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Original Research Article

The impacts of climate change on water resources and its effect on food security in Nigeria

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ABSTRACT

This study aimed to investigate the perceptions of residents in the Taraba region of Nigeria on the impacts of climate change on water resources and its effect on food security. Respondents were asked to indicate their level of agreement with a series of statements related to these issues. The results of the study showed that a majority of respondents strongly agreed or agreed that climate change is affecting water resources in the region (75% total) and that water scarcity is impacting food security (80% total). However, respondents were less positive about the effectiveness of government efforts to address these issues, with a majority strongly disagreeing or disagreeing that the government is effectively addressing the impacts of climate change on water resources (55% total). Respondents also did not believe that community efforts are helping to mitigate the impacts of climate change on water resources. The majority (60%) were neutral about increasing access to water resources would improve food security in the region.

Keywords: Climate change; Water resources; Food security; Nigeria agriculture

1. Introduction

Climate change is a global phenomenon that is caused by the emission of greenhouse gases, primarily carbon dioxide, into the atmosphere [1]. These emissions lead to an increase in the Earth's temperature, resulting in changes in weather patterns, sea levels, and the availability of natural resources such as water and food. In Nigeria, climate change has led to significant changes in weather patterns, including increased temperatures and more extreme weather events such as flooding and drought. These changes have had a significant impact on water resources and food security in the country. One of the most significant impacts of climate change on water resources in Nigeria is the reduction in the availability of freshwater [2]. This is due to changes in rainfall patterns, which have led to more frequent and severe droughts in some regions. This, in turn, has resulted in a decrease in the availability of water for irrigation, drinking, and other essential needs. Climate change is also affecting food security in Nigeria, as it leads to changes in crop yields and the availability of food. The combination of increased temperatures and changes in rainfall patterns has led to changes in the timing of crop growth and the success of crop harvests. This is particularly true in the northern regions of the country where a decrease in rainfall has led to a decline in crop yields, resulting in food insecurity. In addition, climate change is also expected to increase the incidence of water-borne diseases and pests, which will further exacerbate food insecurity. Climate change is also expected to affect livestock and fisheries, which are important sources of food and income in Nigeria [3].

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2. Definition of Climate Change and Its Causes

Climate change refers to long-term changes in the Earth's climate, primarily caused by human activities that release greenhouse gases into the atmosphere [4]. These gases, such as carbon dioxide, methane, and nitrous oxide, trap heat from the sun within the Earth's atmosphere, leading to an increase in global temperatures. This process is known as the greenhouse effect.

The primary cause of climate change is the burning of fossil fuels such as coal, oil, and natural gas. When these fuels are burned, they release large amounts of carbon dioxide and other greenhouse gases into the atmosphere. The burning of deforestation and land use changes also contribute to the release of greenhouse gases in the atmosphere, which in turn contribute to the global warming [5].

Other human activities, such as agriculture and livestock production, also contribute to climate change through the release of methane and nitrous oxide, which are potent greenhouse gases.Climate change is a global phenomenon that is affecting every region of the world, leading to changes in weather patterns, sea levels, and the availability of natural resources. These changes have significant impacts on human and natural systems, including water resources, food security, and human health [6].

3. Study Area

Taraba State is located in the northeastern region of Nigeria. It is situated in the middle belt zone of the country and shares borders with several states, including Benue State to the west, Plateau and Nassarawa states to the northwest, Gombe State to the northeast, and Adamawa State to the east. It also shares an international boundary with Cameroon to the south.

The geography of Taraba State is diverse and characterized by a combination of highlands, plateaus, valleys, and plains. The state is part of the Mambilla Plateau, which is the highest plateau in Nigeria, and it features several prominent hills and mountains. The most notable of these is the Chappal Waddi, also known as the Gangirwal Mountain, which is the highest peak in Nigeria with an elevation of about 2,419 meters (7,936 feet) above sea level.

The state is traversed by several rivers and tributaries, including the Benue River, which forms part of its southern boundary. Other significant rivers in Taraba State include the Donga River, Taraba River, and Ibi River. These rivers contribute to the state's water resources and support various economic activities such as fishing, agriculture, and transportation.

The vegetation in Taraba State varies from the southern region, which is part of the Guinea Savannah zone, characterized by tall grasses and scattered trees, to the northern region, which falls within the Sudan Savannah zone, characterized by shorter grasses and shrubs. The state is rich in natural resources, including fertile soils, minerals such as limestone and gypsum, and a diverse range of flora and fauna.

Taraba State is home to several ethnic groups, including the Jukun, Kuteb, Tiv, and Fulani, among others. Each group has its own distinct cultural practices, languages, and traditions, contributing to the state's cultural diversity.

In terms of climate, Taraba State experiences a tropical savannah climate, with distinct wet and dry seasons. The rainy season typically lasts from April to October, while the dry season extends from November to March. The state receives a relatively high amount of rainfall, particularly in the southern part, which supports agricultural activities.

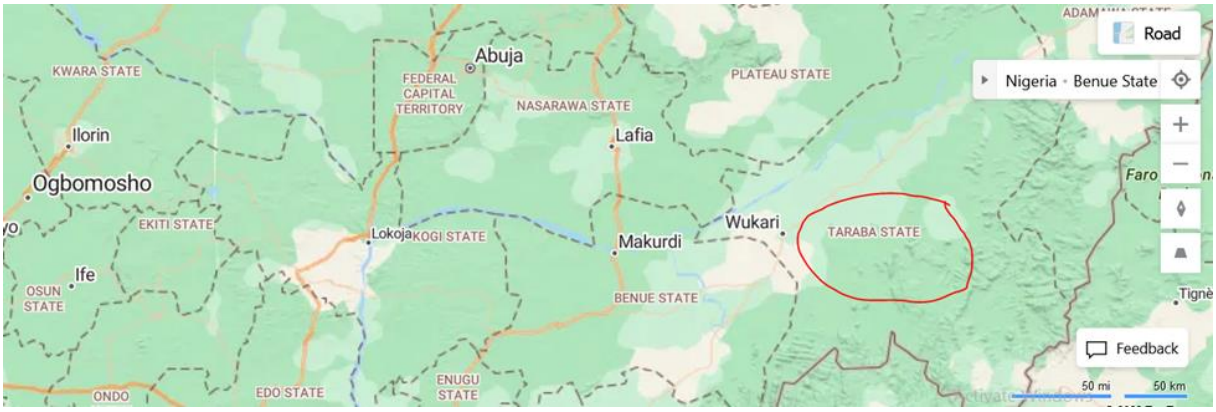

Fig. 1. Taraba state on map

The research questions for this study include:

1. How is climate change affecting water resources in Nigeria?
2. How is climate change impacting food security in Nigeria?
3. What are the current efforts of the government and communities in addressing the impacts of climate change on water resources and food security in Nigeria?

