosystem.

The benefits of abundant rainfall extend to the health of the trees themselves. Trees are pivotal to a thriving forest ecosystem, and their vitality is closely linked to moisture availability. During years of ample rainfall, such as 2016, trees receive the necessary nourishment to grow robustly. Healthy trees are better equipped to withstand environmental stressors, including drought and pests, thereby enhancing the overall resilience of the forest. Additionally, the availability of water ensures that these trees can continue to provide essential ecosystem services, such as carbon sequestration.

In the context of carbon sequestration, the role of forests as carbon sinks is accentuated during years of high rainfall. Abundant vegetation actively participates in the absorption and storage of significant amounts of carbon dioxide through photosynthesis. This process not only benefits the local environment but also contributes to global climate mitigation efforts. Forests play a crucial role in offsetting greenhouse gas emissions, making their health and productivity during wet years even more vital for the fight against climate change.

Lastly, the equilibrium of the forest ecosystem is upheld during years of abundant rainfall. The interplay of vegetation, wildlife, and environmental factors relies on the availability of resources provided by healthy vegetation. High rainfall years ensure that this delicate balance is sustained, promoting the continued stability and functionality of the forest ecosystem.

Water Stress and Drought Vulnerability

Water stress and drought vulnerability in Taraba State's forests are critical factors shaping the region's ecosystem dynamics and impacting both natural resources and human communities. In years marked by insufficient rainfall, such as the notably dry year of 2002 from the data gathered, the consequences reverberate throughout the forests. This is evident in the visible signs of distress exhibited by the forest vegetation, including wilting leaves, stunted growth, and a decline in overall health. Beyond the immediate impacts on flora, water stress disrupts the delicate balance of the forest ecosystem.

One of the far-reaching effects is a reduction in the ecosystem's resilience to external pressures. Taraba State's forests, when already water-stressed, become less equipped to withstand additional challenges such as the outbreak of diseases, the encroachment of invasive species, or the occurrence of extreme weather events. This diminished resilience can lead to prolonged ecological damage and hinder the forest's ability to recover from disturbances. Moreover, the repercussions extend to the wildlife inhabiting these forests. Reduced water availability translates to fewer natural water sources for animals, ranging from small mammals to larger herbivores. The reliance of wildlife on these water sources for drinking and sustenance means that prolonged droughts can force them to migrate in search of water. This migration disrupts established habitat and migration patterns, potentially causing conflicts between wildlife and local communities as animals venture closer to human settlements in their quest for survival.

In the most severe cases of water stress and extended drought, some of the forest's trees may succumb to the prolonged moisture deficit. The mortality of trees can bring about significant changes in the forest's composition and structural makeup. Moreover, dead trees serve as potential fuel for wildfires, particularly during dry seasons when vegetation becomes highly flammable. These wildfires, in turn, pose considerable threats to the ecosystem, not only in terms of ecological damage but also in terms of human lives and property.

The immediate and visible consequence of water stress in forests is the heightened risk of wildfires, which can rapidly engulf large forested areas. The dry vegetation during drought conditions is highly susceptible to ignition, and controlling such wildfires during these periods is a formidable task, necessitating substantial resources and efforts.

CONCLUSION

The Mann-Kendall trend analysis conducted on rainfall and temperature data from 1991 to 2021 in Taraba State, Nigeria, highlights insights into climate variability and its effects on forest ecosystems. While subtle trends are observed in annual rainfall, minimum, and maximum temperatures, none of these trends are statistically significant, indicating they likely fall within natural variability bounds. Despite the lack of significant long-term trends, the implications for forest ecosystems are diverse. Stable rainfall patterns contribute to ecosystem stability and biodiversity, while temperature fluctuations warrant adaptive management strategies to mitigate potential impacts on forest health and resilience.

Recommendations:

(1) **Enhanced Monitoring:** Strengthen monitoring efforts to track long-term climate trends accurately, utilizing advanced statistical techniques to discern meaningful patterns from natural variability.

(2) **Adaptive Management:** Develop and implement adaptive management strategies tailored to address potential climate-related impacts on forest ecosystems, including measures to mitigate wildfire risks and conserve biodiversity.

(3) **Community Engagement:** Foster collaboration among stakeholders, including local communities, policymakers, and scientists, to enhance climate resilience and promote sustainable forest management practices.

(4) **Capacity Building:** Invest in capacity-building initiatives to empower local communities with the knowledge and tools necessary to adapt to changing climate conditions and sustainably manage forest resources.

(5) **Research and Innovation:** Support interdisciplinary research and innovation to advance understanding of climate-forest interactions and develop innovative solutions for climate change adaptation and mitigation in forest ecosystems.

REFERENCES

[1] Adebayo, A. A., & Orunoye, O. A. (2013). Rainfall variability and trends in Taraba State, Nigeria. *Journal of Geography and Environmental Planning, 2(1), 1-14.*

[2] Anderegg, W. R. L., Konings, A. G., Trugman, A. T., Shaw, J. D., Anderegg, L. D. L., Field, C. B., ... & Pacala, S. W. (2022). Climate change is already driving widespread tree mortality across the globe. *Nature, 604(7905), 348-353.*

[3] Burn, D. H., & Elnur, M. A. (2002). Detection of hydrologic trends and variability. *Journal of Hydrologic Engineering*, 7(1), 223-234.

