Climate Change

Climate Change and Variability: Assessing Rainfall, Temperature, and Relative Humidity Trends in Mtwara, Tanzania

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ABSTRACT

Climate change and variability have significant impacts on communities living in third-world countries. The impacts caused by climate change and variability have been more severe on poor people, especially those in agriculture and livestock farming. The assessment of climate trends and their impacts at local scales is not well covered. This study assessed long-term trends in key climatic variables (rainfall, temperature, and relative humidity). A cross-sectional design combined climate data from the Tanzania Meteorological Authority (TMA) with data gathered through household questionnaires, key informant interviews, focus group discussions, and field observations. The study used Microsoft Excel 2021 and SPSS version 26 for data analysis to obtain the descriptive statistics and linear regression methods to model climate trends. The results show increasing trends for rainfall ($p=0.92e^{-55}$), minimum temperature ($p=2.24e^{-26}$), maximum temperature ($p=4.82e^{-17}$) and relative humidity ($p=1.55e^{-35}$). There was a significant positive relationship between climate variables. The climate variables have a unimodal characteristic. Rainfall starts in November and ends in May, while dry periods start from May and end in October. The households experienced increased temperature, unreliable seasonal rainfall, extreme rainfall, increased dry spells and increased frequency of thunderstorms. The community perceive that climate extremes have affected crop production and livestock farming due to reduced soil quality, scarcity of water and increased pests and diseases.

Keywords: Climate change impacts, rainfall trends, temperature trends, humidity Trends

1. INTRODUCTION

The impacts of climate change and variability pose serious problems among households in communities with low economic capital. These communities suffer most due to low adaptive capacity in a face of challenges posed by climate change and variability. In recent years, human actions have accelerated climate change and surpassed causes related to natural forces. These actions produce greenhouse gas emissions altering the composition of the atmosphere. Fossil fuel use, land mismanagement, and cultural lifestyles have caused climate change (Bello et al., 2016; Gwambene et al., 2023). The increase in global average temperature is clear evidence of global warming with a non-reversible change. Climate change has escalated into a crisis, impacting human welfare and various life forms.

Climate change impact is already being felt and is expected to be more evident with the increased frequency of weather-related disasters. The data for climate change are observed globally by measuring temperature and rainfall, the most significant physical variables of climate change. Climate change is evidenced by sea level rise, increased global surface temperature, increased heatwaves, increased frequencies of tropical cyclones, melting glaciers, shifts in rainfall patterns and increased weather-related natural disasters. Since industrial revolution began, humans constantly burn fossil fuels, increased industrial pollution and clearing of forests. These actions generate greenhouse gases such carbon dioxide and methane all which trap outgoing radiation causing global warming (Preetha & Prathap, 2022). There is a direct link between human activities and economic impacts, because one cannot achieve economic stability in a climate change environment (Mkonda & He, 2018).

Climate variables (temperature, rainfall and humidity) are essential assets of climate system of the earth. They are important for water resources, livestock farming, agriculture production, food security, economic activities and ecosystem balance (Mbilinyi et al., 2013; Bharata, 2023). The analysis of average climate variables (temperature, rainfall and humidity) over a long period of time is crucial to determine climate of such particular region. A study by Halda et al., 2023 indicate that global average temperature rise in the past 50 years is above 1.5°C. It is important to understand the dynamics of rainfall, temperature and relative humidity in the context of climate change. The literature dictates that temperature, rainfall and humidity are changing and pose economic hardship to countries which depend on agriculture. A study by Tambo & Abdoulaye, 2012 explains sectors that are vulnerable to climate change include fisheries, agriculture and forests. Tanzania has similar and shares similarities in the climate domain.

Despite the global recognition of climate change and its impacts, a literature gap exists in understanding long-term trends in key climatic variables. Most existing studies disregard climate change at the local scale, where households' livelihoods are susceptible due to poverty.

This study aims to further advance from where other studies ended. The assessment of rainfall, temperature and relative humidity trends in Mtwara was done, using historical climate data collected from the Tanzania Meteorological Authority (TMA) and primary data from households and key informants. The study aims to analyze the trends of these climate variables, determine their interrelationships, and assess local perceptions of climate change impacts.

In this regard, the findings will enhance household knowledge about climate change. This will enable farming communities to systematically put substantial measures to deal with climate stressors for better crop production.

2. MATERIALS AND METHODS

Area of study

The study was conducted in Nanyamba Town Council, Mtwara region shown in Figure 1. Mtwara region is found in south eastern coast of the country bordering with Indian Ocean to the east and Mozambique to the south. The socio-economic activities in the region include agriculture, livestock keeping, natural gas, fisheries, mining, industry, forest, tourism and coastline with beautiful beaches. The region has nine local government authorities and Nanyamba Town Council is among them. The Council is located between grid reference 8803610 and 8851043 south and 570094 and 6636508 east. The economy of Nanyamba Town Council is agricultural dependent and about 92 per cent of the population are farmers. The cash crops grown are cashew nut, coconut, sesame and groundnuts and food crops are maize, cassava, sorghum and rice. Nanyamba Town Council has two ecological zones, the Makonde plateau and Ruvuma valley zone. The ecology of the Makonde plateau is complex with low-lying areas and hills and no river flow in the area. The plateau is the most agriculture-productive zone in Nanyamba Town Council for food crops, cash crops and small livestock keeping. Ruvuma valley zone is characterized by river deposits and agriculture is practised in valley plains and upland areas and fishing is done in a river and in the ocean. The vegetation in Nanyamba Town Council varies from grasslands and bushes to woodlands (Kabanda, 2018).

Nanyamba Town Council was selected because its economy is agricultural dependent which is severely impacted by climate change (Temba & Said, 2023). The district experienced a shift in rainfall, temperature and humidity. These climatic variables influenced the livelihoods and environmental conditions. The experience increase in global average temperature and fluctuating rainfall are clear evidence in the areas with a diversification effect in main economic activities. A study was specifically conducted in Mtimbwilimbwi and Njengwa wards purposively selected because of their location within the Makonde plateau, the most food-producing area in the region.