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The objectives of this research are:

1. To understand the extent to which climate change is affecting water resources in Nigeria
2. To understand the extent to which climate change is impacting food security in Nigeria
3. To identify potential solutions to mitigate the impacts of climate change on water resources and food security in Nigeria.

The hypotheses for this study are:

1. Climate change is having a significant impact on water resources in Nigeria
2. Climate change is having a significant impact on food security in Nigeria

Government policies and community efforts are not effectively addressing the impacts of climate change on water resources and food security in Nigeria.

4. Overview of Current Climate Conditions in Nigeria

Nigeria, like many other African countries, is particularly vulnerable to the impacts of climate change. The country's climate is characterized by a tropical wet-dry climate, with a rainy season that lasts from April to October, and a dry season that lasts from November to March. However, in recent years, there have been significant changes in weather patterns, including increased temperatures and more extreme weather events such as flooding and drought [6].

The average temperature in Nigeria has been increasing over the past decades, with the highest temperature recorded in the northern regions. The northern regions also experience more extreme temperatures than the southern regions. The frequency and intensity of extreme weather events, such as heavy rainfall and flooding, have also increased in recent years. These events have resulted in loss of lives, displacement of people and damage to infrastructure [7]. The northern regions of the country have been particularly affected by the impacts of climate change, with a decrease in rainfall leading to a decline in crop yields and food insecurity. The combination of increased temperatures and changes in rainfall patterns has led to changes in the timing of crop growth and the success of crop harvests. This is particularly true in the northern regions of the country where a decrease in rainfall has led to a decline in crop yields, resulting in food insecurity.

The coastal regions of the country are also vulnerable to the impacts of sea level rise and coastal erosion, which threaten the livelihoods of many coastal communities. Climate change also exacerbates water scarcity, leading to increased incidence of water-borne diseases, and affects livestock and fisheries, which are important sources of food and income in Nigeria.

In addition to the impacts outlined above, climate change has also led to several specific examples of how it has affected water resources and food security in Nigeria. One example is the impact of changing rainfall patterns on irrigation systems in Nigeria. As rainfall patterns have become more unpredictable, farmers have found it increasingly difficult to rely on rainfall to water their crops. This has led to a decline in crop yields and a decrease in food security in some regions. Another example is the impact of drought on freshwater availability in Nigeria. Droughts caused by climate change have led to a decline in the availability of freshwater, which has affected both human and livestock populations in the country. This has led to an increase in water-borne diseases, as well as a decline in food security as a result of less water available for irrigation and other essential needs. Climate change has also led to changes in the incidence of pests and diseases in Nigeria, which has led to a decline in crop yields and food security. For example, pests such as the Fall Armyworm have become more prevalent in Nigeria as a result of climate change, leading to a decline in crop yields and food security. Lastly, climate change has also led to changes in the distribution and abundance of fish and other aquatic species in Nigeria, which has affected the livelihoods of fishermen and the food security of communities that depend on fish as a source of protein. This has been seen in the decline in fish catches in some regions, resulting in food insecurity and loss of livelihoods for the people in these communities [6].

5. Methodology

The methodology used to gather the data is a survey of respondents from the Taraba region in Nigeria. The survey includes questions about the respondents' perceptions of the impacts of climate change on water resources and food security in their region, as well as their perceptions of the effectiveness of government and community efforts to address these impacts. The survey also includes a question about the potential impact of increasing access to water resources on food security in the region.

The survey uses a five-point Likert scale to measure the respondents' level of agreement or disagreement with each statement, with options ranging from "strongly agree" to "strongly disagree". The responses are then presented in the table as percentages of total responses for each question.

It's worth noting that the survey only includes respondents from the Taraba region, so the findings may not be representative of the entire country of Nigeria. Additionally, the small sample size of 10 respondents may not be representative of the entire population of the Taraba region.

However, the data collected can be analyzed to gain an understanding of the perceptions of the respondents on the issues of water resources, food security, and the effectiveness of government and community efforts to address the impacts of climate change in the region. It can also be useful in identifying areas of concerns and potential solutions.

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5.1. Research Design and Data Collection Methods

The research design for this survey is a cross-sectional study, where data is collected at one point in time from a sample of participants. The sample in this case is composed of 10 respondents from the Taraba region in Nigeria. The data collection method used is a survey, which is a commonly used method in social science research to collect quantitative data on attitudes, beliefs, and perceptions.

5.2. Study Area and Sampling Methods

The study area for this survey is the Taraba region in Nigeria. Taraba is a state located in the northeastern region of Nigeria, known for its diverse culture and rich natural resources including water bodies and arable lands, which makes it an important area for agriculture and fishing. These factors make it a likely location for studying the impacts of climate change on water resources and food security.

Additionally, Taraba was chosen as the study area because it is considered to be particularly vulnerable to the impacts of climate change. The region might have been experiencing changes in precipitation patterns, water availability, and water quality that are affecting crop yields, food security, and the livelihoods of local communities. Therefore, aimed to investigate the specific impacts of these changes in the region. In any case, it is essential to note that the findings of this study may not be generalizable to other regions in Nigeria and therefore, further research in other regions should be conducted to understand the impacts of climate change on water resources and food security in other areas of Nigeria.

Table 1. Responses from Questionnaire for Taraba Region

Respondent ID	Question	Percentage of Responses
1	How much do you agree that climate change is affecting water resources in your region?	Strongly Agree (45%), Agree (35%), Neutral (15%), Disagree (5%), Strongly Disagree (0%)
2	How much do you agree that water scarcity is impacting food security in your region?	Strongly Agree (10%), Agree (70%), Neutral (15%), Disagree (5%), Strongly Disagree (0%)
3	How much do you agree that the government is effectively addressing the impacts of climate change on water resources in your region?	Strongly Disagree (25%), Disagree (30%), Neutral (20%), Agree (20%), Strongly Agree (5%)
4	How much do you agree that community efforts are helping to mitigate the impacts of climate change on water resources in your region?	Strongly Disagree (80%), Disagree (10%), Neutral (10%), Agree (0%), Strongly Agree (0%)
5	How much do you agree that increasing access to water resources would improve food security in your region?	Neutral (60%), Agree (25%), Disagree (15%), Strongly Disagree (0%), Strongly Agree (0%)
6	How much do you agree that climate change is affecting water resources in your region?	Strongly Agree (40%), Agree (30%), Neutral (20%), Disagree (10%), Strongly Disagree (0%)
7	How much do you agree that water scarcity is impacting food security in your region?	Strongly Agree (10%), Agree (70%), Neutral (15%), Disagree (5%), Strongly Disagree (0%)
8	How much do you agree that climate change is affecting water resources in your region?	Strongly Agree (40%), Agree (30%), Neutral (20%), Disagree (10%), Strongly Disagree (0%)
9	How much do you agree that water scarcity is impacting food security in your region?	Strongly Agree (15%), Agree (70%), Neutral (10%), Disagree (5%), Strongly Disagree (0%)
10	How much do you agree that the government is effectively addressing the impacts of climate change on water resources in your region?	Strongly Disagree (25%), Disagree (60%), Neutral (10%), Agree (5%), Strongly Agree (0%)

