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Research Article

Effects of 5G Network and Climatic Fluctuations on Sorghum Yield in Nigeria

Umar Danjuma Maiwada[1*], Muhammad Garzali Qabasiyu[2], Muhammad Hamza Dauda[3]

[1]Department of Computer Science, Faculty of Natural and Applied Science, Umaru Musa Yaradua University Katsina Nigeria
[2]Department of Computer Studies, College of Science and Technology, Hassan Usman Katsina Polytechnic, PMB 2052, Katsina State, Nigeria
[3]Department, Action Against Hunger Nigeria

**Corresponding Author: Umar.danjuma@umyu.edu.ng*

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Abstract— In Nigeria, sorghum stands as a staple crop with significant importance for food security and the economy. This study investigates the effects of climatic fluctuations, particularly rainfall variability and temperature changes, on the yield of sorghum across different agro-ecological zones in Nigeria. Additionally, it examines the influence of 5G network technology on agricultural practices and data-driven decision-making processes related to sorghum cultivation. Utilizing a combination of historical climate data, sorghum yield records, and statistical models, we analyze the correlation between climatic factors, including 5G network accessibility, and crop output over the past three decades. Our findings indicate that sorghum yields are highly sensitive to deviations in seasonal rainfall patterns and temperature anomalies. In years of below-average rainfall, sorghum yields declined substantially, highlighting the crop's dependency on water availability. Temperature increases were found to have a dual effect; moderate increases coincided with yield gains, likely due to extended growing seasons, while extreme heat events correlated with yield reductions, likely due to heat stress on the plants. The study also evaluates adaptive farming practices employed by local farmers in response to climatic stresses, including crop variety selection, irrigation use, and planting date adjustments. Despite these efforts, the results suggest that current adaptation strategies may be insufficient against the setting of projected change in climate scenarios. Policy implications were discussed, emphasizing the need for robust agricultural policies that support sustainable farming practices, improved water management systems, and the development of climate-resilient sorghum varieties. Moreover, the study highlights the role of 5G network technology in enhancing agricultural resilience. Access to real-time weather data, market information, and expert advice through 5G networks can empower farmers to adopt wise choices, distribute resources as efficiently as possible, and prevent the impacts of climatic fluctuations on sorghum production. The study underlines the urgency for concerted action to lessen the negative consequences of climatic fluctuations on agriculture in Nigeria, with a focus on safeguarding the sorghum supply chain and, by extension, food security and rural livelihoods. The current investigation examined how variations in rainfall affected the production of sorghum in Kano State, Nigeria. Among the goals are: Analyze how rainfall variability affects sorghum output and note the strategies farmers use to increase sorghum yield. Descriptive statistics and focus group discussions with farmers are part of the study's methodology. The outcomes resulted in FGD indicating a rise in the amount of precipitation leads to a decrease in sorghum output in the research region. Pearson movement correlations analysis was performed to calculate the connection between the cultivation of sorghum and rainfall variability. Additionally, the correlation's result showed that the annual rainfall and sorghum yield had an unfavorable, negligible association, with a correlation coefficient of -0.3713 and an estimated likelihood of 0.255 at the 7% level.

Keywords— Climate fluctuation, Ecosystem, Global challenges, Rainfall variability, Sorghum yield, and 5G network.

1. Introduction

Sorghum (Sorghum bicolor) stands as a fundamental crop in Nigeria, playing a pivotal role in ensuring food security and contributing significantly to the nation's agricultural economy. However, the cultivation of sorghum faces multifaceted challenges, including the adverse impacts of climatic fluctuations and the need for technological innovation to enhance agricultural resilience. In recent years, the advent of 5G network technology has emerged as a potential tool for addressing these challenges, offering opportunities to revolutionize agricultural practices and reduce the impact of crop production being affected by changes in the climate. Rainfall variability is acknowledged as being one of the biggest and most important worldwide issues of the twenty-first century due to its numerous implications on the ecology, water supplies, agriculture, and forests basic human assistance systems (Aklilu & Alebachew 2009). According to (Bates et al 2008), over the previous 30 to 40 years, there has been a noticeable decline in precipitation in the regions between 100 S to 300 N, although overall, precipitation throughout land has risen over the past decade around 300 N and 850 N. The extent of the harm that this alteration in the atmosphere may cause is unknown, and its effects might possibly prove to be localized (Morton 2007). Research has sparked interest in studying rainfall variability problems around the globe. Research indicates that although those living in the highlands and upper altitude locations of the earth may benefit from climate change, those living in low-lying ocean regions including the fringes of Africa may be negatively impacted (Fischer et al. 2001). According to (Rosenzweig & Hillel 1995), those areas are vulnerable due to several factors, including their reliance on agriculture, a lack of advanced technology, widespread poverty, a lack of political will, and above all their physical location, which is marked by extreme temperatures and variable precipitation levels. severe weather has recently had a negative impact on nations like Ethiopia, Indonesia, and Australia. Even while variations in rainfall might not be considered the cause of catastrophe, it is anticipated that similar occurrences would arise from this worldwide issue, endangering sizable rural populations. The impoverished rural population has adjusted their agricultural methods and crop selection in accordance with the weather. However, they have a limited ability to adapt, and changes in the climate could render it necessary for significant areas of precarious agriculture to cease operations (Mendelsohn et al. 2000). It necessitates the creation of strategies that, ideally, are more context-dependent regarding the types of risks connected to changes in the climate, their livelihoods, including geographical region (IFAD 2008). Although agriculture seems the industry most susceptible to the impacts of global warming, experts have worked hard over the years to examine the impacts of variation in rainfall on agriculture. Among the first studies on how global warming affects agricultural output were conducted by (Callaway et al. 1982); (Decker et al 1986); (Rosenzweig& Parry 1994) applying the conventional production function methodology. (Mendelsohn et al 1994) developed the Ricardian cross-sectional method to conduct a more thorough analysis of the financial impact of the changing climate on the average farm's worth. This approach has already been used in identical studies in various regions of the world due to the benefits it offers over the old approach (Dinar & Beach 1998); (Mendelsohn et al 2000). Impact assessments have expanded throughout time from developed to developing nations since they are a global problem. Climate change susceptibility of African agriculture was validated by a paper based on research conducted in eleven African countries (Maddison et al. 2007). Research using the Ricardian technique calculated the effects of variation in rainfall on sorghum output, inputs, technology, and activities in various regions (Mendelsohn et al. 1994). (Deschenes & Greenstone 2007) nevertheless, pointed out that although the Ricardian technique has benefits over the creation function approach, estimations of rainfall impacts may be inconsistent. Their analysis goes further to provide a novel approach that investigates how sorghum output fluctuates in response to erratic fluctuations in precipitation from year to year. The research they conducted found that there will be a 6% rise in annual agriculture sector profits due to climate change. They used intertemporal weather fluctuations to analyze whether growing season rainfall in U.S. farmland affects sorghum productivity. Climatic fluctuations, characterized by shifts in temperature and precipitation patterns, pose significant threats to sorghum production in Nigeria. The country's agriculture is predominantly rainfed, making it highly susceptible to variations in weather conditions. Erratic rainfall, prolonged droughts, and extreme temperature events can lead to reduced crop yields, threatening food security and exacerbating rural poverty. Moreover, climate change projections suggest that these challenges will intensify in the coming decades, necessitating proactive adaptation strategies within the agricultural sector.

By determining the baseline yield of sorghum in various regions of Nigeria, documenting the existing agricultural practices related to sorghum cultivation is required. Analyze historical climate data to identify trends and fluctuations relevant to sorghum agriculture. Then, there is need to correlate climatic factors such as temperature, rainfall, and extreme weather events with sorghum yield data. The role of 5G technology in supporting these strategies, such as through precision agriculture needs to be explored. The study would aim to thoroughly understand the multifaceted relationship between technological advancement (5G networks), environmental change (climatic fluctuations), and agricultural productivity (sorghum yield), with a specific focus on the implications for Nigeria.