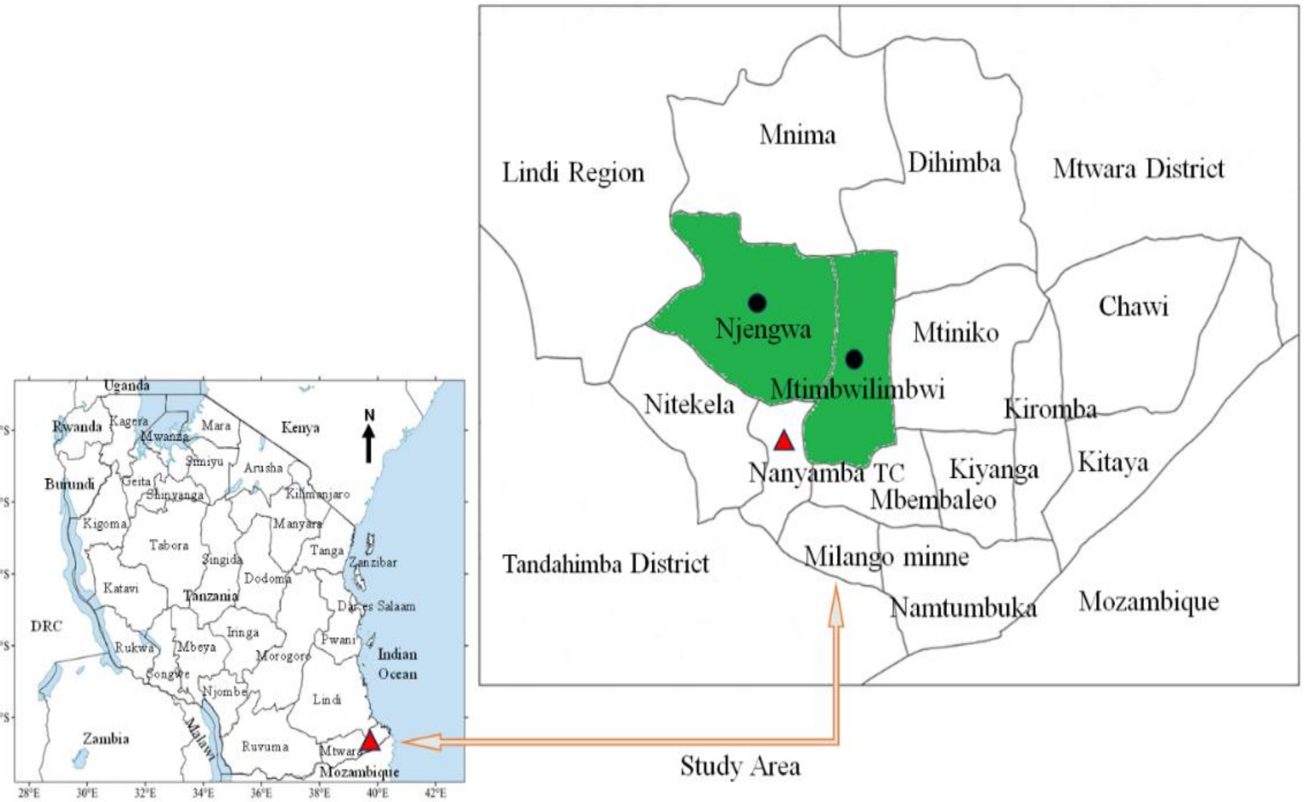

Figure 1 The map indicating the location of the study area

Sampling techniques and sample size

This study employed purposive and random sampling techniques to select an area of study and sample size. One study district was selected in the first place. In the second stage, two wards were selected and in the third stage, one village was selected from each ward. The two villages (Mtimbwilimbwi and Njengwa) share similar ecological zone, the Makonde plateau which is the most agricultural productive zone in Nanyamba Town Council. The population of Njengwa and Mtimbwilimbwi wards were 2451 and 3338 households respectively which make a population pool of 5789. The number of households for Njengwa village was 472 and Mtimbwilimbwi village was 1220. The calculated optimal sample size from the population pool of 5789 is 360 households. The obtained optimal population sample size was divided by a standard value of 0.8 to increase the power of the test to a sample size of 450. To obtain the sample size of each ward, the probability of proportion to size was used. The obtained sample size for Njengwa ward was 191 and Mtimbwilimbwi ward was 259 making a total sample size of 450 households.

Purposive and random sampling technique was also used in determination of sample size for key informants and focus group discussion. The total of seven (7) key informants were government officials notably, one Town Agricultural Livestock and Fisheries Officer (TALFO), two Agricultural Extension Officers (AEO), two Ward Executive Officers (WEO), and two Village Executive Officers (VEO). The key informants were selected because they possess enough knowledge and as trusted leaders of the community. The information obtained was used to supplement data obtained through household questionnaires. One focus group discussion of 10 participants from each village comprising experienced farmers aged 30 years and above was conducted. The focus group discussion aimed to obtain information about self-reported outcome measures that supplemented information from key informants and households (Gwambene et al., 2023; Temba & Said, 2023).

Data collection method

For the search of this research, three instruments were used to collect data including observations, interviews and questionnaires. Mtwara region has a poor meteorological data observation network and only one synoptic station is available. The meteorological data was collected from Tanzania Meteorological Authority (TMA) for Mtwara synoptic station located at latitude 10°21' S, longitude 40°11' E and altitude 370 ft above mean sea level. The station is about 60km from Nanyamba Town Council by road distance. The data collected were monthly rainfall total, minimum and maximum temperature and relative humidity for 34 years from 1990 to 2023. For the interview method, the study used questions outlined to ask the household head to answer the research questions. A close relative familiar with the household's socio-economic activities was interviewed in case the household head was absent during the interview. The interview schedule was prepared where a researcher conducted the interview and responses were recorded per question from the schedule by a researcher (Gwambene et al., 2023). The scheduled face-to-face interviews with key informants and focus group discussions were conducted using questionnaires. The observation tool involved a sense of seeing with the researcher and documenting the observed phenomena by taking pictures and writing descriptions of observations based on the research objectives. The gathered information validated data obtained through household surveys, key informants and focus group discussions (Taherdoost, 2022).

Data analysis

The data collected was processed and analysed using quantitative and qualitative methods. Data collected from households were analysed using Microsoft Excel and Statistical Package for Social Sciences (SPSS version 26). Besides the content and trend analysis employed for the qualitative data (Gwambene et al., 2023). Rainfall, temperature (minimum and maximum), and relative humidity were converted into monthly average rainfall, monthly average temperature, and monthly average relative humidity to capture inter-season attributes, and the same data were converted into annual average rainfall, annual average temperature, and annual average relative humidity to capture annual trends. A linear regression model is used to measure how climatic variables change over time. The coefficient of determination (R-squared) was calculated to measure the variance described by the trend. To assess the trend of climatic variables, each variable was modelled into a different regression equation and one multiple regression equation (Joshi & Dama, 2023). The significance of the trendline was tested using a significance level of p-value = 0.05 (Gwambene et al., 2015; Khanal, 2015; Bello et al., 2016).

3. RESULTS

Demographic characteristics

Age of respondents

The findings presented in Figure 2 reveal different age groups of respondents are 7 (1.6%) were aged between 21-30 years, 95 (21.1%) aged between 31-40 years, 144 (31.9%) aged between 41-50 years, 106 (23.5%) aged between 51-60 years and 9 (21.8%) were aged above 60 years. The majority of respondents were in the middle, adult and elderly age.

Sex of the respondents

The results in Figure 3 show that the gender of respondents was female 286 (64.0%) and male 164 (36.0%). These findings indicate the overall respondents were females because they are better home maker.

Trends of climate variables and Perceived Changes

Annual rainfall distribution and trend

The findings in Figure 4 indicate annual average rainfall from 1990 to 2023. The trends show variations in rainfall where the values above the average line indicate rainfall higher than normal, and values below the line indicate rainfall lower than expected, with some years showing extreme variations. Using the developed model equation ($Y=0.2297X1+85.639$), the evaluation of the fitted line shows R squared = 0.0099, the rainfall trend is positive, and the regression coefficient is positive.