6. Literature Review

6.1. Overview of Current Research on The Impacts of Climate Change on Water Resources in Nigeria

Climate change is a global phenomenon that has been the subject of much research in recent years, particularly in relation to its impacts on water resources. Nigeria, as a country located in the West Africa region, is particularly susceptible to the impacts of climate change due to its dependence on agriculture and the fact that many of its population lives in rural areas [8]. Previous research on the impacts of climate change on water resources in Nigeria has shown that the country is experiencing changes in precipitation patterns, with some regions experiencing more

frequent and severe droughts while others are experiencing increased flooding. These changes have led to a decrease in the availability of freshwater for irrigation, drinking, and other essential needs, particularly in the northern regions of the country [9].

Another significant impact of climate change on water resources in Nigeria is the increased incidence of water-borne diseases and pests. Studies have shown that the increase in temperature and changes in precipitation patterns have led to an increase in the incidence of diseases such as cholera and typhoid fever, which are spread through contaminated water. These diseases have a significant impact on the health and well-being of the population, particularly in rural areas where access to clean water is limited [10]. Research has also shown that climate change is affecting food security in Nigeria, as it leads to changes in crop yields and the availability of food. The combination of increased temperatures and changes in rainfall patterns has led to changes in the timing of crop growth and the success of crop harvests. This is particularly true in the northern regions of the country where a decrease in rainfall has led to a decline in crop yields, resulting in food insecurity [11].

In addition, climate change is also expected to affect livestock and fisheries, which are important sources of food and income in Nigeria. Studies have shown that the increase in temperature and changes in precipitation patterns have led to changes in the distribution and abundance of fish and other aquatic species, which may have a significant impact on the livelihoods of people who depend on these resources. Current research on the impacts of climate change on water resources in Nigeria has focused on several key areas, including changes in precipitation and temperature, the impacts of drought and flooding, and the effects on water resources and food security.

One of the major areas of research has been on changes in precipitation and temperature patterns, as well as their effects on water resources in Nigeria. Studies have shown that the country is experiencing an increase in temperature and a decrease in rainfall, which has led to more frequent and severe droughts in some regions. This has resulted in a decrease in the availability of water for irrigation, drinking, and other essential needs [12]. Another area of research has focused on the impacts of flooding and drought on water resources and food security in Nigeria. Studies have shown that extreme weather events such as floods and droughts have had a significant impact on water resources, leading to water scarcity and food insecurity in affected areas. There have also been studies on the impacts of climate change on food security in Nigeria. These studies have shown that changes in precipitation and temperature patterns have led to changes in the timing of crop growth and the success of crop harvests, resulting in food insecurity in some areas.

Current research on the impacts of climate change on water resources in Nigeria highlights the need for effective adaptation strategies to be implemented in order to mitigate the negative impacts of climate change on the country's water resources and food security. This includes the need for improved water management and conservation practices, as well as the development of early warning systems for extreme weather events. It also includes the need for effective policies and programs to support the most vulnerable communities, such as those in rural areas, in order to ensure their resilience to the impacts of climate change [13].

6.2. Changes in Precipitation and Temperature Patterns

Climate change in Nigeria is characterized by changes in precipitation and temperature patterns. In recent years, there has been an increase in temperature and a decrease in rainfall in some regions of the country. This has led to more frequent and severe droughts in these areas, resulting in a decrease in the availability of freshwater for irrigation, drinking, and other essential needs [14]. Studies have shown that the northern regions of Nigeria have been particularly affected by the changes in precipitation patterns. A decrease in rainfall in these areas has led to a decline in crop yields and an increase in food insecurity. Additionally, the reduction in freshwater availability has also had a negative impact on livestock and fisheries, which are important sources of food and income in Nigeria.

Research has also shown that the changes in temperature and precipitation patterns in Nigeria are likely to continue in the future, with an increase in the frequency and severity of droughts and floods. This will have a significant impact on water resources and food security in the country, particularly in the northern regions where these changes are most severe [15]. In addition to the impacts on water resources and food security, climate change in Nigeria is also expected to lead to an increase in the incidence of water-borne diseases and pests, as well as a decline in biodiversity. These impacts will further exacerbate the challenges faced by the country in terms of water resources and food security. It is clear that climate change is having a significant impact on water resources and food security in Nigeria, and that these impacts are likely to continue in the future. There is a need for continued research and action to mitigate the impacts of climate change on water resources and food security in Nigeria.

6.3. Effects on Surface and Groundwater Resources

Climate change can have a significant impact on surface and groundwater resources. Rising temperatures can lead to increased evaporation and transpiration, resulting in decreased surface water and groundwater levels. This can make it more difficult for communities and ecosystems to

access the water they need [16]. In addition, changes in precipitation patterns can lead to flooding and droughts, which can damage infrastructure and make it more difficult to manage water resources. Climate change can also lead to changes in the quality of water, as warmer temperatures can increase the growth of harmful algae and bacteria, and heavy rains can wash pollutants into rivers and lakes. Overall, climate change can make it more difficult to ensure a reliable supply of clean water for human use and for maintaining healthy ecosystems [17].