Each hypothesis would be tested using appropriate research methods, such as field trials for direct effects on crops, statistical analysis of yield data against climatic patterns, surveys, or interviews for socio-economic impacts, and technology assessments for the capability of 5G in agricultural applications. There is a significant correlation between climatic fluctuations (temperature, precipitation, and extreme weather events) and the annual yield of sorghum in Nigeria. The presence of 5G networks does not significantly affect the growth and yield of sorghum crops in areas where the networks are implemented compared to areas without such networks. The interaction between climatic fluctuations and the presence of 5G networks leads to a statistically significant difference in sorghum yield outcomes, compared to the impact of climatic fluctuations alone. The introduction of 5G networks in sorghum farming areas positively correlates with socio-economic benefits, such as improved market access and farming efficiency, potentially offsetting negative impacts of climatic fluctuations on crop yield. Sorghum yields in areas with both climatic fluctuations and 5G network exposure show significant improvement when specific adaptation strategies are employed, leveraging 5G technology, compared to traditional farming practices.

1.1 Research Problem

The primary cause of variations in the production of food worldwide has been and still is rainfall variability, especially in countries that are developing semi-arid and arid tropical nations like Nigeria. Extreme weather phenomena like droughts, floods, and temperature fluctuations have historically presented serious difficulties for these regions' farming operations. Vulnerability, economic losses, starvation, famine, and relocation are caused by changes in the climate in combination with other social, physical, and economic variables (Sivakumar, 1992). The effects of rainfall unpredictability on the farming industry are especially severe in Nigeria, since over 85% of society depends on rain-fed farming and fishing being their main sources of income. Food availability and rural livelihoods are seriously threatened by adverse impacts on crop production caused by variations in when and how much of rainfall, as well as by frequently occurring outbreaks of diseases and pests that affect crops and heat stress. Therefore, to develop environmentally friendly policies and strategies to support farming in arid and semi-arid regions, it is vital that these characteristics be fully understood. In addition, the incorporation of 5G wireless networks into farming operations offers fresh ways to tackle the difficulties brought about by variations in rainfall and the effects of climate change. 5G networks have the potential to enable farmers to make well-informed decisions, maximize resource allocation, and reduce risks associated with climate swings by giving them access to meteorological data, market data, and professional guidance in real time. But to fully utilize 5G technology in agriculture, infrastructural issues must be resolved, accessibility and cost must be guaranteed, and farmers' digital literacy must be raised. Therefore, rainfall unpredictability continues to be a major factor influencing changes in agricultural output, which has a big impact on Nigeria's food security, agricultural production, and efforts to reduce poverty. Stakeholders and policymakers can create stronger, more sustainable farming practices that lessen the damaging impacts of climate change while encouraging inclusive economic growth by comprehending and addressing the complex effects of variability in the climate and integrating cutting-edge technologies like 5G networks. Changes in the climate will cause further food shortages and may cause numerous farmers to abandon their livelihoods (Dabi, et al, 2012). By supplying data on the effects of variation in rainfall on sorghum production, this study will close the information gap related to food shortages and poverty. Additionally, by investigating the relationship between 5G networks and climatic changes in the wider context of Nigerian sorghum production, the study fills a significant vacuum in the present literature. The research attempts to contribute to the creation of comprehensive solutions that protect food security, support rural livelihoods, and encourage agricultural growth that is sustainable amid climate change by utilizing scientific knowledge and technical innovation.

2. Related Work

Amidst these climatic challenges, advancements in communication technology, particularly the deployment of 5G networks, offer new opportunities to bolster agricultural resilience. The high-speed connectivity and low latency provided by 5G networks facilitate real-time data collection, analysis, and dissemination, enabling farmers to make informed decisions and optimize resource allocation. Through applications such as remote sensing, weather forecasting, and precision agriculture, 5G technology has the potential to enhance productivity, mitigate risks, and improve the overall efficiency of sorghum cultivation. However, despite the promise of 5G technology, its integration into agricultural systems in Nigeria remains limited, with challenges related to infrastructure development, affordability, and digital literacy. Additionally, the synergistic effects of 5G network technology and climatic fluctuations on sorghum yield have not been comprehensively studied, necessitating further research to elucidate the interactions between technological innovation and environmental variability. According to the United States Global Climate Research Program (USGCRP, 2009) research, excessive rainfall variability has had a negative impact on production in some years, even while technological advancements have increased crop yields. The study makes the case that variations in rainfall cause shorter growing seasons as well as decreased crop yields. In regions with low moisture content in the soil, shorter growth periods might be suitable. However, this shortens the time needed for seed germination, crop growth, and maturity, which speeds up the growth of crop varieties, like sorghum. The yields of crops for a particular area of land ultimately decline significantly because of faster crop growth. (Tubiello et al., 2002) believes that rainfall fluctuation has a significant impact on sorghum output, even though the exact amount will range depending on the location and crop because of several anthropogenic and natural variables that are causing climate change. Many studies demonstrate that increased precipitation has a negative influence on sorghum cultivation and, consequently, agricultural yields; nonetheless the effects range between plants and among areas because different crops react differently to variations in rainfall (Thornton et al., 2006; Mendelsohn, 2008; USGCRP, 2009; Lee et al., 2012). (Ringler et al. 2010) evaluated the unpredictability of rainfall effects on Sub-Saharan Africa's availability of food using a thorough scenario based on composites of 17 GCMs. Beyond 2050, the study's findings predicted high temperatures along with a range of rainfall patterns. The study additionally found that all agricultural yields were going to decrease due to rainfall variability, without the exception of maize. Through 2050, the yield of wheat would decrease by the greatest amount, or 22%. In addition, the study found that by 2050, costs of corn, rice, and wheat will rise by 4%, 7%, and 15%, respectively, due to rainfall variability. Other anticipated 2050 effects include: adjustments to crop yield and expansion of the growing region; a decrease in food availability because of rising food prices; a decrease in calorie consumption; and an increase in growth area.

2.1 Rainfall variability and climate change

Rainfall variability and climate change present significant challenges to agricultural productivity, food security, and rural livelihoods in Nigeria. As rainfall patterns become increasingly erratic and extreme weather events become more frequent due to climate change, the vulnerability of agricultural systems to these fluctuations escalates. In this context, the integration of 5G network technology offers promising opportunities to enhance resilience and mitigate the impacts of climate variability on agricultural production. 5G networks provide high-speed connectivity and low latency, enabling real-time data collection, analysis, and dissemination. This technology facilitates the monitoring of weather patterns, soil moisture levels, and crop health, allowing farmers to make timely and informed decisions to optimize resource management and mitigate risks associated with climate variability. For example, remote sensing technologies powered by 5G can provide early warnings for impending droughts or floods, enabling farmers to implement adaptive measures such as adjusting irrigation schedules or selecting drought-tolerant crop varieties. Furthermore, 5G networks support the deployment of precision agriculture techniques, which enable precise and targeted application of inputs such as water, fertilizers, and pesticides. By optimizing resource use, precision agriculture practices can enhance resilience to climate variability while reducing environmental impacts and improving overall agricultural productivity. Additionally, 5G-enabled communication platforms can facilitate knowledge sharing and extension services, allowing farmers to access expert advice, market information, and training programs, thereby strengthening their capacity to adapt to changing climatic conditions. However, the realization of the potential benefits of 5G technology in agriculture depends on addressing several challenges. These include ensuring widespread coverage and affordability of 5G networks, enhancing digital literacy among farmers, and addressing concerns related to data privacy and security. Moreover, efforts to harness 5G technology must be complemented by broader policy interventions aimed at promoting sustainable agricultural practices, enhancing infrastructure development, and strengthening institutional capacity to support climate adaptation and mitigation efforts. Climate alteration is defined by the Inter-Governmental Panel with Global Climate Change (IPCC, 2007) as "a shift in the current state of the climate which can be discovered (e.g. using statistical tests) by alterations to the average temperature and/or variation of its characteristics and that continues for a prolonged period, usually decades or longer." This description encompasses any change in climate as time passes, resulting from both natural variations and human activity. In contrast, the United Nations Framework Convention on Climate Change (UNFCC) regulates climate change as "a modification to the climate that is linked solely to human activities that alter the structure of the world's atmosphere along with that is in contrast to the variations in rainfall noticed over times that are comparable (IPCC 2007)." The results of the Intergovernmental Panel on Global Climate Change's second and third evaluations (IPCC 1996) and (IPCC 2001) have made it abundantly evident in the past few years that global climate change has become a verifiable reality.