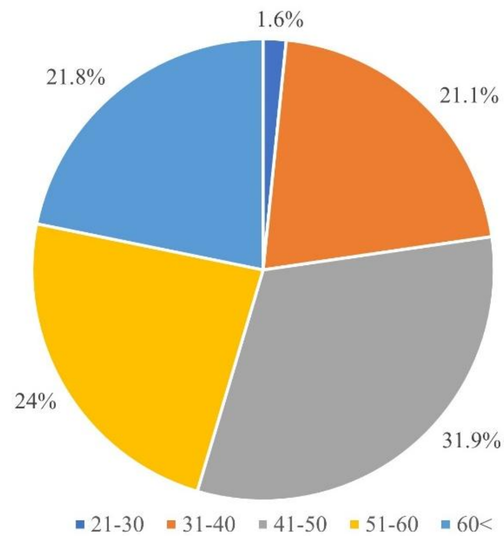

Figure 2 Age of respondents (n = 450)

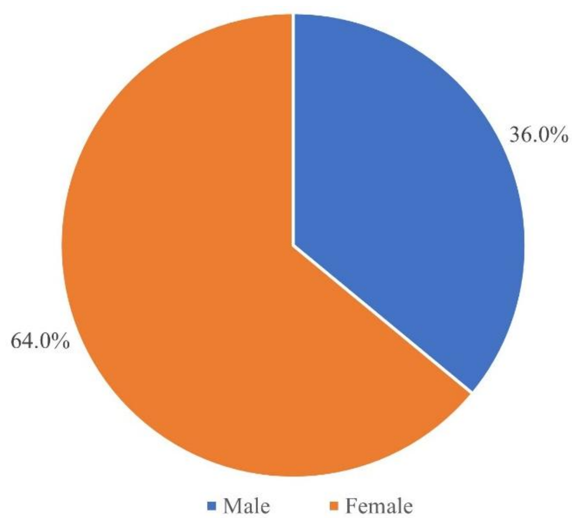

Figure 3 Sex of respondents (n = 450)

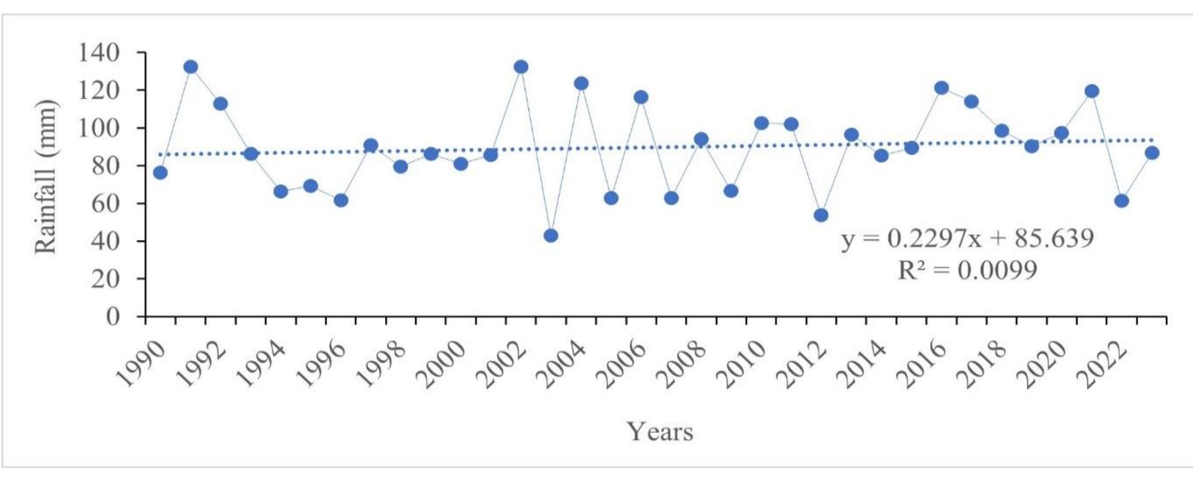

Figure 4 A 33-year average annual rainfall (1990–2023)

Annual minimum temperature

The findings presented in Figure 5 shows 34 years analysis of minimum temperature. The evaluation of graph shows variations of minimum temperature with years with low temperature and years with higher temperature but the overall graph has a consistent upward direction. From the graph, years with lowest temperatures are 1990 (20.3 °C), 1993 (20.2 °C) and 2013 (20.9 °C), while years with highest minimum temperatures are 2003 (22.0 °C), 2007 (22.1 °C), 2009 (22.4 °C) and 2023 (23.0 °C). The coldest minimum temperature was observed in 1993 (20.2 °C) and warmest minimum temperature was observed in 2003 (22.0 °C). The formulated regression equation is Y=0.039X2+20.765 which has a positive gradient of 0.0394 and coefficient of determination R^2 = 0. 4291.

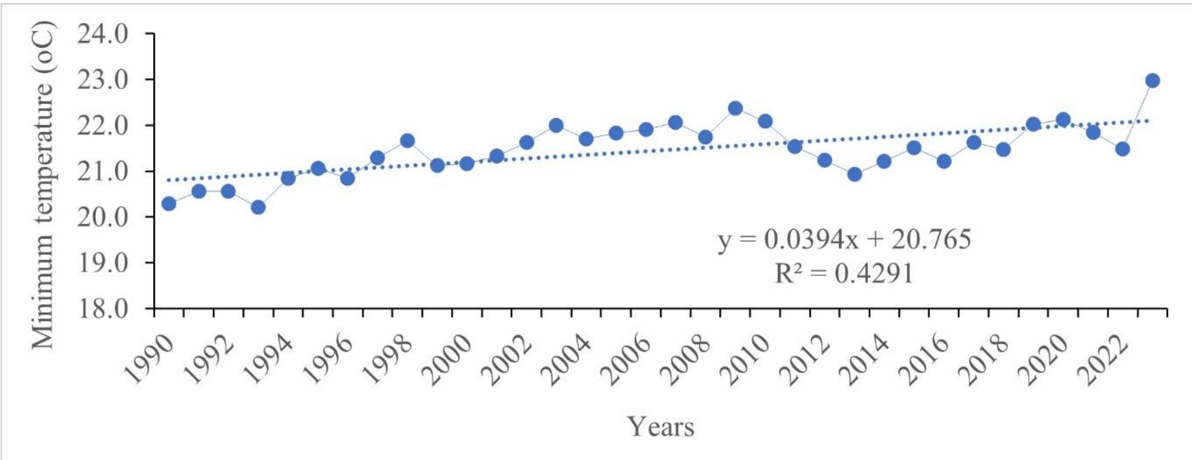

Figure 5 A 33-year average annual minimum temperature (1990–2023)

Annual maximum temperature

The findings presented in Figure 6 shows 34 years analysis of annual maximum temperature. The results on graph indicate high variations in inter-annual maximum temperatures with an overall upward graph. The year 1992 (29.7 °C) and 2008 (29.9 °C) recorded lowest maximum temperature while highest temperatures were observed in 2015 (31.1 °C), 2017 (31.1 °C), 2018 (31.1 °C) and 2019 (31.2 °C). The lowest average annual maximum temperature was observed in 1992 at 29.7 °C and warmest maximum temperature observed in 2019 at 31.2 °C. The results indicate consecutive years from 2015 to 2019 having highest maximum temperature in record. The formulated regression equation is Y=0.0294X3-28.481 have a positive gradient of 0.0294 and coefficient of determination R^2 = 0.5502. The calculate has p-value = $4.82e^{-17}$ and tested against p-vale=0.05. The positive feedback of temperature to climate change shows trend of maximum temperature was increasing.