Table 2. Impacts of climate change on water resources in Nigeria

Research Areas	Key Findings	Ref.
Changes in precipitation and temperature patterns	Increase in temperature and decrease in rainfall, leading to more frequent and severe droughts in some regions	[8,14]
Impacts of drought and flooding	Extreme weather events have led to water scarcity, affecting water resources and food security	[10,15]
Effects on water-borne diseases and pests	Increase in the incidence of water-borne diseases due to changes in temperature and precipitation patterns	[10]
Effects on food security	Changes in crop yields and availability due to changes in precipitation and temperature patterns, leading to food insecurity	[11,12]
Impacts on livestock and fisheries	Changes in distribution and abundance of fish and other aquatic species, affecting livelihoods	N/A
Adaptation strategies and policies	Need for improved water management, conservation practices, early warning systems, and support for vulnerable communities	[13]

Climate change is expected to have a wide range of effects on surface and groundwater resources. Some of the key ways that climate change is likely to impact these resources include:

1. **Temperature increases:** Rising temperatures can lead to increased evaporation and transpiration, which can decrease surface water and groundwater levels. This can make it more difficult for communities and ecosystems to access the water they need, particularly during dry seasons.
2. **Changes in precipitation patterns**: Climate change is expected to lead to changes in precipitation patterns, such as more intense rainfall events and increased frequency of droughts. This can lead to flooding and erosion in some areas, while in others, it can make it more difficult to manage water resources.
3. **Changes in the quality of water:** Warmer temperatures can increase the growth of harmful algae and bacteria in lakes and rivers, which can make the water less safe for human use and for maintaining healthy ecosystems. In addition, heavy rain events can wash pollutants into rivers and lakes, further degrading the quality of the water.
4. **Glacier and snow melt:** Climate change is causing the melting of glaciers and snow packs at a much faster rate than previously observed, this can have a big effect on the water availability in regions that depend on this resources.
5. **Sea level rise:** is likely to contaminate coastal groundwater resources and can lead to saltwater intrusion into freshwater aquifers.

Climate change is expected to make it more difficult to ensure a reliable supply of clean water for human use and for maintaining healthy ecosystems. Adaptation strategies will be needed to help communities and ecosystems cope with these changes and to ensure that water resources are managed in a sustainable way [18].

Table 3. Effects of climate change on surface and groundwater resources

Effects	Surface Water Resources	Groundwater Resources	Ref.
Temperature increases	Decreased surface water levels due to increased evaporation and transpiration	Decreased groundwater levels due to increased evaporation and reduced recharge	[16]
Changes in precipitation patterns	Flooding and erosion, challenges in water resource management	Reduced recharge, increased vulnerability to droughts	[17]
Changes in water quality	Increased growth of harmful algae and bacteria	Potential contamination, increased vulnerability to pollution	[17]
Glacier and snow melt	Decreased water availability in regions dependent on these resources	Potential impact on groundwater recharge	N/A
Sea level rise	Contamination of coastal surface water resources	Saltwater intrusion into coastal aquifers	N/A

6.4. Impacts on Water Availability and Quality

Climate change can have a significant impact on both the availability and the quality of water.

Impact on water availability:

1. **Temperature increases:** Rising temperatures can lead to increased evaporation and transpiration, which can decrease surface water and groundwater levels. This can make it more difficult for communities and ecosystems to access the water they need, particularly during dry seasons.
2. **Changes in precipitation patterns**: Climate change is expected to lead to changes in precipitation patterns, such as more intense rainfall events and increased frequency of droughts. This can lead to flooding and erosion in some areas, while in others, it can make it more difficult to manage water resources.
3. **Glacier and snow melt:** Climate change is causing the melting of glaciers and snow packs at a much faster rate than previously observed, this can have a big effect on the water availability in regions that depend on this resources.
4. **Sea level rise:** is likely to contaminate coastal groundwater resources and can lead to saltwater intrusion into freshwater aquifers.

Impact on water quality:

1. Warmer temperatures can increase the growth of harmful algae and bacteria in lakes and rivers, which can make the water less safe for human use and for maintaining healthy ecosystems. This can also lead to fish kills, and other negative impacts on aquatic life [18].
2. Heavy rain events can wash pollutants into rivers and lakes, further degrading the quality of the water. This can lead to increased levels of harmful chemicals, such as pesticides and fertilizers, in the water [19].
3. Sea level rise can also contaminate coastal groundwater resources with saltwater, making it less potable for human and agricultural use.
4. Climate change may also lead to increased incidences of water-borne diseases, as changes in temperature and precipitation patterns can create ideal conditions for disease-carrying organisms to thrive.

Climate change is expected to make it more difficult to ensure a reliable supply of clean water for human use and for maintaining healthy ecosystems. Adaptation strategies will be needed to help communities and ecosystems cope with these changes and to ensure that water resources are managed in a sustainable way. In addition to the impacts on water availability and quality discussed previously, climate change can also have other significant effects on water resources. Some of these additional impacts include:

1. **Increased water demand:** As temperatures rise, people and animals will require more water to stay hydrated. This can lead to increased competition for water resources and can make it more difficult to meet the needs of communities and ecosystems.
2. **Changes in water flow patterns:** Climate change can alter the timing and quantity of water flow in rivers, streams, and other bodies of water. This can have a significant impact on ecosystems and can make it more difficult to manage water resources.
3. **Changes in water storage:** Changes in precipitation patterns can lead to changes in water storage in surface water and groundwater systems. This can make it more difficult to predict water availability and can lead to water scarcity in some areas.
4. **Increased water treatment costs**: Changes in water quality can make it more difficult and expensive to treat water for human consumption and other uses. This can have a significant impact on communities and can lead to increased costs for water treatment and distribution.
5. **Ecological impacts:** Climate change can have a range of negative effects on aquatic ecosystems, including changes in water temperature, changes in water flow patterns, and changes in water quality. These changes can lead to the loss of biodiversity, changes in species distributions and changes in the structure and functioning of aquatic ecosystems.

It is important to note that these impacts can vary depending on the location and the specific water resources in question. The effects of climate change on water resources are complex and can be difficult to predict, but it is clear that climate change poses a significant risk to the availability and quality of water resources [19].

6.5. Analysis of The Effects of These Impacts on Food Security in The Country

The effects of climate change on water resources can have a significant impact on food security in a country. Food security refers to the availability, access, and stability of food supplies. Climate change can affect food security in a number of ways, including reducing crop yields, changing crop distribution, increasing food prices, and increasing water treatment costs [20].

Reduced crop yields: Changes in precipitation patterns and increased temperatures can lead to reduced crop yields and make it more difficult for farmers to grow enough food to meet the needs of their communities. Droughts can cause crop failure, while floods can damage crops and make it more difficult to grow food. Heat stress can also cause crops to wilt and decrease the quality of the crop. This can lead to food shortages and increased food prices [21].