Three factors contribute to the sensitivity of our atmospheric ecosystem to different forms of pollution: flooding, depletion of the ozone layer, and, most importantly, local pollution from the air. The increased radioactive radiation might result in a 1.5-to-5.8-degree Celsius increase in the average global temperature by the peak of the next century, based to the Intergovernmental Panel upon Climate Change (2011). When contrasted to the diurnal or biannual magnitudes of the temperature period, this may seem like a slight warming. It is important to note that this warming is unlike anything seen in the previous 10,000 years. The scientific community is concerned not only about the magnitude of change along with about the rapidity of warming, particularly about how vulnerable the natural and socioeconomic systems are to climate change and how they will respond to it.

The atmosphere, seas, cryosphere, subsurface lithosphere, and biosphere all work together to form the complex, dynamic climate framework that is responsible for actual climate change (Le Treut et al., 2007). This shift is being caused by human activities, specifically the combustion of fossil fuels and forest destruction, which is raising the quantities of greenhouse gases (GHGs) like carbon dioxide in the atmosphere. The outcome is an increase in heat and cold waves, altered rainfall patterns, increased frequency of droughts and floods, and increased weather extremes worldwide. The environment, as well as the lives and livelihoods of people, are negatively impacted by these events. Although they bear the least responsibility for these changes, marginalized communities in the most impoverished regions are disproportionately impacted (United Nations Development Programme, 2009).

2.2 Rainfall variability and Agriculture

Rainfall variability poses significant challenges to agriculture, affecting crop yields, water availability, and overall productivity. In Nigeria, where agriculture plays a crucial role in the economy and livelihoods of millions, understanding and adapting to rainfall variability are paramount. The integration of 5G network technology into agricultural practices offers innovative solutions to mitigate the impacts of rainfall variability and enhance agricultural resilience. The integration of 5G network technology into agriculture holds immense potential for addressing the challenges posed by rainfall variability in Nigeria. By enabling real-time data monitoring, precision agriculture, early warning systems, knowledge sharing, and market access, 5G networks empower farmers to adapt to changing weather conditions and enhance agricultural resilience. However, to fully realize these benefits, concerted efforts are needed to ensure widespread access to 5G infrastructure, promote digital literacy among farmers, and foster collaboration between stakeholders across the agricultural value chain. The Nigerian Sudano-Sahelian regions are known for their intermittent drought, as well as its wet and dry seasons (Sawa, 2002), decreasing the intensity of the rainfall and lengthening the period of drought (Ojonigu, 1990). (Olaniran, 2002) compiled a list of all these irregularities and verified that the location's rainfall regions have experienced a change in climate. The observed combined impacts of rising potential water loss and dryness by (Ayoade and Oyebande 1983), (World Book 2001), (Salama and Okafor 2003) Place the budget or water balance on the shortfall, which denotes a shortage. Once the population of the area is considered, which has increased to roughly 33,039,886 people (NPC, 2007), the per capita household water consumption clearly defines an increasing residential demand for water in a confirmed low water shortage (Ndabula and Jidauna, 2010).

According to the IPCC study from 2002, the Sudano-Sahelian region has been seeing a steady reduction in rainfall since the 1960s. Furthermore, there has been a rise in desertification and drought. The ways in which farmers have adjusted to the decreasing pattern of rainfall due to climate change have an impact on agriculture and agricultural productivity. The region now experiences a persistent water shortage because of this trend. Climate change has disguised the local level of forecast made by farmers due to the region's shifting patterns of rainfall and temperature. As a result, it is difficult to determine when the rainy season will start and finish. Most farmers grow a variety of crops. However, rain is a major factor in the production of many crops, including rice, melons, groundnuts, sugar cane, and maize. With irrigation, crops such as onions, tomatoes, peppers, and even maize are produced. Chemical fertilizers are frequently employed as a supplemental tool to address climate variability; this promotes both crop development and maximum output.

2.3 Effect of Rainfall variability on Farmers

With 5G networks, farmers can access real-time weather information more efficiently. This includes data on rainfall patterns, temperature changes, and forecasts for upcoming weather events. By having access to accurate and timely weather data, farmers can make informed decisions about their farming practices, such as adjusting planting schedules, irrigation timings, or implementing protective measures against extreme weather conditions. 5G technology can support the development and implementation of early warning systems for farmers. These systems can alert farmers to potential risks associated with rainfall variability, such as droughts, floods, or storms, allowing them to take proactive measures to protect their crops and livelihoods. By receiving early warnings through mobile applications or other connected devices, farmers can minimize the impact of adverse weather events on their farms. The integration of 5G network technology has the potential to revolutionize how farmers cope with and adapt to rainfall variability. By providing access to real-time weather data, early warning systems, precision agriculture tools, remote monitoring capabilities, and knowledge-sharing platforms, 5G networks empower farmers to optimize their farming practices, improve crop resilience, and sustainably manage their agricultural operations in the face of changing climatic conditions. The El Nino-Southern Cycle of the Pacific Ocean, tropical convection, and monsoon variation are the three main macro-level sources of rainfall variability in Africa. The first couple are local mechanisms that control the seasonal and local distributions of rainfall and temperature. Although the third's origin is farther away, it has a significant impact on Africa's annual patterns of rainfall and temperature. Despite the significance of each of the three processes, little is known about their interactions or how climate change affects them. Variation in rainfall will have a profound influence on soil quality, water availability, and human health and nutrition worldwide. Increased rainfall will result in lower yields, while variations in rainfall will impact crop and livestock output quantity and quality, decrease irrigation water availability, and reduce overall fertility of the soil (Trade and Agricultural agency).

Across Africa, a heavy reliance on rain-fed agriculture and restricted availability of agricultural inputs worsens the poor yields and a prevalence of poverty. Climate change is projected to put a strain on production, which means important crops in certain nations will likely see price increases. Reduced agricultural productivity will result in even lower earnings for the most vulnerable groups farmers, women, and girls who reside in nations exposed to natural disasters. As a result, they will have less money to spend on wholesome food, inputs for agriculture, and other necessities. Resources and funding for adaptation are accessible in the industrialized nations, which are the source of many of the problems of climate change. Nonetheless, resources may not be as easily available to dedicate to discovering adaptations for the effects of climate change in numerous underdeveloped nations. Due to their unique positions, these are frequently the countries particularly vulnerable to weather-related calamities or the consequences of general variation in rainfall (Roberts and Parks, 2007). Farmers are among those most vulnerable to the consequences of climate change, particularly smallholder farmers. For guidance on when they ought to start and finish their crops most effectively, they rely on regular seasons. It is much harder to rely on continuous or typical yields because the weather and rain are erratic and vary from year to year. Due to the dispersed nature of farms and the difficulty of navigating the roads, it can be challenging for farmers to sell their produce and for banks to finance or insurance them if they tend to not be readily available. Those small-scale farmers are vital to the world's food supply in a changing climate, but their survival and prosperity depend on their ability to adapt. Smallholder farmers can increase their land investment and reduce their susceptibility to rainfall unpredictability in a variety of creative ways, but most of these come with upfront expenses that most cannot afford. Smallholders may encounter financial constraints when making decisions on how best to care for their land and when making investments. Due to increased financial expenses and restrictions imposed by banks in those regions due to their rural locations and associated risks, lending is much more difficult to obtain in rural communities (Kloeppinger-Todd and Sharma, 2010). Farmers can choose that the security is not value the risk, a practice known as "risk-rationing" (Boucher et al., 2008), or they may not be able to obtain credit since they fail to satisfy the requirements. Moreover, security and land tenure issues complicate investment decisions. Smallholders are far less inclined toward making investments in land they are unsure they will possess in the future because they lack a clear title to it. In addition, they cannot use their land as collateral (Deininger and Ali, 2007). Land is typically not valuable enough to be used as collateral, even when it is owned. Because farming involves so many unknowns, it is also challenging to provide insurance or finance for. Despite knowing which other person is growing it nor what kind of harsh weather could harm crops that year, farmers must decide what to cultivate and the amount of it (Peck and