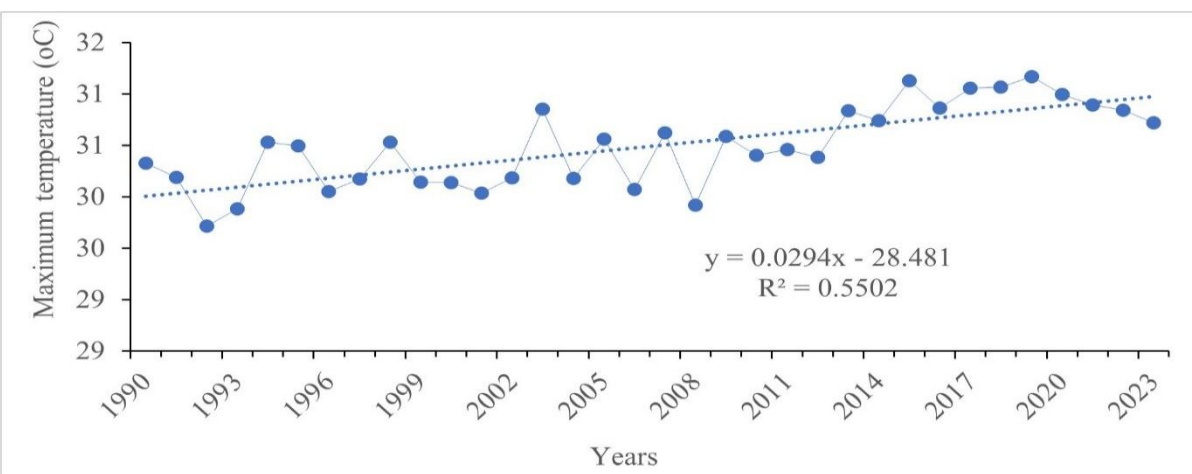

Figure 6 A 33-year average annual maximum temperature (1990–2023)

Annual relative humidity

The finding presented in Figure 7 represents the trend of annual average relative humidity, where the variation in relative humidity is visible. The graph shows that 2011 was a year with a higher relative humidity of 84%, and the year with the lowest relative humidity was 2003 with a relative humidity of 73%. The model equation is $Y=0.2596X_4-442.68$, and the fitted regression line indicates that the trend of relative humidity was increasing. The gradient of the regression equation is 0.259 and R-squared = 0.6064. To test for the significance of the trend, the p-value was calculated and found to be $1.55e^{-35}$, which is smaller than the suggested p-value of 0.05.

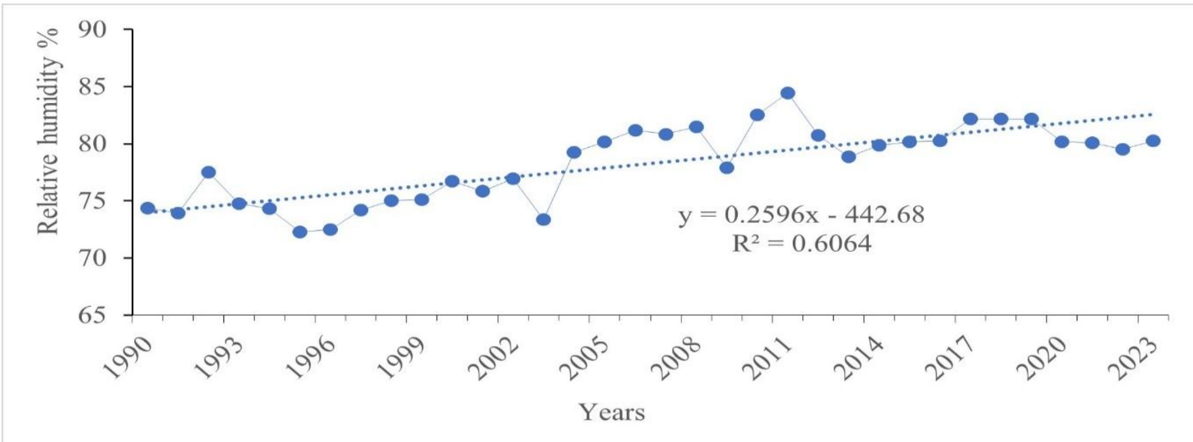

Figure 7 A 33-year annual relative humidity (1990–2023)

The inter-relationship between rainfall, temperature and relative humidity

The inter-relationship of climate variables was conducted using multiple linear regression model where the following equation was fitted $Y = a+b_1X_1+b_2X_2+b_3X_3+ b_4X_4$. The results for annual multiple linear regression model indicate that intercept of the model is 1478.54 and coefficients of determination are 0.02 for rainfall, 2.76 for minimum temperature, 11.72 for maximum temperature, 1.424 for relative humidity, standard error of 4.137 and p-value = $7.04e^{-21}$. The fitted regression model is $Y=0.02X_1+2.76X_2+11.717X_3+1.424X_4+1478.54$. The findings reveal that the calculated p-value from the model is $7.04e^{-21}$.

The climate variables are seasonal dependent with low values during dry season and higher values during rainy season. Low atmospheric moisture controls temperatures to low values and higher moisture contributes to increased temperature as shown on Figures 8, 9, 10 and 11 for rainfall, minimum temperature, maximum temperature and relative humidity respectively.

Inter-seasonal rainfall, temperature and relative humidity

Inter-seasonal rainfall

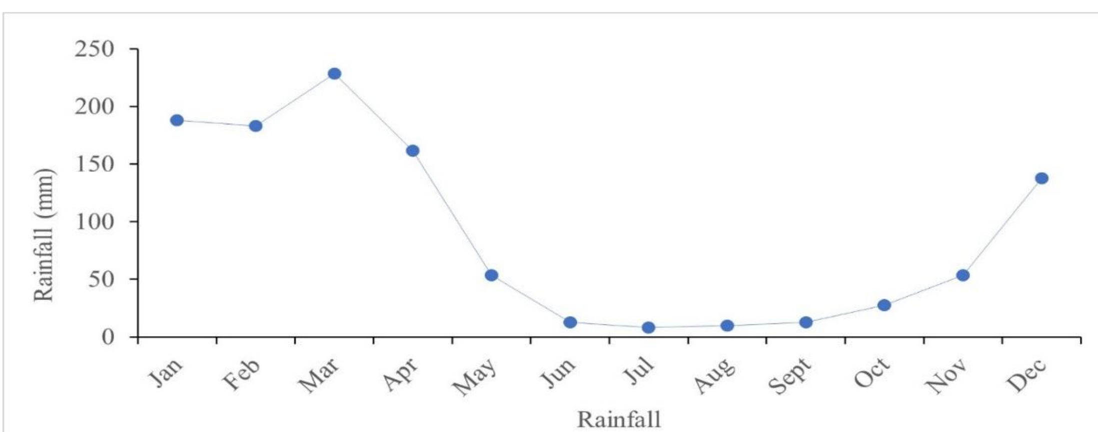

Figure 8 A 33-Year Inter-Seasonal Rainfall Pattern (1990–2023)

Figure 8 shows inter-seasonal rainfall characteristics for the period from 1990 to 2023. The results indicate unimodal rainfall, whereby one rainfall season is experienced in the area. Rainfall starts in November and ends in April, with a dry spell in February. The findings depict off-season rainfall for dry months from May to October, with the highest amount of rainfall recorded in May and October.

Inter-seasonal minimum temperature

The findings shown in Figure 9 represents graph of average inter-seasonal minimum temperatures for 34 years period. The curve show lower minimum temperatures were observed during the months of June to September. The variation of minimum temperature is seasonal dependence. The lower temperatures were observed during dry season with slight increase in rainy season. The average annual minimum temperature was found to be 21.5 ^{o}C lower than the values determined in the months of November to April and higher than values determine during the months of May to October. Moisture content in the atmosphere (Figures 8 & 11) have shown clear patterns similar to that of temperatures. The results signify rainy season has higher minimum temperature that dry season.

