Advanced Journal of Environmental Sciences (AJES)
Volume.1, Number 1; February-2023;
Published By: Zendo Academic Publishing
https://zapjournals.com/Journals/index.php/ajes/index
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CLIMATE CHANGE-INDUCED AGRICULTURAL LOSSES, FOOD SCARCITY AND ADAPTATION STRATEGIES IN THE FRESHWATER AND MANGROVE SWAMPS OF DELTA STATE, NIGERIA

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ABSTRACT This paper investigated climate change-associated agricultural losses, food scarcity and adaptation This study investigates the climate change-induced agricultural losses, food scarcity and adaptation strategies in the freshwater and mangrove swamps of Delta State in the Niger Delta region. Data was collected from 1600 respondents using structured questionnaires, with 800 respondents equally selected from two local government areas per ecological zone. The study found that loss of farm land and inputs and crop failure mainly account for agricultural losses due to climate change, while flooding is primarily responsible for food losses due to climate change in both ecological zones. Purchase of food within and outside the community accounts for over 80% and 74% of the respondents' main sources of food during climate change incidence in the freshwater and mangrove swamps, respectively. The study also revealed that dietary management, change of occupation and livelihood diversification are the primary coping strategies against climate change-induced food shortage in the freshwater swamps, while dietary management, outmigration and relief materials make up the primary adaptation strategies in the mangrove swamps. The study recommends ecological zone-specific prioritization in tackling climate change-induced agricultural losses and food shortage, as well as provision of nutrition education for households in both ecological zones.

Keywords: climate change, agricultural losses, food scarcity, adaptation strategies, freshwater swamps, mangrove swamps, Delta State, Niger Delta region

INTRODUCTON: Climate change is increasingly being recognized as a critical factor in food production amid the increasing world population. Its role in food production is exacerbated by the fact that climate affects every phase of agricultural production (Gornall et al., 2010; Gizachew & Shimelis, 2014; Ochieng & Mathenge, 2016). Crop and livestock production thrive within their climatic range, which varies from minimal, optimal, and maximal. Thus, climate change affects agricultural productivity in diverse regions of the world (Chandio et al., 2019; Lemi& Hailu, 2019). Crops and livestock respond to alterations in climatic patterns, with favorable and adverse conditions leading to increased productivity and poor yield, respectively. Severe alterations in rainfall patterns and an increase in temperatures induce adverse environments in cropping seasons, subsequently impacting crop yield (Kim et al., 2014; Adeagbo et al., 2021). Thus, agriculture in sub-Saharan Africa is highly susceptible to climate change due to the prevalence of rainfed small-scale farming (Ogungbenro&Morakinyo, 2014; Alemayehu &Bewket, 2017).
Agriculture is a significant contributor to the Nigerian economy, accounting for 22% of the country's GDP and employing over 70% of the population (NBS, 2019). The country is experiencing climate change-

induced challenges such as extreme fluctuations in rainfall patterns and an increase in temperature. These challenges have presented increasing undesirable conditions in the cropping calendar, altering growing seasons with a resultant impact on crop productivity. Among others, climate change has induced year-round food shortage in most households in coastal environments (Zacarias, 2019). The Niger Delta region suffers widespread climate threats that vary from storm surges, rising risks of flooding, erratic and extreme rainfall, heat waves, disruption of the mangrove, and adverse impacts on livelihoods (Ogbona et al., 2017; Adewumi et al., 2018; Authority, 2020) coupled with low adaptive capacity (Ighedosa, 2019). The harmful effects of climate change on agriculture are critical due to the linkage between agriculture and food security (Belloumi, 2014; Ayo et al., 2014; Arora, 2019; Chen et al., 2021). Therefore, a large proportion of the Nigerian populace has continued to suffer food insecurity as a result of rising costs of imported food (Matemilola & Elegbede, 2017) and unfolding unfavorable conditions imposed by climate change.