Pearce, 2005). Due to the highly variable nature of payment schedules in farming, it is optimal for both the lender and the borrower if they can collaborate closely, something that larger banks find challenging to accomplish (Peck and Pearce, 2005).

2.4 Rainfall Variability

2.4.1 Rainfall

Since there is a shortage of it throughout the dry season, rainfall is a vital component in the area (Olofin, 1980, 1987). The average annual rainfall throughout the region is roughly 1000 mm in the south, 800 mm in the area surrounding Metropolitan Kano, and 600 mm in the northeast and north in a typical year. Anywhere in the region, the quantity of rainfall experienced varies greatly over time. The amount recorded in two separate years is never the same, and the average determined over either of the two periods is never the same. Over a lengthy period (more than 30 years), Kano Airport has had 884 mm of yearly rainfall on average. On the other hand, a mean of 748 mm was recorded throughout the following five decades (1975–1979), Analyses based on data from 1965 to 1974 indicate that deviations from the mean of as much as 30% are deemed normal. Conditions of drought cause further variations. As a result, Kano Airport only got roughly 48% of its historical mean annual rainfall throughout the 1972–1975 drought. According to (Olofin 1980), three rainfall regimes are produced by differences in the quantity and other characteristics of rainfall.

a). A wet regime is present when the total amount of precipitation received exceeds the long-term average, the rainy season lasts longer than usual, and the sequence of precipitation is consistent.
b). When the sequence of rain is consistent and the quantity and period of the rainfall are roughly typical, there is a reasonable regime.
c). When any combination of less rainfall and a more variable rain structure, or when combined are less rainfall and a more variable rain trend either with or without a constant irregular rain pattern, then is a dry regime.

Regimes come and go at random. A significant drought is indicated by the dry regime occurring for two years in a row.
Farmers ought to take advantage of Kano State's increased rainfall, that's a result of climate change brought on by rising temperatures. Rainfall falls across agricultural land and provides a free supply of water for livestock and crops. With higher rainfall comes increased recharging of the rivers that feed the dams, the dams individuals, the irrigation projects overall, and the groundwater. This improves agriculture even more to produce crops and, indirectly and directly, animals. The crops that are grown serve as certain forms of food or drink for the animals, and they also drink from the collected rainwater. For a region like Kano State, where the rainy season lasts for barely five months, a lack of water supply is typically the misery of agriculture. Thus, farmers and entrepreneurs in the farming industry should take advantage of a rise in the quantity of rainwater that can be collected, stored in ponds, dams, and underground.

2.5 Seasonal Effects of the Climatic Controls

According to (Olofin 1980), the general impacts of climatic controls and temporal fluctuations in precipitation and temperature variables offer Kano Region four distinct seasons, not merely the prevalent belief of a dry and a wet season. These seasons are as follows:

a) A dry and cool season b). a dry and hot season
c). a wet and warm season d). a dry and warm season

i. The Dry and Cool Season (kaka): begins in Metropolitan Kano in the middle of November and finishes in February. Towards the north from the station, it begins approximately 10 days before and ends approximately ten days later. The season begins and ends in the south around 10 days later than it does in Metropolitan Kano. As a result, the time lengthens as one moves northward. The weather during this time of year is cool and dry, with sporadic dusty Harmattan haze. For the relevant months, additional meteorological factors are represented in addition to a preponderance of northerly winds.

ii. The Dry and Hot Season (bazara): is the brief period that separates the wet season from the Harmattan season. Even with the highly changeable winds, the region is still located north towards the ITD. In Kano, the season begins with the close of the cool weather and lasts until roughly mid-May (adding 10 days towards the north and subtracting 10 days towards the south). In Stevenson's Screen, midday air temperatures can reach over 400 C during this, the warmest season of the year.

iii. The Wet and Warm Season (damina): ends in Kano about mid-September after the hot season (plus ten days farther south and less days due to ten days towards the north). If southerly winds predominate and over 90% of the region's yearly precipitation is recorded, this is the appropriate rainy season. The year's lowest monthly and daily temperature ranges are the result of the cozy, constant temperature.

iv. The Dry and Warm Season (rani): begins with the conclusion of the rainfall season and finishes with the arrival of the Harmattan around the middle of November near Kano (+10 days in the north and south). This is the second warmest time of year, with relative humidity still high enough to make comfortable temperatures nearly intolerable. There is a great deal of variation in the winds, and there are the most calms throughout this season. October's weather is remarkably typical.

v. Normal or Seasonal Variation: The quantity and length of rainfall throughout Nigeria vary over time on various scales. Given the tropical wet-and-dry climate, average or seasonal variation happens once a year and is thought to be in the range of +30% about the mean value. Therefore, any number in the range of 605mm (dry) through 1123mm (moist) in the location in question is implied by a median measurement of, say, 864mm, and anything in the range within 3 and 5 months is implied by a median duration of 4 months. Long-term data reflect the majority of these "normal" changes; therefore, one must use caution when calculating probabilities based on such records. Records with short durations are unsuitable for probability calculations as they may overemphasize or underemphasize the effects of dramatic fluctuations that are considered "normal." In any event, one should be aware that any probability estimate for this kind of environment pertains to a very long-time horizon.