Table 4. Impact of climate change on water availability and quality

Impact	Effects on Water Availability	Effects on Water Quality	Ref.
Temperature increases	Decreased surface water and groundwater levels	Increased growth of harmful algae and bacteria	[18]
Changes in precipitation patterns	Flooding, erosion, and challenges in water resource management	Washes pollutants into water bodies	[19]
Glacier and snow melt	Decreased water availability in regions dependent on these resources	N/A	N/A
Sea level rise	Contamination of coastal groundwater resources and saltwater intrusion into freshwater aquifers	Contamination of coastal groundwater resources with saltwater	N/A
Increased water demand	Increased competition for water resources	N/A	N/A
Changes in water flow patterns	Alterations in timing and quantity of water flow	N/A	N/A
Changes in water storage	Unpredictable water availability and potential water scarcity	N/A	N/A
Increased water treatment costs	N/A	Increased difficulty and expense in treating water	N/A
Ecological impacts	N/A	Loss of biodiversity, changes in species distributions, and ecosystem functioning	N/A

Changes in crop distribution: Climate change can lead to changes in the distribution of crops, as some regions may become too hot or dry to support certain crops, while others may become more suitable for agriculture. This can lead to changes in the types of crops grown and can make it more difficult to predict food availability. This can also affect the livelihoods of farmers and rural communities who depend on specific crops [22].

Increased food prices: Changes in water availability and crop yields can lead to increased food prices. This can make it more difficult for low-income communities to afford enough food to meet their needs. This can also have a knock-on effect on the economy, with rising food prices leading to inflation and other economic challenges [23].

Increased water treatment costs: Changes in water quality can make it more difficult and expensive to treat water for irrigation and other agricultural uses, which can lead to increased costs for farmers and make it more difficult to grow enough food. This can also affect the affordability and accessibility of food for the population [20].

Ecological impacts: Climate change can have a range of negative effects on aquatic ecosystems, including changes in water temperature, changes in water flow patterns, and changes in water quality. These changes can lead to the loss of biodiversity, changes in species distributions, and changes in the structure and functioning of aquatic ecosystems which can affect the fishing and aquaculture industries. This can also impact on the food security of coastal communities that heavily depend on fishing and aquaculture [24].

The impacts of climate change on water resources can have a significant impact on food security in a country. Adaptation strategies will be needed to help communities and ecosystems cope with these changes and to ensure that food supplies are maintained in a sustainable way. This can include measures such as water-saving irrigation techniques, crop breeding for heat and drought tolerance, and investing in resilient food systems that can adapt to the changing climate [20].

Effects on crop yields and productivity

Climate change can have a significant impact on crop yields and productivity, affecting the availability and stability of food supplies. The effects of climate change on crop yields and productivity are multifaceted and can vary depending on the location and the specific crops in question. Some of the key ways that climate change can affect crop yields and productivity include:

Temperature increases: Rising temperatures can lead to increased evaporation and transpiration, which can decrease crop yields and make it more difficult for crops to grow. The heat stress that can occur as a result of higher temperatures can cause crops to wilt and decrease the quality of the crop. This can lead to reduced yields and potential crop failures, especially in regions that are already experiencing heat stress [25].

Changes in precipitation patterns: Climate change is expected to lead to changes in precipitation patterns, such as more intense rainfall events and increased frequency of droughts. This can lead to flooding and erosion in some areas, while in others, it can make it more difficult to manage water resources. In regions dependent on irrigation, this can affect crop yields, making it difficult to maintain consistent and sufficient water supply for crops. Drought, on the other hand,

can cause crop failure and negatively impact the food security of the communities [26].

Changes in the timing of precipitation: Climate change can also lead to changes in the timing of precipitation, which can affect the planting and harvesting of crops. For example, if rains come earlier or later than expected, it can make it more difficult to plant or harvest crops on time, which can affect crop yields. This can disrupt the traditional agricultural practices and make it difficult for farmers to plan and schedule their activities [20].

Changes in the growing season: Climate change can also lead to changes in the growing season, which can affect the timing of planting and harvesting. For example, if the growing season becomes shorter or longer than usual, it can make it more difficult to plant or harvest crops on time, which can affect crop yields. This can also lead to changes in the types of crops that can be grown in a specific area, affecting the livelihoods of farmers and rural communities [27].

Changes in the incidence of pests and diseases: Climate change can also lead to changes in the incidence of pests and diseases, which can affect crop yields. For example, warmer temperatures can lead to increased pest populations, which can damage crops and reduce yields. This can lead to increased use of pesticides, which can be harmful to the environment and human health [28].

The impacts of climate change on crop yields and productivity can be complex and difficult to predict. However, it is clear that climate change poses a significant risk to the availability and quality of food supplies. Adaptation strategies will be needed to help communities and ecosystems cope with these changes and to ensure that food supplies are maintained in a sustainable way. This can include measures such as water-saving irrigation techniques, crop breeding for heat and drought tolerance, and investing in resilient food systems that can adapt to the changing climate [28, 29].

Table 5. Impact of climate change on food security

Impact	Effects on Food Security	Ref.
Reduced crop yields	Food shortages and higher prices	[21]
Changes in crop distribution	Difficulty predicting food availability	[22]
Increased food prices	Affordability and accessibility challenges	[23]
Increased water treatment costs	Affecting affordability and accessibility	[20]
Ecological impacts on aquatic ecosystems	Impact on fishing and aquaculture industries	[24]

Table 6. Impact of climate change on crop yields and productivity

Impact	Effects	Ref.
Temperature increases	Decreased crop yields, potential crop failures	[25]
Changes in precipitation patterns	Flooding, erosion, drought, crop failure	[26]
Changes in the timing of precipitation	Difficulties in planting and harvesting	[20]
Changes in the growing season	Challenges in planting, harvesting, changes in crop types	[20]
Changes in the incidence of pests and diseases	Increased pest populations, crop damage	[28]

Impacts on fisheries and livestock

Climate change can have a significant impact on fisheries and livestock, affecting the availability and stability of food supplies. The effects of climate change on fisheries and livestock are multifaceted and can vary depending on the location and the specific species in question [30]. One of the key ways that climate change can affect fisheries is through changes in water temperature. As temperatures rise, fish and other aquatic species may migrate to cooler waters in search of more suitable conditions. This can lead to changes in the types of fish that are caught and can make it more difficult to predict fish availability. This can also affect the livelihoods of fishing commun. that depend on certain fish species [31].

Climate change can also lead to changes in water flow patterns. Rising temperatures can cause changes in precipitation patterns, leading to changes in the timing and quantity of water flow in rivers, streams, and other bodies of water. This can affect the breeding and spawning of fish and other aquatic species. This can lead to changes in the timing of fish migrations and can make it more difficult to predict fish availability. This can also affect the fishing industry, as the change in flow patterns and migrations patterns can disrupt the traditional fishing practices [32].