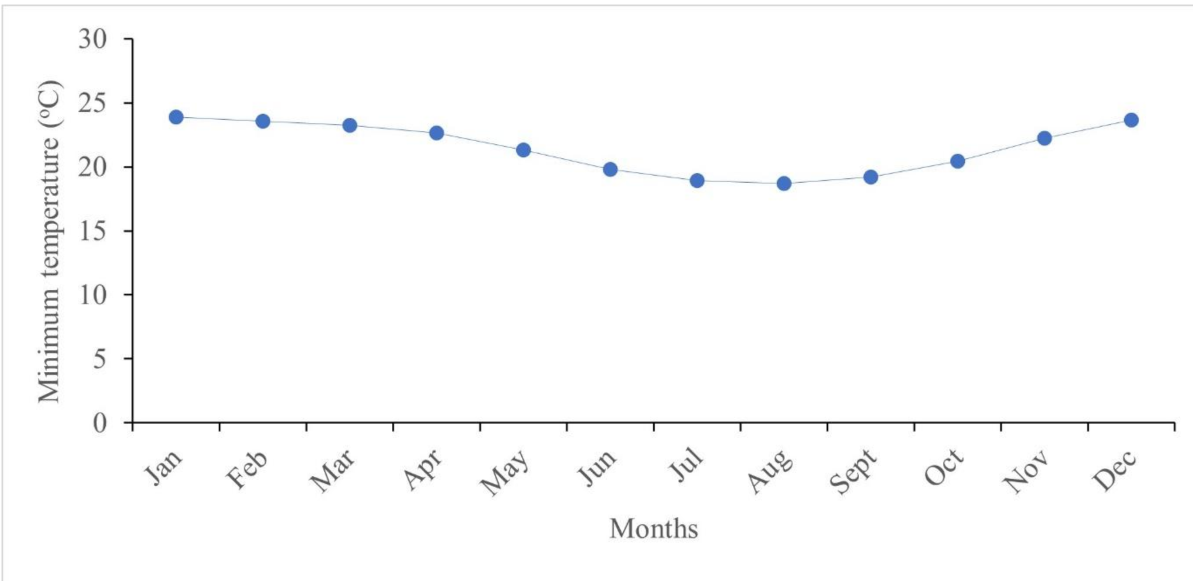

Figure 9 A 33-year inter-seasonal minimum temperature (1990–2023)

Inter-seasonal maximum temperature

The findings shown in Figure 10 represents graph of inter-seasonal maximum temperatures. The maximum temperatures are seasonal dependence, lower during dry season and higher temperatures during rainy season. The highest maximum temperature was observed in November 31.5 ^{o}C and lowest maximum temperature was observed in July 29.4 ^{o}C. The temperature is colder in the months of June to August and warmer in the months of October to May. This is attributed by higher atmospheric moisture during rainy season. Relative humidity and rainfall have positive feedback on temperature where inter-seasonal trends of these variables (Figures 8 & 11) have similar pattern to that of maximum. Their trends have a unimodal characteristic with lower amplitude during dry season and higher amplitude during rainy season.

Inter-seasonal relative humidity

The findings in Figure 11 represent inter-seasonal average relative humidity for 34 years of analysis. The results show that relative humidity was higher during months of December to April with highest value observed in March at 84% and lowest during months of June to November where the lowest value was observed in July at 74%. From the result, it can be noted that relative humidity is seasonal dependence and follows similar pattern observed in inter-seasonal rainfall (Figure 8) and inter-seasonal maximum temperature (Figure 10).

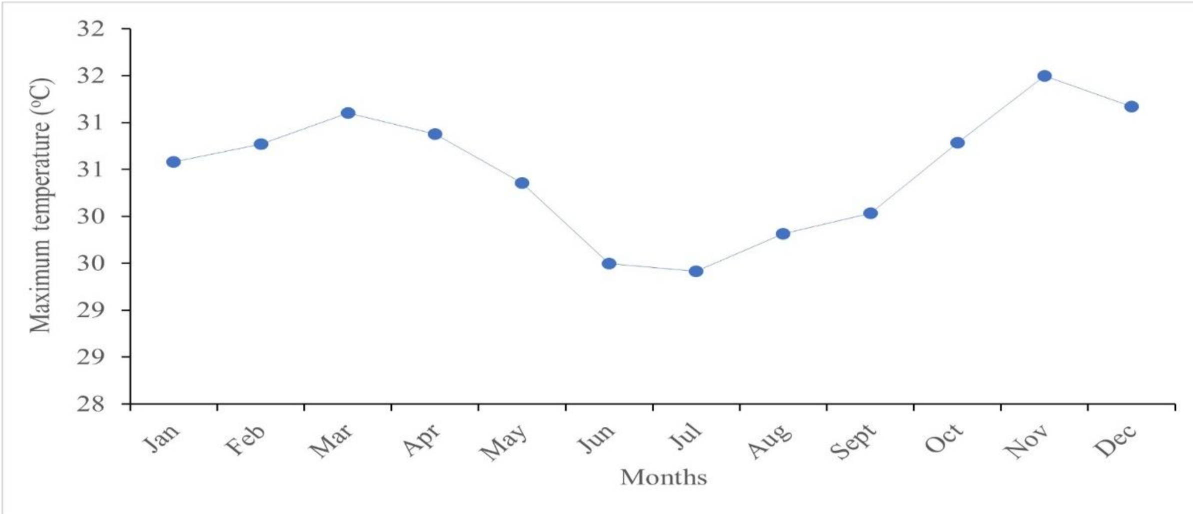

Figure 10 A 33-year inter-seasonal maximum temperature (1990–2023)

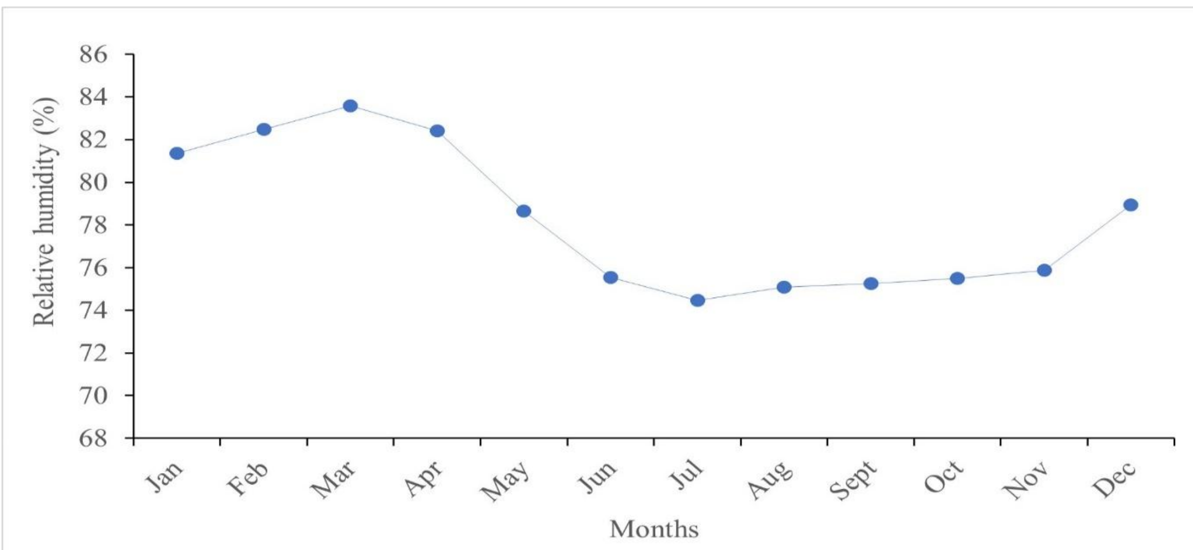

Figure 11 A 33-year inter-seasonal relative humidity (1990–2023)

Perceived climate change

The findings presented in Figure 12 indicate that farmers perceived differently on matters regarding climate change and its impacts. The differences in household perception on matters of climate change are mostly due to differences in adaptation and resilience. According to the findings, the community was affected by seasonal drought, where 33.1% and 47.7% of households reported the phenomena occurring more frequently. There were perceptions of stormy rainfall 42.3%, high temperature 45.4%, extreme cold 43.8%, off-season rainfall 54.6, crop insect pests 50%, plant disease epidemics 52.3% and human diseases 51.5% reported by households to occur more frequently. Households had mixed reactions to seasonal dry spells and erratic rainfall, where an overwhelming number indicated these aspects occur less regularly. The climate change aspects are reported to have changed, and the impacts are noticeable for the agricultural and water sectors. Results of key informants and focus group discussions show an increased frequency of thunderstorms and casualties related to them.