2.6 Impacts of Climate Change on Social and Economic life

With 5G networks, emergency response teams can receive real-time data on weather patterns, natural disasters, and other climate-related events. This allows for more efficient and coordinated disaster response efforts, potentially saving lives, and minimizing damage to infrastructure. Additionally, 5G-enabled communication systems can enhance the resilience of critical infrastructure, such as power grids and transportation networks, ensuring continuity of essential services during extreme weather events. 5G networks can support various sustainable development initiatives aimed at addressing climate change and promoting environmental stewardship. For example, smart city projects leveraging 5G technology can improve energy efficiency, reduce waste, and enhance urban resilience to climate-related hazards. Similarly, 5G-enabled precision agriculture techniques can optimize resource use in farming, mitigate the impacts of climate variability on crop yields, and promote sustainable land management practices. The integration of 5G network technology has the potential to catalyze transformative changes in social and economic life, enabling more resilient, sustainable, and inclusive societies in the face of climate change (A. Narayanan, 2021). Through the utilization of 5G networks' potential to improve connectivity, interaction, and cooperation, stakeholders may unite to tackle the obstacles presented by the effects of climate change and construct a future that is more resilient for all. In addition to negatively affecting overall development attempts, the consequences of recent severe weather and steady climatic changes have hampered efforts to reduce poor and food insecurity. The effects of climate change have grown more noticeable in economic sectors like fishing and agriculture that primarily rely on weather patterns, whether directly or indirectly (IPCC, 2012). Furthermore, the severity of the effects of climate change continues to increase due to the exhaustion of natural resources brought on by growing environmental and demographic constraints. In summary, there is growing apprehension regarding the growing risks to the present income and spending habits of people and their families who depend on these industries for their livelihood (Foresight, 2011; IPCC, 2012). Global model data suggests that farming people in tropical (low pole) areas should expect a decline in their agricultural revenues and yields. As a result, poverty and lack of food will become more common and persistent. When local temperatures rise by 3 °C, estimates for these areas indicate that production losses for rice, wheat, and maize vary between 5 to 20 percent; the amount of yield could halve once temperatures rise by up to 5 °C. As few as 0.5 and as nearly 23.5 percent of a nation's GDP (gross domestic product) are predicted to be lost economically. Yields might slightly rise or fall in temperate (higher latitudes) zones, resulting in modifications to GDP that vary from minor losses to increases of more than 13 percent (IPCC, 2007; Tol, 2009). Each of the climate change components considered in the Global Climate Change and Food Security (CCFS) system have an impact on various resources (infrastructure, productive resources, and human capital, involving health), in addition to biophysical variables (like plant growth) and agricultural management techniques that are either directly or indirectly used in food systems (FAO, 2008a). When statistics allow, a thorough evaluation of the effects on food availability should keep a careful eye on climate change and meteorological factors like:

• Mean, maximum, and lowest temperatures (the number of days with a growing degree of products is connected to that).
• Variations in precipitation over time:
– The frequency, length, and severity of shortages and dry periods.
– Modifications to the amount, timing, quantity, and location of snow along with rain.

The office of the secretariat of the United Nations Framework Convention on Climate Change (UNFCCC) has brought attention to the issues and requirements that developing nations have when it comes to climate change adaptation. Asia, Latin America, Africa, and small island nations are the four regions of developing countries that are most affected by climate change. These regions are also vulnerable to future climate change, and there are plans, strategies, and activities in place for current adaptation as well as future adaptation alternatives and needs. The UNFCCC secretariat has predicted that by 2030, developing countries will need between USD 28 and USD 67 billion in funding to enable modification to climate change. This estimate is based on current information accessible through current and projected investments and financing necessary for the development of an efficient and suitable international reaction to climate change. The following translates to 0.06–0.21% of the estimated world GDP in 2030, or 0.2–0.8% of global investment expenditures. The amount of money allocated to adaptation currently in the world is minuscule, and developing nations sometimes face difficult and drawn-out procedures to obtain these monies.

3. Climate Change Adaptation and Mitigation

3.1 Adaptation

The formal practical description of the adaptation given by the IPCC is as follows:

Adaptation is the process through which human or natural systems change in response to real or predicted climatic stimulus or the repercussions to mitigate harm or take advantage of advantageous circumstances. It is possible to distinguish between several forms of adaptation, such as proactive versus reactive adaptation, both public and private adaptation, and spontaneous and organized adaptation (IPCC, 2001). Similarly, a successful adaptation to some perceived or actual shift in the local environment may eventually become inappropriate when circumstances change. Adaptation as a reaction to change needs to be suited to the hazards or risks in each era. It's crucial to remember, though, that some reactions to change must be viewed as reactionary right from the start since they lacked preparation or planning. Maladaptation is the term used to describe behavioral changes in a creature (or a community) that are counterproductive to the intended results.

Even though the term "adaptation" is crucial to scientists and lawmakers dealing with climate change, not everyone who uses it agrees on its definition. Also, more individuals need to be made aware of the fact that several terms, such as (but not restricted to) adjustment, modification, accommodation, modification, and adjustment, are substitutes for adaptation to foster better cross-disciplinary and cross-cultural communication and understanding. Additionally, people need to be aware that although these alternative terminologies are like adaptation in some ways, they do lead to differing interpretations of what is occurring beneath the guise of adaptation.

3.2 Mitigation

Something needs to set at some point, which is the second law of ecology, is closely related to the realization that continuously adding more greenhouse gases to the atmosphere will include a significant, observable impact on the climate, ecosystems, and society in the far future. Unfavorable indicators are emerging globally, indicating that change is happening at a faster pace than scientists had predicted. These indicators include the melting of most glaciers on Earth, rising sea levels, the upslope migration of warm-temperature ecosystems into higher altitudes, and the quickly decreasing area covered by Arctic Sea ice. Governments have begun looking for ways to decrease their sources of greenhouse gases and improve their sinks for them to prepare for any unanticipated negative effects. This is because scientists have recently learned where those gases are heading and what damage they are causing to the atmosphere of the earth and oceans. Technology replacement and change that lowers the inputs of energy resources and pollution per unit of result is referred to as mitigation. While several technological, social, and economic initiatives would also result in lower emissions, mitigating climate change also entails putting laws in place to improve sinks and lower greenhouse gas emissions. The (IPCC 2007b) Synthesis Assessment provides several instances of mitigation technology, strategies, and initiatives alongside possibilities and limitations for agriculture and forests.

3.3 Mitigating climate change through agriculture

Agriculture is one of the main sources of greenhouse gas emissions because of the gases that crops and livestock release, including CO_2, methane, and nitrous oxide. Agriculture contributes within percent of global greenhouse gas emissions, according to the pollution inventories that states provide to the UN's Framework Protocol on Climate Change. Agriculture is the main driver of deforestation, therefore adding emissions from this source in developing nations brings the total amount of greenhouse gas emissions from this source to between 26 and 35 percent. Developing nations account for about 80% of all agricultural emissions, especially deforestation. Methane and nitrous oxide are two of the greenhouse gases with the greatest impact that are not carbon dioxide, and they are primarily emitted globally due to agriculture. A little over one third for agriculture's overall non-carbon dioxide emissions come from fermentation in the digestive tract in cattle production and nitrogen oxides released from soils (fertilizers application and compost), both of which are expected to increase. The burning of biomass, the cultivation of rice, and the handling of manure account for the remaining non-carbon dioxide emissions. Although precise figures are unknown, land use changes related to agriculture such as the omission of soil organic material in farmland and grazing and the conversion of forests to agriculture also significantly contribute to decreased carbon sequestration (preservation). By reducing deforestation, carbon dioxide released from modifications to agricultural land use may prove minimized. Furthermore, because the benefits from converting forests to agricultural purposes are typically poor, there are a lot of potential chances for the decline via carbon trading. The transformation of forest compared to conventional grazing in Acre, Brazil, results in a decline of 14 tons exceeding sequestered carbon dioxide, or less below \$0.01 per tons of CO_2, but at the other end, it yields a net present worth of future revenue of \$2 per hectares in land value. With Cameroon, the value of converting forests to rigorous cocoa plantations is \$3 per tonne of CO_2.20 By 2050, 5 million acres of forestry may be prevented from being converted if carbon markets were to charge about \$27 per ton of CO_2 (equivalent to the May 2007 transaction rate in the European Climate Market for 2008–10 carbon allowances). (WDR 2008 team, using information from www.unfccc.int, the United Nations International Council on Climate Change).

3.4 Adaptation and mitigation strategies

Society will inevitably experience a certain amount of change in the climate and its corresponding negative effects due to inertia in the socio-economic and climate systems that drive greenhouse gas emissions, irrespective of the mitigation approach that is selected. On the other hand, the less likely the effects, the earlier the mitigation efforts start. Even in the case of moderate climate change, however, adaptation will be necessary to safeguard food security and livelihoods in many of the developing nations that are anticipated to be the most susceptible. This suggests that the main obstacle facing climate action will be determining the best combination of adaptation and mitigation strategies to reduce the overall effects of climate change. It begins with realizing that there are several mutually reinforcing synergies between different adaptation and mitigation strategies, which can result in a more effective use of "climate response" resources. Significantly, many such synergies are relevant to rural life in poor nations and are found in the agricultural and forest industries.