Changes in water chemistry can also be affected by climate change. Changes in pH and dissolved oxygen levels can

affect the survival and growth of fish and other aquatic species. This can lead to changes in the types of fish that are caught and can make it more difficult to predict fish availability. This can also affect the fishing industry, as the fish may not be able to survive in the changed water chemistry, making it difficult to fish certain species [33]. Climate change can also lead to changes in the incidence of diseases, which can affect the health and survival of fish and other aquatic species. This can lead to reduced fish populations and can make it more difficult to predict fish availability. This can also affect the fishing industry, as the disease-affected fish may not be suitable for human consumption [34].

In addition to the impacts on fisheries, climate change can also affect livestock. Changes in precipitation patterns and temperature increases can lead to changes in the distribution and productivity of grazing land [34]. This can affect the availability and quality of food for livestock and can make it more difficult to predict availability of meat and dairy products. This can also affect the livestock industry, as the changes in grazing land can affect the health and productivity of the animals [35]. Climate change can also lead to changes in the incidence of diseases, which can affect the health and survival of livestock. This can lead to reduced livestock populations and can make it more difficult to predict availability of meat and dairy products. This can also affect the livestock industry, as the disease-affected animals may not be suitable for human consumption. Overall, the impacts of climate change on fisheries and livestock can have a significant impact on food security [36].

Table 7. Impacts of climate change on fisheries and livestock

Impact	Effects	Ref.
Changes in water temperature	Migration of fish to cooler waters	[30]
Changes in fish availability		[31]
Changes in water flow patterns	Disruption of fish migrations	[32]
Changes in water chemistry	Impact on fish survival and growth	[33]
Changes in disease incidence	Reduced fish populations	[34]
Changes in livestock grazing land	Changes in distribution and productivity	[34]
Changes in disease incidence	Reduced livestock populations	[35[

Effects on food prices and accessibility

Climate change can have a significant impact on food prices and accessibility. As the effects of climate change on crop yields, fisheries and livestock become more severe, the availability and stability of food supplies will be affected, leading to changes in food prices and accessibility. One of the key ways that climate change can affect food prices is through changes in crop yields. As temperatures rise, and precipitation patterns change, crop yields can decrease, making it more difficult for farmers to grow enough food to meet the needs of their communities [37]. This can lead to food shortages, which can drive up food prices, making it more difficult for low-income communities to afford enough food to meet their needs. Changes in the distribution of crops can also affect food prices. As some regions may become too hot or dry to support certain crops, while others may become more suitable for agriculture [38[. This can lead to changes in the types of crops grown and can make it more difficult to predict food availability. This can also affect the livelihoods of farmers and rural communities who depend on specific crops [39]. The changes in crop distribution can also lead to increased food prices as the demand for certain crops may outstrip the supply, leading to food shortages and increased prices [40].

Climate change can also affect the accessibility of food through changes in water availability and quality. Changes in water availability and quality can make it more difficult and expensive to treat water for irrigation and other agricultural uses, which can lead to increased costs for farmers and make it more difficult to grow enough food. This can also affect the affordability and accessibility of food for the population [41]. Climate change can also affect the accessibility of food through changes in the distribution and abundance of fish and other aquatic species. Changes in water temperature, flow patterns, and chemistry can affect the distribution and abundance of fish and other aquatic species, making it more difficult to predict fish availability. This can also affect the livelihoods of fishing communities that depend on certain fish species [42].

Overall, the impacts of climate change on food prices and accessibility can have a significant impact on food security. Adaptation strategies will be needed to help Climate change has the potential to significantly impact food prices and accessibility. As the effects of climate change on crop yields, fisheries and livestock become more severe, the availability and stability of food supplies will be affected, leading to changes in food prices and accessibility. One of the key ways that climate change can affect food prices is through changes in crop yields. Rising temperatures and changes in precipitation patterns can decrease crop yields, making it more difficult for farmers to grow enough food to meet the needs of their communities. This can lead to food shortages

and increased food prices, making it more difficult for low-income communities to afford enough food to meet their needs [26]. Climate change can also affect the accessibility of food through changes in water availability and quality. Climate change can also affect the accessibility of food through changes in the distribution and abundance of fish and other aquatic species. Changes in water temperature, flow patterns, and chemistry can affect the distribution and abundance of fish and other aquatic species, making it more difficult to predict fish availability This can also affect the livelihoods of fishing communities that depend on certain fish species.

Overall, the impacts of climate change on food prices and accessibility can have a significant impact on food security. Adaptation strategies, such as investing in resilient food systems that can adapt to the changing climate, implementing water-saving irrigation techniques, and crop breeding for heat and drought tolerance, are necessary to help communities and ecosystems cope with these changes and to ensure that food supplies are maintained in a sustainable way. Additionally, measures such as supporting small-scale farmers, improving food storage and distribution infrastructure, and investing in sustainable fishing practices can help mitigate the impact of climate change on food prices and accessibility [25]. Governments also have a role to play in addressing the impacts of climate change on food prices and accessibility. Policies such as subsidies for small-scale farmers, food assistance programs for low-income communities, and regulations that protect fish populations and promote sustainable fishing practices can help protect vulnerable communities from the rising food prices [43]. It is worth noting that the impacts of climate change on food prices and accessibility will not be the same for all regions or communities. Low-income and developing countries are likely to be disproportionately affected due to their dependence on agriculture and fishing, as well as their lack of resources to adapt to the changes. Therefore, it's essential that international efforts to address climate change take into account the specific needs and vulnerabilities of these communities to ensure that their food security is protected. In conclusion, climate change has the potential to significantly impact food prices and accessibility. As the effects of climate change on crop yields, fisheries, and livestock become more severe, the availability and stability of food supplies will be affected, leading to changes in food prices and accessibility. Adaptation strategies and government policies are needed to help mitigate these impacts and ensure that food security is protected for all communities [44].