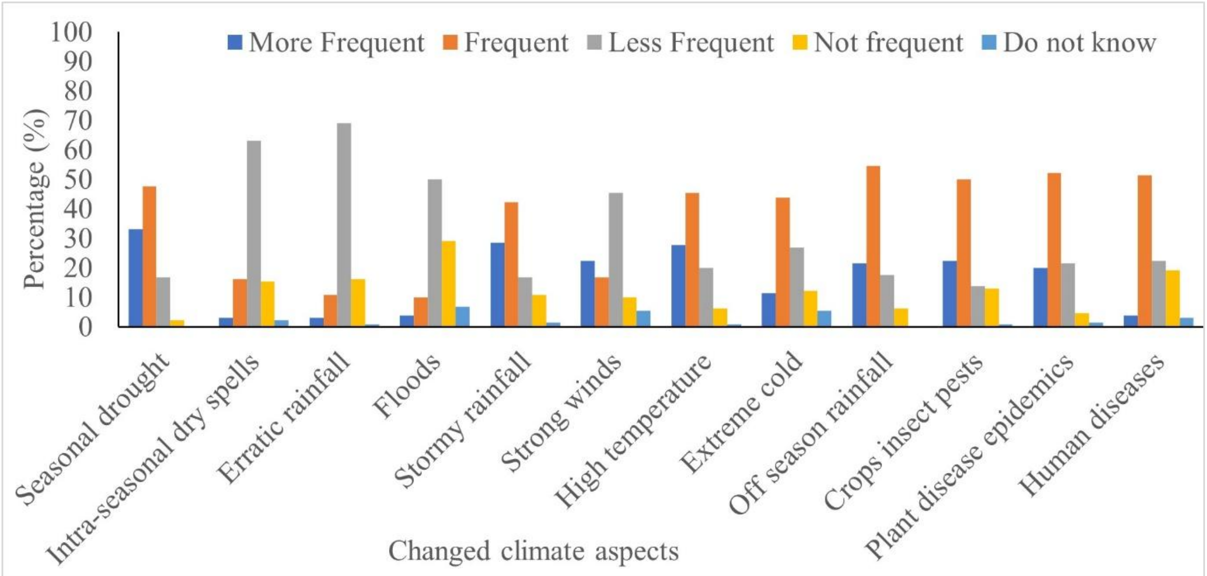

Figure 12 Household perceptions on climate change impact (n = 450)

Figure 13 gives an insight into household perceptions of climate change severity. The majority of households observed severity of the impacts of climate change on the aspects of seasonal drought 33.1%, stormy rainfall 40.0%, high temperature 49.2%, extreme cold 35.4%, off seasonal rainfall 54.6% and plant diseases epidemics 53.1%. These aspects were reported to have caused severe impacts on agricultures by increased crop pests and diseases. The respondents believed irregularity of seasonal rains, extended dry periods and decrease in crop yield was a result of climate change. Results from key informants and focus group discussion suggest increased frequencies of thunderstorms with reported deaths of up to three people each year and loss of water reservoirs which they used to call ponds. The respondents also mentioned increased intra-seasonal dry spells, high temperature and prolonged dry conditions affecting water, agricultural, livestock sectors. The community has experienced impacts of scarcity of water, increased pests and diseases.

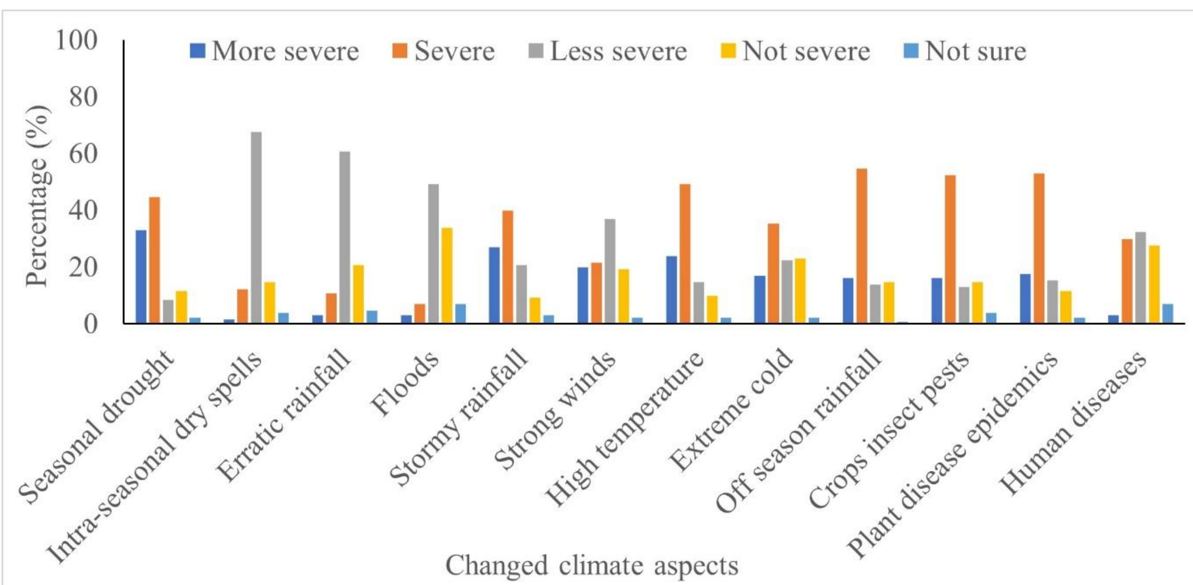

Figure 13 Household perceptions on climate change and impact severity (n = 450)

4. DISCUSSION

Demographic characteristics

The results indicate 9 (21.8%) were aged above 60 years, 106 (23.5%) aged between 51-60 years, 144 (31.9%) aged between 41-50 years, 95 (21.1%) aged between 31-40 years, 7 (1.6%) were aged between 21-30 years. The age for all categories was suitable for understanding climate change because of their long life. The results revealed that the majority of the people in the study area were in the category of middle, adult and elderly age population. Similar findings about the age of people with climate change knowledge were obtained by Mkonda & He (2018). The findings reveal that age of respondents were in the middle, adult and elderly groups. Economically productive population in Saharan Africa ranges between 15 to 64 years of age. According to Mberu and Ezeh (2017), this is the age of people who are decision makers and can be engaged in agriculture production, therefore, they can produce more.