3.5 Adaptation strategies in agriculture

Changing inputs, species, and kinds to increase rebellion to heat shock, flooding, drought, and salinity; adjusting fertilizer rates to preserve grain or fruit excellence; adjusting irrigation quantities and schedules alongside additional water management; and adjusting cropping activities' measuring or location. using a greater range of techniques to "harvest" water and preserve soil moisture; controlling river basins to provide irrigation services better and to avoid logging of water, eroding, and nutrient leakage; and using and transporting water more skillfully. combining the cultivation of fish in rice fields and the breeding of livestock to generate additional revenue streams. Expanding the application of holistic pest and pathogen administration; creating and utilizing species and kinds resistant to diseases and pests; enhancing monitoring programs and quarantine capacities. Climate forecasting is being used more often to lower production risk. integrating livestock and agricultural operations by using adjusted forage crops, reevaluating fertilizer applications, using supplemental feeds and concentrates, changing pasture rotation, modifying grazing times, changing species of animals and breeds, and integrating livestock levels with pasture manufacturing. Making adjustments to forest management practices, such as varying the proportion of hardwood and softwood species, harvesting and growth structures, and rotation periods; switching to species or regions more productive in new climate scenarios; designing landscapes to mitigate fire and insect damage; modifying fire management systems; starting prescribed burning to serve as non-chemical insect control method to lessen the susceptibility of forests to increased insect epidemics; and modifying harvesting timetables. introducing agroforestry, forest conservation, and forest-based businesses to diversify rural incomes. Changing the effort and quantity of the catch, as well as the breeding habitat, and lowering fishing pressure to maintain fish stock yields.

3.6 Agronomic values and utilization of sorghum

The cereal crop sorghum ranks fifth in importance, following wheat, corn, rice, and barley (Food Security Department, 2003; Saballos, 2008). As an alternative to rice, there exists a little but expanding market with pearled sorghum in places like South Africa and Kenya (Food Security Department, 2003). Among the arid areas, it is a particularly significant food crop (FAO, 1995a), providing over 750 million individuals who reside in the semi-arid tropical regions of Asia, Africa, and Latin America with their primary source of grains (Food Security Department, 2003). According to Oyidi 1976, sorghum is used to prepare porridge that forms a smooth paste and has good flavor and a purple colour; the colour development of which is an interesting peculiarity of this cereal. He pointed out that the grains of the white variety could also be roasted with salt and spice and eaten. (Food Security Department 2003) noted that the phenolic of the red-grained variety gives a desired flavor and colour in some traditional foods and beverages. In Nigeria, cake and biscuit have been successfully made from the flour of sorghum (Oyidi, 1976). Though those made from wheat flour were larger, (Oyidi 1976) reported that the flour from sorghum did not hold moisture; it dried and crumbled easily. Additionally, it had a certain flavor which the wheat flour did not have, an attribute which could be used to give variety to cakes and cookies. Sorghum could also be used for making bread, as has been testified in Ethiopia (Mesfine et al., 2005). The beer and candy industries have acknowledged it as a potentially important industrial crop (Oyidi, 1976; Food Security Department, 2003; ICS-Nigeria, 2003a). The beneficial characteristics of this power crop have elevated it to a stage where it is being given significant consideration for utilization in the wake of the recent upsurge in demand for the manufacture of biofuel (Saballos, 2008). According to Food Security Department (2003), because tannins affect the digestion of protein, livestock feed makers choose to use grains either white sorghum nor low tannin colored sorghums.

3.7 Ecology of sorghum

Although sorghum is native to semi-arid parts of Africa, it has evolved to thrive in a wide range of temperatures, especially humid and temperate ones (Saballos, 2008). subsequently is suited to grow in a variety of ecological situations in both settings. Subsequently, is suited to growing in a variety of ecological situations in both settings. It is the most significant and, as a result, the most extensively cultivated cereal crop among all those farmed by farmers in Nigeria's desert zones (Andrews, 1975; ICS-Nigeria, 2003a; Chiroma et al., 2006). Thus, although sorghum performs similarly well in the modified savanna region (ICS-Nigeria, 2003a), Nigeria's savanna region produces most of the crop (Chiroma et al., 2006). Because of its exceptional qualities, the crop can thrive in perhaps the most unforgiving conditions, an ability that numerous additional crops cannot match. According to the Food Security Department (2003), sorghum has a lower absorption ratio (kg of water needed to generate a kg of plant material) at 141 than maize (170) and wheat (241). Compared to most other cereals, it can tolerate waterlogging considerably better and is extremely resistant to drought (Saballos, 2008). Typically, it is cultivated in regions where it is excessively hot, too humid, or lacking in fertility to support the cultivation of maize (Zaongo et al., 1994; Food Security Department, 2003). However, its successful production is, according to ICS-Nigeria (2003a), most possible when a well-drained, fertile land that has not been cropped with the crop the previous year is selected. Sorghum is very sensitive to acidity and, so, the preferable soil pH for optimum yield is 6.5 (Hagan, 2008). Although yields are adversely affected when mean temperature exceeds 28ºC during the heading period (Zaongo et al., 1994), sorghum can withstand temperatures above 38ºC (Food Security Department, 2003). Its production in West Africa requires around 400 to 500 mm of rain (FAO, 1995a). However, with the long growth cycle variety (the late- maturing cultivar), the water requirement is doubled, ranging from 950 to 1100 mm (Food Security Department, 2003). The local varieties are typically very tall plants (Chiezey and Egharevba, 1987), and can grow to a height of 3 to 5 m (Andrews, 1975; Olufajo, 1995). Among them are the long growth cycle varieties, which take about 170 days to mature (Olufajo, 1995). The recommended sowing date for this late-maturing sorghum cultivar in the forest-savanna transition zone of Nigeria is 10 to 12 June (Bello, 1999) or early to mid- July in the southern Guinea Savanna (ICS-Nigeria, 2003a). In Nigeria, the mean seed yield (SDY) of sorghum could be as low as 0.88 Mg ha-1 at Nsukka in the southeast, as reported by Amana (2008); or 1.18 Mg ha-1 at Owo in the southwest, as reported by Agbede et al. (2008). However, the commonly obtained mean SDY in the core sorghum-growing areas of Nigeria included 1.12 Mg ha-1 in the Northeastern Zone7 (Chiroma et al., 2006) and 1.15 Mg ha-1 at Mokwa in the Southern Guinea Savanna Zone (Andrews, 1975). Others reported from other semi-arid tropical areas outside Nigeria included ranges of 0.6-2.5 Mg ha-1 from a sandy loam in Burkina Faso (Zougmore et al., 2004) and 2.2-4.7 Mg ha-1 in Ethiopia (Mesfine et al., 2005), and a mean value of 1.57 Mg ha-1 in India (Patil and Sheelavantar, 2006).

4. Experimental Method/Procedure/Design

The Pearson moment co-relation analysis was used with a view to establish the level of significant relationship between the sorghum yield and annual rainfall. The statistical method known as the coefficient of Pearson correlation, or Pearson-R test, quantifies the strength of the association between the two parameters by calculating the correlation between them.

$$r = \frac{N\Sigma xy - (\Sigma x)(\Sigma y)}{\sqrt{[N\Sigma x^2 - (\Sigma x)^2][N\Sigma y^2 - (\Sigma y)^2]}}$$

Where:

- N = number of pairs of scores
- Σxy = sum of the products of paired scores
- Σx = sum of x scores
- Σy = sum of y scores
- Σx^2 = sum of squared x scores
- Σy^2 = sum of squared y scores

Figure 1: Pearson Correlation (Source: KHOTARI, 2004)

The magnitude and trajectory of a linear correlation between two independent variables can be determined using this statistical technique. In this case, the two variables being analyzed are sorghum yield and annual rainfall. The purpose of using the Pearson correlation analysis in this context is to determine the level of significant relationship between sorghum yield and annual rainfall. Certainly, the research wants to understand if there is a meaningful association between these two variables. The coefficient, which is sometimes called the Pearson-R test, has an integer number between -1 and 1. It displays the linear relationship that exists among the variables' intensity and direction.