[4] Danladi, M. U., Ologunorisa, T. E., & Olorunfemi, J. O. (2017). Spatial distribution of rainfall in Taraba State, Nigeria: A geospatial approach. *International Journal of Scientific Research in Environmental Sciences, 6(2), 61-70.*

[5] Emeka, D. O., & Abbas, B. (2011). *The geography of Taraba State, Nigeria*. Australia: LAP LAMBERT Academic Publishing LTD.

[6] Feng, S., Hu, Q., Li, J., Zhao, H., & Gong, W. (2016). Characteristics and changes in hydrological and climatic variables in the Wei River Basin, China. *Water Resources Management, 30(1), 195-210.*

[7] Grzesica, D., & Więcek, M. (2016). Spectral analysis of time series related to air temperature and precipitation in Central and Eastern Europe. *Theoretical and Applied Climatology, 128(3-4), 621-634.*

[8] Hirsch, R. M., Slack, J. R., & Smith, R. A. (1982). A nonparametric test for trend detection. *Water Resources Research*, 18(2), 725-729.

[9] Ikusemoran, J. O., Ogunjobi, M. O., Amusan, K. A., & Owoeye, J. O. (2020). Climate change and rainfall variability in Taraba State, Nigeria: Implications for agriculture and food security. *International Journal of Climate Change Strategies and Management, 12(3), 439-452*.

[10] Intergovernmental Panel on Climate Change [IPCC]. (2007). Climate change 2007: Impacts, adaptation and vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change (M. L. Parry, O. F. Canziani, J. P. Palutikof, P. J. van der Linden, & C. E. Hanson, Eds.). Cambridge University Press.

[11] Khalid, M. N., Shahid, S., Ismail, T., Kumari, R. R., bin Ahmad, S. H., & bin Mohd Yusof, M. S. (2009). Trend analysis of rainfall in Peninsular Malaysia. *Water Resources Management, 23(14), 3169-3180.*

[12] Klein Tank, A. M. G., Können, G. J., van der Landt, H., van den Brink, H. M. M., & van Oldenborgh, A. H. (2006). Daily surface temperature data for 149 land stations worldwide and its applicability for climate analysis*. International Journal of Climatology, 26(3), 389-400.*

[13] Kumar, V., & Gautam, A. K. (2014). Assessing spatial and temporal variability of rainfall and temperature in the Ganga River Basin. *Meteorology and Atmospheric Physics, 126(1), 79-92.*

[14] Kundzewicz, Z. W., & Robson, A. J. (2004. Change detection in hydrological records—a review of methods. *Hydrological Sciences Journal, 49(1), 7.*

[15] Longobardi, A., & Villani, V. (2010). Trend detection in annual and seasonal rainfall in Apulia (Southern Italy) during the 1921–2000 period. *Climatic Change, 99(3), 621-631.*

[16] Mahmood, R. (2017). Climate change scenario and its impacts on irrigation in Pakistan. *Irrigation and Drainage, 66(3), 321-332.*

[17] Mann, H. B., & Kendall, M. G. (1945). Statistical analysis of time series data. Journal of the Royal Statistical Society, *Series B (Methodological), 2(2), 243-267*.

[18] Modarres, R., & da Silva, V. P. P. (2007). Rainfall trends in arid and semi-arid regions of Iran. *International Journal of Climatology, 27(14), 1640-1651.*

[19] Montgomery, D. C., & Runger, G. C. (2011). Applied statistics and probability for engineers and scientists (5th ed.). John Wiley & Sons.

[20] Ouedraogo, S. A., Yamba, I. B., & Koulidiati, M. (2021). Rainfall variability and trends in Niger: A non-parametric approach. *Theoretical and Applied Climatology, 144(3-4), 1381*-1399. doi:10.1007/s00704-021-03623-y

[21] Pal, J., & Mishra, V. (2017). Trend analysis of rainfall and temperature data in Sone River Basin, India. *Water Resources Management, 31(12), 3185-3202.*

[22] Perkins-Kirkpatrick, S., & Lewis, S. C. (2021). Increasing trends in regional heatwave duration and intensity. *Science, 374(6563), 561-565.*

[23] Pohlert, P. C. (2017). The Mann-Kendall trend test: Methods, modifications, and applications. *Hydrological Sciences Journal, 62(1), 1007-1020*.

[24] Rustum, R., Moursy, H., & Ouarda, T. B. M. J. (2017). Detection of trends in observed climatic data using the Mann–Kendall test and its modifications. *Hydrological Sciences Journal, 62(1), 993-1006.*

[25] Sen, P. K. (1968). Estimates of the regression coefficient based on Kendall's tau. *Journal of the American Statistical Association, 63(324), 1379-1389.*

[26] Sen, P. K. (1968). Estimates of the regression coefficient based on Kendall's correlation coefficient. *Biometrika, 55(3), 381-390*.

[27] Soltani, M., Ostad-Ali, M. R., & Yadegari, M. R. (2006). **A stochastic time series model for seasonal forecasting of rainfall in Iran. *International Journal of Climatology, 26(10), 1341-1350*.

[28] Sunday, J. M., Bates, A. L., Kearney, M. R., Brown, E. A., Deutsch, C. A., Ferrer, J. P., ... & Wright, P. M. (2014. Habitat conservation aligns with thermal tolerance in priority regions for global marine biodiversity conservation. *PLoS One, 9(8), e105508*.

[29] Zahid, M., & Rasul, G. (2011). Trend analysis of rainfall in Jhelum basin, Pakistan. *Pakistan Journal of Meteorology & Geophysics, 47(3), 231-239.*