The sex of respondents was female 286 (64.0%) and male 164 (36.0%). These findings indicate that the overall respondents, majority were female because females are better home makers. The results by Obayelu et al., (2019) concluded that women are vulnerable to climate change and involved in climate adaptation strategies. The overall respondents were females, meaning that the society is well organized in terms of responsibility like in other areas where women participate in economic activities. The findings concur with previous studies which indicated that women are involved across all stages of the agricultural production chain. They are often regarded as pivotal to the progress of both national economies and local communities (Obayelu et al., 2019; Matthew et al., 2022).

Rainfall characteristics and trends

Rainfall in the study area has unimodal characteristics; it starts in November and ends in April. According to Al-Ansari et al., (2014), rainfall drops significantly during the dry season with off-season rainfall from May to October. Similar findings were observed by Rakib (2018), who determined heavy rainfall during monsoon months (November to April), and Haldar et al., (2023) determined an increase in rainfall during monsoon (November to April) and a decrease during post-monsoon (May to October).

The trends in annual rainfall show values above the line indicate higher rainfall than normal and below the line indicate lower rainfall than expected with some years showing extreme variations. The evaluation of the fitted regression line shows significant increasing rainfall trend and positive coefficient indicate increasing rainfall. The study by Mahmood et al. (2019) found that time series indicated the trends of rainfall in the study area was strongly decreasing at $\alpha = 0.05$. From the results, rainfall extremes above normal were observed in 1999, 2002, 2004, 2016 and 2021. The annual rainfall extremes below normal were observed in 1996, 2003, 2012 and 2022 which was also observed by Haldar et al., (2023) who found the slope coefficient of yearly rainfall demonstrated the variation rate in a precipitation attribute. All these are credited evidences of climate change and also similar findings revealed by Temba & Said (2023). The calculated p-value from the analysis was $0.92e^{-55}$ lower than suggested p-value=0.05. Since the p-value in a regression model measures the significance of evidence, the low p-value that was calculated suggest that the model trend is statistically significant. Similar findings were determined by Bello et al., (2016) where significant changes in inter-annual rainfall and maximum temperature were noticed. Therefore, the rainfall in the study area was slightly increasing. In South West Bangladesh rainfall trends were decreasing between 1960 to 2010 and the obtained trends were not statistically significant (Rakib, 2018).

Minimum temperature characteristics and trends

The lower minimum temperatures were observed during dry season with slight increase temperature during rainy season. Moisture content in the atmosphere (Figures 8 & 11) plays a crucial role in moderating temperatures. This signifies that rainy season has higher minimum temperature that dry season. Haldar et al., (2023) reported similar characteristics of minimum temperature as seasonal dependence where minimum temperature was warmest during the monsoon season (November to April) followed by post monsoon (May to August) and pre-monsoon months (September to October) and annual average minimum temperature was 19.9 ^{o}C. The study by Joshi & Dama (2023) determined minimum temperature as seasonal dependent with an annual average observed in February at 11.2 ^{o}C.

The minimum temperature has been variable annually, with years of low temperature and years of higher temperature, but the overall graph from the analysis has a consistent upward direction. From the graph, years with lowest temperatures are 1990 (20.3 ^{o}C), 1993 (20.2 ^{o}C) and 2013 (20.9 ^{o}C), while years with highest minimum temperatures are 2003 (22.0 ^{o}C), 2007 (22.1 ^{o}C), 2009 (22.4 ^{o}C) and 2023 (23.0 ^{o}C). The coldest minimum temperature was observed in 1993 (20.2 ^{o}C) and warmest minimum temperature was observed in

2003 (22.0 ^{o}C). Similar results were found by Mahmood et al., (2019) who determined increasing temperature trend. The significance of the trends reveals that minimum temperature have a calculated p-value = $2.24e^{-26}$ indicating an increase in minimum temperature and is statistically significant and similar results were found by Haldar et al., (2023). Karabulut et al., (2008) determined statistical significance in annual temperature caused by higher temperature during summer months.

Maximum temperature characteristics and trends

The maximum temperatures are seasonal dependence with lower temperatures during dry season and higher temperatures during rainy season. This is attributed by higher atmospheric moisture during rainy season. The study by Haldar et al., (2023) observed similar patterns of temperature during wet and dry season. The study by Karabulut et al., (2008) determined temperature was higher during summer months and lower in winter. The seasonal dependence of rainfall, relative humidity and temperature is crucial for economic activities especially agricultural production.

The annual maximum temperature analysis indicates consecutive years from 2015 to 2019 have the highest maximum temperature in the record. The positive feedback of temperature to climate change shows that the trend of maximum temperatures is significantly increasing. In the metropolitan city of Guwahati in India, it was found that the maximum temperature was increasing annually and seasonally at statistically significant of 95% (Haldar et al., 2023). In India, state of Maharashtra maximum temperature was found to have significant increasing trend annually with highest values observed in May (Joshi & Dama, 2023). Karabulut et al., (2008) conducted similar study and determined that overall annual temperature had increasing trend. In 2016, Bello et al., observed similar temperature trends of warmer maximum temperature than previous records. The study by Sapala et al., (2021) found similar change in climatic condition in Papua New Guinea where rainfall and temperature increased for the last 60 years.

Relative humidity characteristics and trends

The relative humidity was higher during rainy season December to April and lowest during months dry season June to November. The relative humidity is seasonally dependent and follows a similar pattern observed in inter-seasonal rainfall (Figure 8) and inter-seasonal maximum temperature (Figure 10). Rakib (2018) found similar results of increasing relative humidity seasonally. The higher relative humidity values are found in June to October, and lower values during February to April, and average values are found during May and November (Joshi & Dama, 2023). The study by Arshad et al., (2021) found that higher relative humidity contributed to pest outbreaks.

The annual relative humidity is variable, ranging between 73% to 84% annually and has a positive orientation. The result signifies that the relative humidity in the annual trend of relative humidity is increasing (Rakib, 2018; Arshad et al., 2021).

The inter-relationship of climate variables

The findings have shown that rainfall, temperature, and relative humidity are significantly interrelated. These variables are seasonally dependent, with low values during the dry season and higher values during the rainy season. Results suggest temperatures are controlled by rainfall and humidity. Similar findings were determined by Oyedokun et al., (2022) where their study found decreasing trends for evaporation, relative humidity, and minimum temperature and increasing trends for maximum temperature and wind speed. The trends of these variables harm the availability of rainfall, which in turn impacts agricultural production. The inter-seasonal characteristics of climate variables have shown unimodal rainfall characteristics, whereby one rainfall season is experienced in the area.

Perceived climate changes

The differences in household perception on matters of climate change are mostly due to differences in adaptation and resilience. According to the findings, the community was affected by climate change. The climate change aspects of seasonal rainfall, dry spell, extreme rainfall, high temperature and drought are reported to have changed, and the impacts are noticeable for the agricultural and water sectors. Similar findings were reported by Temba & Said, (2023) and Mkonda & He, (2017) indicates that farmers perceive climate change differently.

The households believed irregularity of seasonal rains, extended dry periods, decreases and low crop yield was a result of climate change (Bello et al., 2016). The community has experienced impacts of loss of water ponds and increased pests and diseases (Mongi et al., 2010; Aidoo, 2021). The differences in capability to climate change adaptation and resilience among households are due to various factors, including risk exposure, individuals' knowledge and ability (Ahmed & Ahmed, 2019).

5. CONCLUSION AND RECOMMENDATIONS

This study assessed climate change and variability. The findings revealed that climate variables (rainfall, temperature and relative humidity) had positive trends. The trends were statistically significant at a suggested p-value = 0.05. There was a significant positive relationship between climate variables. The variables are seasonally dependent with unimodal characteristics. The rainfall season starts from November and ends in April, and the dry season starts from May to October. The findings reveal temporal and spatial climate change and variability in Mtwara region. The changes in climate trends were evidenced through historical meteorological data and analysis of perceptions from households.