Vulnerability to climate change within a country can vary regionally (Mandu, 2012; Schneiderbauer et al., 2020; Venus et al., 2022). Studies have highlighted the Niger Delta region as a climate change vulnerability hotspot (Ighedosa, 2019; Authority, 2020; Hassan et al., 2020) without taking into cognizance the diverse ecological zones that make up the region. Similarly, despite the high number of studies, especially on the impacts of climate change on agriculture in the Niger Delta region (Onyeneke et al., 2019; Wali et al., 2020; Lobari&Ukiwo, 2021), ecological zone-specific aspects of the impacts of climate change on food security have remained neglected. Yet, adaptation to climate change depends on environmental and socio-economic factors (Mugi-Ngenga et al., 2016), which engender place-specific coping strategies (Chandio et al., 2019; Adeagbo et al., 2021).

Climate change is a global challenge that has significant implications for agricultural productivity and food security, particularly in regions where smallholder farmers rely on rainfed agriculture. The Niger Delta region of Nigeria is one such region that is highly vulnerable to climate change due to its dependence on agriculture, high poverty levels, and low adaptive capacity. Although numerous studies have investigated the impacts of climate change on agriculture and food security in the region, there is a dearth of knowledge on ecological zone-specific aspects of these impacts, especially in the freshwater and mangrove swamps forests. Therefore, this study aims to evaluate variations in climate change-associated agricultural losses, food scarcity, and adaptation strategies in the freshwater and mangrove swamps forests of Delta State in the Niger Delta region. By identifying the specific causes of food insecurity and adaptation strategies in each ecological zone, this study seeks to inform the development of targeted interventions that can improve food security and livelihoods for smallholder farmers in the Niger Delta region.

2.0. Methodology

2.1. Study Area

Based on vegetation, the coastal zone of Nigeria can be divided into two broad ecological zones, namely, freshwater swamps and mangrove swamps. The coastline of Nigeria which runs from western parts to the eastern parts of the country stretches to about 853km. This study however, covers the freshwater swamps and mangrove swamps of Delta State (Figure 1). The two ecological zones comprise major parts of the Niger Delta region of Nigeria richly endowed with biodiversity (Iniaghe*et al*., 2013). Adjacent to the mangrove swamps which is characteristically saline, is the freshwater swamps. While the mangrove swamps is an ecotone with *Rhizophora species* appearing to be most dominant (Oboho, 2014; Arabomen*et al*., 2016) unlike the freshwater swamps which is heterogeneous with species such as *Musangacecropioides*, *Annona senegalensis* and *Raphia hookeri*. The mangrove and freshwater swamps are generally low-lying and in the lower course of river Niger with braided channels. The swamps forests of the Niger Delta region experience warm humid climate with wet season commencing in mid-March and lasts till October/November. The low-lying topography coupled with heavy rainfall partly account for frequent flood incidences. Crude oil exploration and exploitation have been major causes of environmental degradation since its discovery in the ecological zones (Folami, 2016). Traditionally, the livelihood engagements of the people of the Niger Delta region are basically agriculture and fishing (Onyena& Sam, 2020).