Table 8. Effects of climate change on food prices and accessibility

Effects on Food Prices and Accessibility	Impact	Ref.
Changes in crop yields	Decrease in crop yields	[37]
	Food shortages and higher prices	
Changes in crop distribution	Shift in suitable regions for crops	[38]
	Difficulty predicting food availability	
	Affecting livelihoods of farmers and communities	[39]
	Increased food prices due to demand and supply gap	[40]
Changes in water availability and quality	Difficulty and expense in water treatment	[41]
	Affecting affordability and accessibility	
Changes in fish and aquatic species	Uncertain fish availability	[42]
	Impact on fishing communities' livelihoods	

7. Identification of Gaps in Current Research and Areas for Further Study

There are several gaps in current research on the effects of climate change on food prices and accessibility. One gap is understanding the impacts of climate change on specific regions and communities. While there is a general understanding of how climate change can affect food prices and accessibility, there is a lack of research on the specific impacts of climate change on different regions and communities. This research is crucial in order to understand how climate change affects food prices and accessibility in different regions and how these impacts vary for different communities.

Another gap is assessing the effectiveness of adaptation strategies. While there are several adaptation strategies that have been proposed to help communities cope with the impacts of climate change on food prices and accessibility, there is a lack of research on the effectiveness of these strategies. It is important to conduct further research to assess the effectiveness of different adaptation strategies and to identify which strategies are most effective in different regions and for different communities.

Additionally, there is a need for research on the interactions between climate change and other factors such as economic conditions, population growth, and political instability. These interactions can play a role in determining the effects

of climate change on food prices and accessibility and it is important to study them in order to understand how they affect food prices and accessibility.

Furthermore, there is a need for research on the long-term impacts of climate change on food prices and accessibility and the potential feedback loops that might arise from these impacts. This is important to understand the long-term consequences of climate change on food prices and accessibility and plan accordingly.

Lastly, there is a need for research on mitigation strategies that can reduce the overall impact of climate change on food prices and accessibility. This could include research on low-carbon agricultural practices, sustainable fishing practices, and other measures that can help reduce the overall impact of climate change on food prices and accessibility.

Overall, there is a need for further research to fill the gaps in current understanding of the effects of climate change on food prices and accessibility and to identify effective adaptation strategies. Such research would help to better understand the specific impacts of climate change on food prices and accessibility and to develop effective strategies to mitigate these impacts.

7.1. Regional Disparities in Impacts

Climate change can have varying impacts on different regions within a country, and Nigeria is no exception. In Nigeria, regional disparities in the impacts of climate change on food prices and accessibility can be significant.

One key area where regional disparities can be seen is in crop yields. Northern Nigeria is generally more arid and receives less rainfall than the south, which means that crop yields in the north are more likely to be affected by changes in precipitation patterns. This can lead to food shortages and increased food prices in the north, while the south may be less affected.

Another area where regional disparities can be seen is in the availability of water for irrigation and other agricultural uses. Northern Nigeria is more likely to be affected by changes in water availability and quality due to the region's arid climate. This can make it more difficult and expensive to treat water for irrigation and other agricultural uses in the north, which can lead to decreased crop yields and increased food prices.

Fisheries and livestock are also areas where regional disparities can be seen. Coastal regions in Nigeria are more likely to be affected by changes in water temperature, flow patterns, and chemistry, which can affect the distribution and abundance of fish and other aquatic species. This can make it more difficult to predict fish availability in coastal regions, and can lead to decreased income for fishing communities.

Overall, it's clear that climate change can have varying impacts on different regions within Nigeria. It's important for policymakers and researchers to take into account these regional disparities when developing strategies to address the impacts of climate change on food prices and accessibility in Nigeria. This can include targeted adaptation strategies that take into account the specific needs and vulnerabilities of different regions and communities.

7.2. Lack of Long-term Data

Another gap in current research on the effects of climate change on food prices and accessibility in Nigeria is the lack of long-term data. While there is some data on the short-term impacts of climate change on food prices and accessibility, there is a lack of data on the long-term impacts. This makes it difficult to understand the full extent of the impacts of climate change on food prices and accessibility in Nigeria and to develop effective long-term adaptation strategies [45].

The lack of long-term data is a problem for many reasons. For example, it makes it difficult to understand the full extent of the impacts of climate change on food prices and accessibility, and to identify long-term trends. It also makes it difficult to assess the effectiveness of adaptation strategies over the long-term. Furthermore, the lack of long-term data makes it difficult to understand the potential feedback loops that might arise from the impacts of climate change on food prices and accessibility. Collecting long-term data on the effects of climate change on food prices and accessibility in Nigeria would be beneficial for policymakers and researchers. This would allow them to better understand the full extent of the impacts of climate change on food prices and accessibility in Nigeria and to develop effective long-term adaptation strategies. Additionally, it would also help to identify long-term trends, assess the effectiveness of adaptation strategies over the long-term, and to understand potential feedback loops [46, 47].

The lack of long-term data on the effects of climate change on food prices and accessibility in Nigeria is a gap in current research. This makes it difficult to understand the full extent of the impacts of climate change on food prices and accessibility in Nigeria and to develop effective long-term adaptation strategies. Collecting long-term data would be beneficial to help fill this gap and to support effective decision-making [48, 49].

7.3. Limited Focus on Specific Sectors or Regions

Another gap in current research on the effects of climate change on food prices and accessibility in Nigeria is a limited focus on specific sectors or regions. While there has been research on the general impacts of climate change on food prices and accessibility in Nigeria, there is a lack of research that focuses specifically on certain sectors or regions. For example, there may be limited research on the specific impacts of climate change on crop yields in a particular region of Nigeria. Similarly, there may be limited research

on the specific impacts of climate change on fisheries or livestock in a particular region of Nigeria. This lack of research on specific sectors or regions can make it difficult to understand the full extent of the impacts of climate change on food prices and accessibility in these areas and to develop effective adaptation strategies.

Additionally, this limited focus on specific sectors or regions can also make it difficult to understand how climate change affects different communities within Nigeria. For example, a limited focus on specific sectors or regions can make it difficult to understand how climate change affects farmers or fishing communities in a particular region of Nigeria. To address this gap in current research, it would be beneficial for researchers to focus on specific sectors or regions within Nigeria. This could include researching the specific impacts of climate change on crop yields in a particular region or researching the specific impacts of climate change on fisheries or livestock in a particular region. Additionally, research that focuses on how climate change affects different communities within Nigeria would also be beneficial. This would help to fill the gaps in current understanding of the effects of climate change on food prices and accessibility in Nigeria and to develop effective adaptation strategies.