The households in Mtwara region realized changes in climate in their locality. The farmers have experienced increased temperature, a shift in seasonal rainfall, and increased frequencies of thunderstorms. The change in environmental conditions caused by climatic extremes affects crop production. The climate extremes were perceived to have affected crop production as they reduced soil quality, reduced soil moisture and increased pests and diseases. Furthermore, most households did not have proper knowledge and were not well informed about climate change and its mitigation measures.

This study recommends that the government and well-wishers strategize on climate change awareness and cost-effective adaptation measures. Furthermore, there is a need to provide capacity building to the community about climate data interpretation and application.

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Authors contributions

Elewa Msomba, participated in the proposal and tool development, data collection, data analysis, drafting and development of draft and final article. Josephat Saria participated in proposal and tool validation, data collection supervision, and article writing. Brown Gwambene participated in proposal writing and tool validation, data collection and statistical data analysis supervision, and writing of the first and final draft of the article.

Disclosure statement

The authors declare that they do not have competing interests.

Informed consent

Oral informed consent was obtained from individual participants included in the study.

Ethical approval

The ethical guidelines for Human Subjects are followed in the study.

Conflicts of interests

The authors declare that there are no conflicts of interests.

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Data and materials availability

The meteorological data is available upon request from Tanzania Meteorological Authority through email: met@meteo.go.tz and data from household perception are available by request through korrosso@yahoo.com.

REFERENCES AND NOTES

1. Ahmed MA, Ahmed MA. Farmers' perception and adaptation to climate change: Multinomial logistic model evidence. Int J Econ Manag Stud 2019;6(10):143–51.
2. Aidoo DC, Boateng SD, Freeman CK, Anaglo JN. The effect of smallholder maize farmers' perceptions of climate change on their adaptation strategies: the case of two agro-ecological zones in Ghana. Heliyon 2021;7(11): e08307. doi: 10.1016/j.heliyon. 2021.e08307
3. Al-Ansari NA, Abdellatif M, Ezeelden M, Ali SS, Knutsson S. Climate change and future \long-term trends of rainfall at north-eastern part of Iraq. Journal of Civil Engineering and Architecture 2014;8(6):790-805.
4. Arshad M, Rasib K, Ali G, Amanat T, Munir A, Riaz S. Effect of weather parameters on pest dynamics of maize in summer at district bahawalnagar (Pakistan). Egypt Acad J Biol Sci 2021;14(1):195–203.
5. Bello OD, Akponikpè PBI, Ahoton EL, Saidou A, Ezin AV, Kpadonou GE, Aho N. Trend Analysis of Climate Change And Its Impacts On Cashew Nut Production (Anacardiumoccidentalel.) In Benin. Octa Journal of Environmental Research 2016;4(3):181-197
6. Bharata A. Impact of temperature on Insect Behavior in India. International Journal of Natural Sciences 2023;3(2):1-13.
7. Gwambene B, Liwenga E, Mung'ong'o C. Climate change and variability impacts on agricultural production and food security for the smallholder farmers in Rungwe, Tanzania. Environmental Management 2023;71(1):3-14.
8. Gwambene B, Saria JA, Jiwaji NT, Pauline NM, Msofe NK, Mussa KR, Tegeje JA, Messo I, Mwanga SS, Shija SM. Smallholder farmers' practices and understanding of climate change and climate-smart agriculture in the Southern Highlands of Tanzania. J Resour Dev Manag 2015;13:37-47.
9. Haldar S, Choudhury M, Choudhury S, Samanta P. Trend analysis of long-term meteorological data of a growing metropolitan city in the era of global climate change. Total Environment Research Themes 2023;7:100056.
10. Joshi PS, Dama LB. Analysis of rainfall, humidity and temperature during the year January 1990 to December 2020 in Solapur district, Maharashtra State, India. International Journal of Engineering Technology and Management Sciences 2023;3(7):65-69.
11. Kabanda T. Long-term rainfall trends over the Tanzania coast. Atmosphere 2018;9(4):155.
12. Karabulut M, Gürbüz M, Korkmaz H. Precipitation and temperature trend analyses in Samsun. Journal International Environmental Application & Science 2008;3(5):399-408.
13. Khanal B. Correlation of climatic factors with cereal crops yield: a study from historical data of Morang district, Nepal. Journal of Agriculture and Environment 2015;16:21-32.
14. Mahmood R, Jia S, Zhu W. Analysis of climate variability, trends, and prediction in the most active parts of the Lake Chad basin, Africa. Sci Rep 2019;9(1):6317.
15. Matthew O, Osabohien R, Lakhani KH, Aderounmu B, Osadolor NE, Adediran O, Mabinuori O, Igharo AE. Women engagement in agriculture and human capital development in developing countries. An African sub-regional analysis PLoS One 2022;17(12): e0277519
16. Mberu BU, Ezeh AC. The population factor and economic growth and development in Sub-Saharan African countries. African Population Studies 2017;31(2):3833-3844
17. Mbilinyi A, Saibul GO, Kazi V. Impact of climate change to small scale farmers: Voices of farmers in village communities in Tanzania, Dar es Salaam. Economic and Social Research Foundation 2013;1-36:ESRF Discussion Paper No. 47
18. Mkonda M, He X. Are rainfall and temperature really changing? Farmer's perceptions, meteorological data, and policy implications in the Tanzanian semi-arid zone. Sustainability 2017;9(8):1412.
19. Mkonda MY, He X. Climate variability and crop yields synergies in Tanzania's semiarid agroecological zone. Ecosyst Health Sustain 2018;4(3):59–72.
20. Mongi H, Majule AE, Lyimo J. Vulnerability and adaptation of rain fed agriculture to climate change and variability in semi-arid Tanzania. Afr J Environ Sci Tech 2010; 4(6):371–81.
21. Obayelu AE, Ogbe AO, Edewor SE. Gender gaps and female labour participation in agriculture in Nigeria. Afr J Econ Manag Stud 2019;11(2):285–300.
22. Oyedokun JA, Adikwu JP, Abiodun LO, Salman SI, Fasina ET, Mechanization I. Development of a Multiple Linear Regression Model for Rainfall Distribution on Other Meteorological Parameters: A Case Study of Idofian, Kwara State, Nigeria. GSJ 2022; 10(4):609-620

23. Preetha S, Prathap L. Awareness On Recent Trends of Global Climate Change. JETT 2022;13(6):153-163.
24. Rakib Z. Characterization of climate change in southwestern Bangladesh: trend analyses of temperature, humidity, heat index, and rainfall. Clim Res 2018;76(3):241–52.
25. Sapala N, Cheng Y, Li D. Analysis of rainfall and temperature variations between 1956 and 2016 for Papua New Guinea. J Geosci Environ Prot 2021; 09(06):66–85.
26. Taherdoost H. Designing a questionnaire for a research paper: A comprehensive guide to design and develop an effective questionnaire. Asian Journal of Managerial Science 2022; 11(1):8–16.
27. Tambo JA, Abdoulaye T. Climate change and agricultural technology adoption: the case of drought tolerant maize in rural Nigeria. Mitigation and Adaptation Strategies for Global Change 2012;17:277-92.
28. Temba AN, Said MK. Small-holder farmers' perceptions of the impacts of climate change on maize crop in Dodoma, Tanzania. Ghana J Geography 2023;15(2):184–211.