• A strong positive association is shown by a value near 1, which means that when one variable rises, another variable is also likely to rise.

• A significant negative association is shown by a value around -1, which means that when one variable rises, another tends to fall.

• There is little or no linear correlation among the variables when the value is around 0.

Hence, examining the Pearson correlation coefficient, the research can determine how strong the relationship is between sorghum yield and annual rainfall. If the coefficient is statistically significant (i.e., the p-value associated with the correlation is below a certain threshold, often 0.05), then the relationship observed is unlikely to have occurred by chance. Once the Pearson correlation coefficient is calculated, it can be interpreted to determine the strength and direction of the relationship between sorghum yield and annual rainfall. Although a coefficient around 0 would indicate no significant linear association, a coefficient closer to +1 or -1 would indicate an important positive or negative link, respectively. Pearson correlation analysis is being used to assess the degree of association between sorghum yield and annual rainfall, and the resulting correlation coefficient will provide insight into the strength and direction of this relationship.

5. Results and Discussion

5.1 The impact of rainfall variability in sorghum production

Figure 2 below indicates a yearly fluctuation in the distribution pattern and its intensity with an upward movement of trend line indicating an increase in annual rainfall movement reaching up 11000 in 2002 and with a lower precipitation level in 2007 - 2008 falling between 200 - 400 annual rainfall levels which served as the favorable stage for sorghum optimum production. Sorghum is sensitive to water availability, and variations in rainfall can directly impact its growth and yield. With 5G-enabled precision irrigation systems, farmers can optimize using water in real-time weather data and crop water requirements. This ensures that sorghum plants receive adequate moisture levels even during periods of rainfall variability, thereby enhancing crop resilience and productivity. The integration of 5G network technology can enhance sorghum production by granting farmers availability of current weather data, precision irrigation systems, early warning systems, remote monitoring capabilities, and improved market access. By leveraging the capabilities of 5G networks, sorghum farmers can adapt to rainfall variability more effectively, mitigate risks, and optimize their agricultural practices to achieve higher yields and greater resilience in the face of changing climatic conditions (H Fourati, 2021).

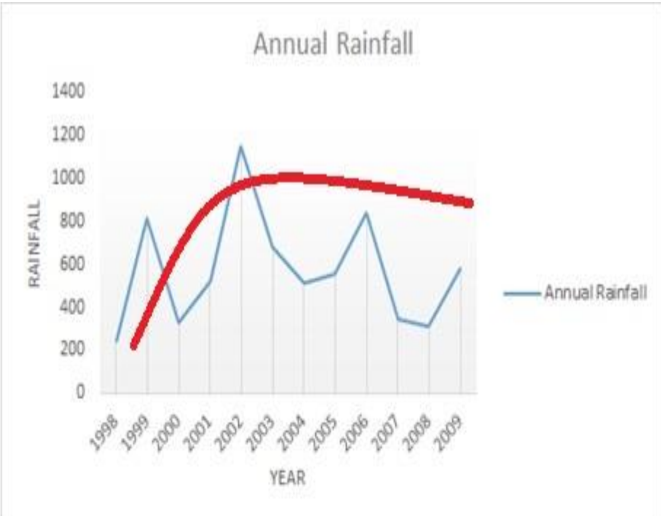

Figure 2: **Annual rainfall variation 1998-2009**

Figure 3: below illustrates a yearly production output variations covering a period of 11 years from 1998 - 2009. The production output was at its peak in 1998 but with a sudden decline of yield in 2001 and slightly picking up from 2007 - 2009. These up and downward movements of the trend line indicate a yearly fluctuation in yield which occurred due to an increase in precipitation level and changes in annual rainfall distribution pattern which has an impact on the final production output or yield.

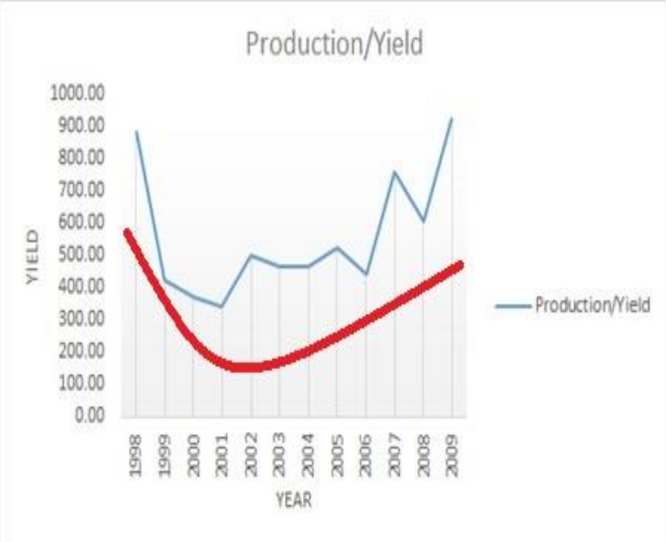

Figure 3:Sorghum Productivity output 1998-2009

Figure 4 below shows how rainfall variability affects yield compared to sorghum cultivars according to lengthy historical rainfall records projections with highest precipitation rate of over 1000.00 in 2002. The result in the chart verified that the variability of rainfall does, in fact, yield sorghum varieties with a decline in production outcome when the rainfall is above precipitation rate of 800.00 - 1000.00 respectively. The result also indicates a future sorghum response which shows that an impact temperature increase will be greater than the variability of rainfall on sorghum.

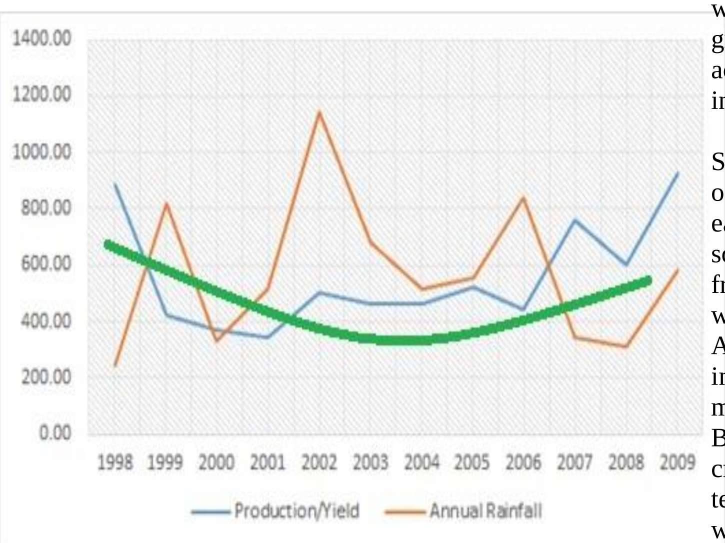

Figure 4:Annual rainfall variability and sorghum productivity output 1998-2009

5.2 Method adopted by farmers to maximize sorghum production

Farmers can employ 5G-enabled pest monitoring and control systems to detect and manage pest infestations in sorghum fields. By deploying sensors, drones, or cameras connected to 5G networks, farmers can monitor for signs of pests or diseases in real-time. Farmers can take prompt action thanks to this early diagnosis, such as using tailored herbicides or adopting biological control methods, minimizing crop damage, and maximizing sorghum yield. Using 5G-connected farming equipment and machinery, farmers can collect and analyze data on soil health, crop growth, and yield performance. Farmers can discover regions for enhancement and obtain important insights on sorghum growth patterns by utilizing machine learning techniques and sophisticated analytics. With the use of this data-driven strategy, farmers may increase sorghum output by optimizing crop management techniques including applying fertilizer, planting weight, and rotation of crops. By adopting these methods and leveraging the capabilities of 5G network technology, farmers can optimize sorghum production, improve resilience to environmental challenges, and enhance economic sustainability in the agriculture sector. Based on the information obtained from the FGD the farmers reveled some important methods they adopted in maximizing sorghum production which as include Cultivating the soil with farmyard manure, compose manure, and NPK as a critical component of keeping the farmland's sorghum soil in ideal condition; consequently, nourishing the sorghum at seeding time gives the seedlings vital nutrients. Since the sorghum's root region at the base is the most crucial location for fostering growth that will result in a remarkable yield. According to the farmers, utilizing hybrid seeds that are bred to develop quicker, stronger, and more efficiently is essential to optimizing sorghum production. Having high-quality seeds is the foundation for enhancing sorghum yield.