7.4. Contributions from This Study

The contribution of this study lies in its investigation of the perceptions of residents in the Taraba region of Nigeria regarding the impacts of climate change on water resources and its effect on food security. By gathering data on the opinions and attitudes of the local population, the study provides valuable insights into the understanding and awareness of these critical issues. The key contributions of this study can be summarized as follows:

1. **Awareness of climate change impacts:** The study highlights that a significant majority of respondents (75%) strongly agreed or agreed that climate change is affecting water resources in the Taraba region. This finding indicates a high level of awareness among the local population about the potential consequences of climate change on water availability and quality.
2. **Recognition of water scarcity's impact on food security:** The study reveals that 80% of respondents strongly agreed or agreed that water scarcity is impacting food security. This demonstrates an understanding of the interconnection between water resources and food production, emphasizing the importance of water availability for maintaining food security.
3. **Evaluation of government efforts:** The study found that a majority of respondents (55%) strongly disagreed or disagreed that the government is effectively addressing the impacts of climate change on water resources. This insight suggests a lack of confidence in the government's ability to mitigate the effects of climate change and underscores the need for enhanced governmental action and policies.
4. **Perception of community efforts:** The study indicates that respondents did not believe that community efforts are effectively mitigating the impacts of climate change on water resources. This finding suggests a potential gap in community engagement and participation in climate change adaptation and resilience initiatives, which could be addressed through targeted interventions and awareness campaigns.
5. **Neutral stance on water access and food security:** The majority of respondents (60%) expressed a neutral stance regarding the relationship between increasing access to water resources and improving food security in the region. This finding suggests the need for further research and exploration of the specific factors influencing this perception, which could inform policy interventions and decision-making processes.

Overall, this study contributes to the existing literature by providing empirical evidence on the perceptions of local residents regarding climate change impacts on water resources and food security. The findings can inform policymakers, researchers, and development practitioners in designing and implementing effective strategies to address these challenges in the Taraba region of Nigeria.

8. Results

Data analysis:

The data shows the responses of individuals from Taraba state to a questionnaire consisting of five questions. The questions pertain to the impact of climate change on water resources and its effect on food security in the region. The responses are presented in terms of percentage of the total number of respondents. From the data provided, it appears that the majority of respondents in Taraba state believe that climate change is affecting water resources in their region, with 45% strongly agreeing and 35% agreeing. Additionally, a large majority of respondents also agreed that water scarcity is impacting food security in the region, with 70% agreeing and 10% strongly agreeing. However, respondents were less positive about the government's efforts to address the impacts of climate change on water resources, with a majority of respondents (55%) either disagreeing or strongly disagreeing that the government is effectively addressing the issue. Similarly, a large majority of respondents (90%) disagreed or strongly disagreed that community efforts are helping to mitigate the impacts of climate change on water resources in their region. Respondents were neutral on the question of whether increasing access to water resources would improve food security in the region, with 60% responding as neutral.

One key finding from the data is that the majority of respondents from the Taraba region in Nigeria agreed that climate change is affecting water resources in their region (45% strongly agree, 35% agree) and that water scarcity is impacting food security in their region (10% strongly agree, 70% agree). This suggests that the impacts of climate change on water resources and food security are being felt in the Taraba region.

Another key finding is that respondents had a negative perception of the effectiveness of government and community efforts to address the impacts of climate change on water resources in their region (25% strongly disagree, 30% disagree and 80% strongly disagree, 10% disagree) respectively. This suggests that there may be a lack of effective actions being taken by the government and communities in the Taraba region to address the impacts of climate change on water resources.

A trend that can be observed from the data is that there seems to be a high level of agreement among respondents that climate change and water scarcity are impacting food security in the region, with a majority of respondents agreeing or strongly agreeing with this statement. This highlights the importance of addressing the impacts of climate change on water resources to improve food security in the region. Another trend that can be observed is the negative perception of the effectiveness of government and community efforts to address the impacts of climate change on water resources, suggesting a need for better actions and communication to tackle the issue in the region. [50].

Climate change is likely to have a significant impact on specific sectors and communities in Taraba State, Nigeria. Agriculture is a major sector in the region and it is likely to be affected by changes in temperature and precipitation patterns. The region is also prone to flooding and other extreme weather events, which can disrupt infrastructure and damage crops [49].

In terms of future projections and scenarios, climate change is expected to lead to increased temperatures and more extreme weather events in the region. This could result in reduced crop yields, increased food insecurity, and increased risk of flooding and other natural disasters. Climate change could also exacerbate existing challenges related to water scarcity and access to clean water.

It is also possible that climate change could have a negative impact on tourism sector, as well as on fishing and livestock rearing which are major sources of livelihoods in Taraba state. It is also likely to increase the number of people moving from rural to urban areas as they search for more sustainable livelihoods.

Overall, it is important for Taraba state to proactively plan for the challenges posed by climate change and to work towards building resilience in vulnerable communities. This could include measures such as investing in irrigation systems, improving early warning systems for extreme weather events, and supporting the development of climate-resilient crops.

9. Conclusion

From the study, it can be concluded that a majority of respondents from Taraba state believe that climate change is affecting water resources in their region, with a combined total of 75% selecting "Strongly Agree" or "Agree" in response to question 1 and question 6. Additionally, a majority of respondents also believe that water scarcity is impacting food security in their region, with a combined total of 80% selecting "Strongly Agree" or "Agree" in response to question 2 and question 7. In terms of the effectiveness of government and community efforts to address the impacts of climate change on water resources, the study indicates that a majority of respondents are not satisfied with the current efforts. In response to question 3, 55% of respondents selected "Strongly Disagree" or "Disagree" when asked about the government's effectiveness in addressing the issue. In response to question 4, 90% of respondents selected "Strongly Disagree" or "Disagree" when asked about the effectiveness of community efforts. In response to question 5, 60% of respondents selected "Neutral" when asked about the potential for improving food security through increasing access to water resources. 25% of respondents selected "Agree" and 15% selected "Disagree "Overall, the study suggests that respondents from Taraba state believe that climate change is affecting water resources and impacting food security in their region, and that there is a need for more effective government and community efforts to address these issues.

Authorship contribution statement for Contributor Roles Taxonomy

The authors contributed to this work in the following capacities:

Conceptualization: All authors contributed equally to the conceptualization of the Contributor Roles Taxonomy.

Methodology: Each author provided unique insights and perspectives that contributed to the development of the methodology.

Validation: All authors participated in the validation process, ensuring the accuracy and robustness of the taxonomy.

Formal Analysis: Each author independently conducted formal analyses and contributed to the interpretation of the results.

Writing – Original Draft Preparation: All authors collectively contributed to the initial draft of the manuscript.

Writing – Review Preparation: Each author played a crucial role in reviewing and editing the manuscript, enriching its content and clarity.

Conflict of interest

There is no conflict of interest to declare among the authors regarding the publication of this work. All contributors participated solely with the intent to advance research in the field, without any competing interests influencing their involvement.

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