Some of the farmers opined that scouting their farmlands on foot is also of the methods they use in maximizing sorghum yield. They can evaluate the soil's qualities, look for any weeds that may be emerging, and make sure the sorghum is growing healthily at this time. A greater sorghum yield can be achieved by getting down on the ground and carefully inspecting the crop.

Sorghum does not require too much water, rather it needs only moisture to grow. The farmers further expressed that early and regular weeding of the farmlands maximizes sorghum yield as weeds are invasive siphons nutrients away from the crop and compromises the farmlands therefore weeds need to be dealt with as early and often as possible. Additionally, according to the farmers, an especially important aspect of cultivating sorghum along with the best method to raise productivity is picking the ideal time to plant. But a few of the farmers additionally brought up how the crop's total yield is impacted by the veteran soil rotation technique. Sorghum to sorghum growing is best avoided when the quality of the soil is strong necessary or the land mass is limited; in other cases, they might choose various crops in alternative years, such as corn. Planting sorghum in successive years has been proven to be insufficient for optimal yields. However, the farmers claim that a lack of technical assistance for the farming community is to blame for the low production of sorghum. Some of the respondents also mentioned that some farmers adhere to traditional agricultural practices and that even the few advisory offices that do exist have trouble persuading farmers to embrace new technologies, like the usage of hybrid seed.

Lastly, the farmers expressed their opinion that they may increase sorghum yield by using better farming inputs. Tractors, bullocks, seed, ploughs, and even labor for weeding are some examples of these inputs. When it comes to input requirements, most farmers only harvest the amount of land they personally can manage. For example, most farmers only use one or two livestock rather than the four needed to pull a plow. The farmers stated that in some locations, more than 57% of farmers do not have access to quality farming inputs necessary to produce vast farms. The respondents suggested that the situation can be improved if the government provides modern farming tools at a subsidized rate to the farmers.

5.3 Relationship between rainfall and Sorghum production.

Table 1: Correlation between Rainfall and sorghum yield

Variables	R (correlation Coefficient	P-value
Annual rainfall and sorghum production	-0.374	0.255

Correlation is significant at the 0.05 level (2-tailed)

Table 1 shows the Pearson moment correlation co-efficient of annual rainfall and sorghum production from 1998 to 2009 the result indicated that the rainfall is negatively correlated with sorghum at -0.374 the correlation was competed at 5% level of significance. The result also shows that the probability value (p-value) is 0.255. This implied that the relationship between the 2 variables, that is annual rainfall and sorghum yield is statistically insignificant at 7% level.

5G technology promises faster and more reliable internet connectivity, which can be beneficial for farmers in terms of accessing real-time data, market information, and agricultural apps for crop management. It can facilitate precision agriculture techniques, such as remote monitoring, smart irrigation, and automated machinery, leading to potential improvements in productivity and efficiency. Exploring how Nigerian farmers can leverage 5G technology in their farming practices, such as using drones equipped with sensors for crop monitoring, implementing IoT devices for soil moisture monitoring, or employing AI algorithms for pest detection and crop management. These advancements could optimize resource utilization and enhance overall crop yields. Despite the potential benefits, there may be challenges in adopting 5G technology in Nigeria's agricultural sector, including infrastructure limitations, affordability concerns, and the need for technical skills among farmers to effectively utilize these technologies. Additionally, issues related to network coverage, particularly in rural areas where agriculture is prominent, need to be addressed. Nigeria's agriculture is highly vulnerable to climatic variations, including changes in rainfall patterns, temperature extremes, and occurrences of pests and diseases. Sorghum, being a drought-tolerant crop, is crucial for food security in many parts of Nigeria. However, unpredictable weather conditions can significantly affect sorghum yields, leading to economic losses for farmers and food insecurity for communities. Talk about possible adaptation tactics farmers might use to lessen the negative effects of weather variations on sorghum yield. This could involve implementing improved water management techniques and the use of drought-resistant sorghum cultivars, diversification of crops, and investment in climate-smart agricultural techniques. Exploring potential synergies or trade-offs between the adoption of 5G technology and adaptation to climatic fluctuations in sorghum cultivation. For instance, while 5G-enabled precision agriculture may enhance productivity and resilience, it may also require significant energy consumption, potentially exacerbating environmental concerns.

6. Conclusion and Future Scope

In conclusion, this study has demonstrated that climatic fluctuations significantly impact sorghum yield in Nigeria, and integrating 5G network technology into agricultural systems presents new opportunities to address these challenges. Our analysis revealed that variations Extreme weather conditions have a significant impact on sorghum yield, as do changes in precipitation and temperature patterns such as droughts and floods posing considerable challenges to agricultural productivity. Additionally, we found that the vulnerability of sorghum to climatic changes varies across different regions of Nigeria, highlighting the need for localized adaptation strategies. These findings underscore the urgency of implementing effective climate change mitigation and adaptation measures within the agricultural sector, alongside harnessing the potential of 5G technology. Policies aimed at enhancing resilience to climatic risks, such as promoting the adoption of drought-tolerant sorghum varieties, improving irrigation infrastructure, and providing timely weather information to farmers, are crucial for safeguarding food security and enhancing the livelihoods of rural communities. Furthermore, interdisciplinary research efforts combining climatology, agronomy, and telecommunications engineering are essential for developing holistic approaches to address the complex challenges posed by climate change on agricultural systems. By integrating scientific knowledge with local knowledge and stakeholder engagement, we can develop context-specific strategies that enhance the adaptive capacity of farmers and foster sustainable sorghum production in Nigeria. The study concluded that the production of optimum sorghum yield requires low rainfall moisture content. The sorghum yield decline at higher rainfall variability, and it was also concluded that good farming inputs, fertilizer application, and improved hybrid seed, among others, are some of the ways of maximizing sorghum production considering the significance of sorghum as an essential crop for the country and its ability to improve the livelihoods of smallholder, low-resource farmers who account for a large portion of sorghum production. Moreover, the inclusion of 5G network technology in agricultural practices offers new avenues for improving resilience and optimizing resource allocation in the face of climatic variability. By providing real-time access to weather data, market information, and expert advice, 5G networks empower farmers to make informed decisions and mitigate risks associated with climate change. Overall, this study underscores the importance of proactive measures to mitigate the adverse effects of climatic fluctuations on sorghum yield, thereby ensuring food security, rural livelihoods, and environmental sustainability in Nigeria. Through continued research, policy interventions, and technological innovations, we can enhance the resilience of agricultural systems and promote sustainable sorghum production in the face of climate change and technological advancement.

Data Availability
There is no data available for this research.

Conflict of Interest
Authors declare that they do not have any conflict of interest.

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Authors' Contributions
All authors reviewed and edited the manuscript and approved the final version of the manuscript.

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