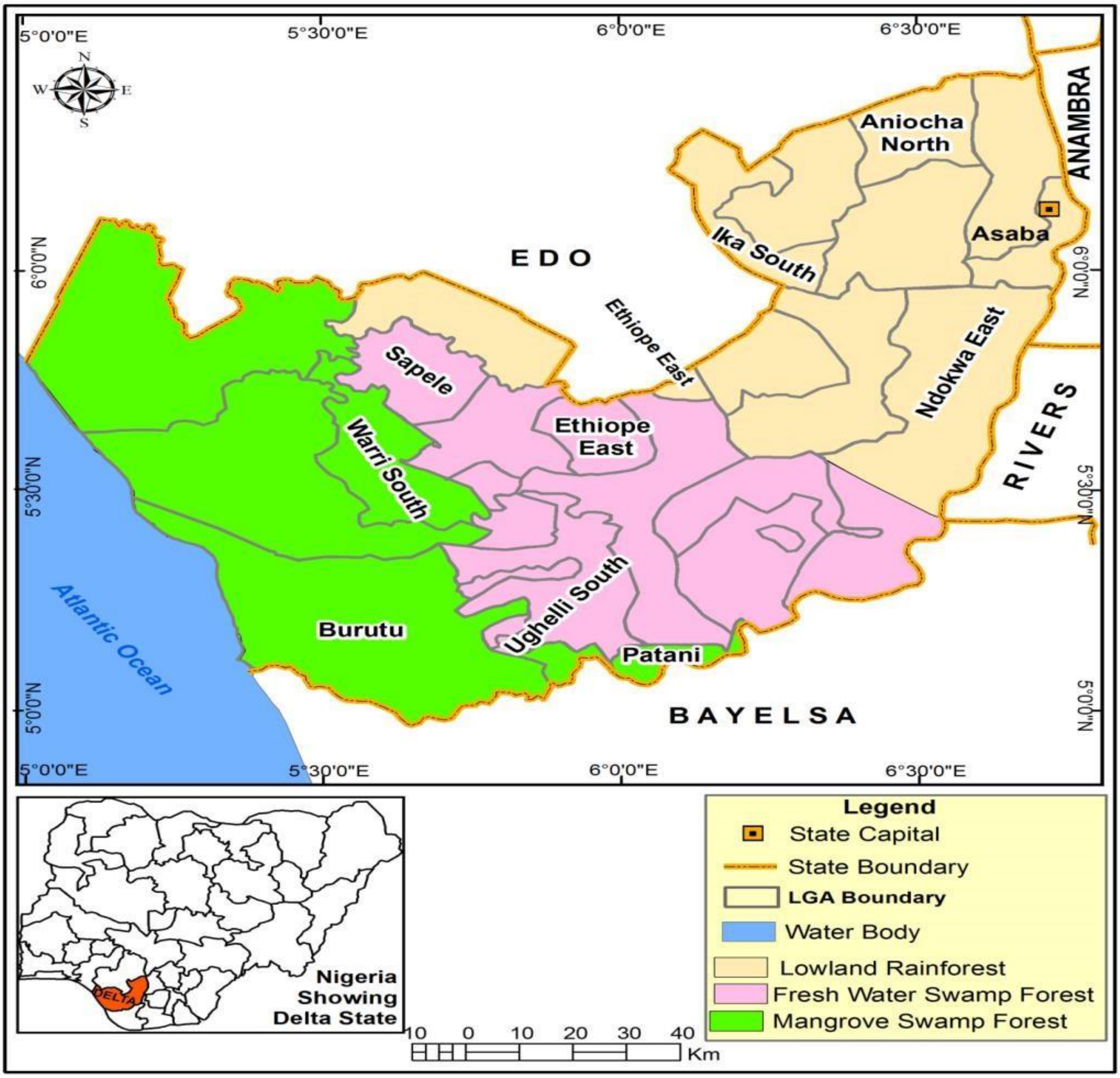

Figure 1: Major ecological zones in Delta State, Nigeria

Source: Atedhor et al (2022)

2.2 Sources of Data

In this study, due to non-availability of climatic data specifically for the freshwater, we have attempted to construct the climatic setting of the study area using monthly rainfall and temperature data (19612012) of Warri synoptic weather station which is located in the mangrove swamps forest. The climatic data were collected from the archives of the Nigerian Meteorological Agency. The authors are of the view that the disparities in the impacts of climate change between the two ecological zones are due to non-climatological attributes such as proximity to the Atlantic Ocean, salinity and biodiversity. Structured questionnaire was used to collect data on the impacts and adaptation to climate change adaptation in the freshwater and mangrove swamps forests of Delta State of Nigeria. Two Local Government Areas (LGAs) were selected from each of freshwater swamps (Ethiope East and Sapele) and mangrove swamps (Burutu and Warri South. Ten (10) political wards were randomly selected per LGA to ensure that every part of the LGAs has equal chance of being included in the study. Since there are no reliable and up-to-date household listings in different parts of Nigeria, particularly in the rural communities, each political ward was demarcated into blocks of 10 housing units to ensure that individual in all parts of the ward have equal chance of being selected. On the basis of the block of housing demarcation, forty (40) respondents were randomly selected per socio-economic and political ward. Male and Female respondents were included in this study. Thus, 400 respondents comprising males and females (10 socio-economic and political wards x 40 respondents) were selected per LGA while a total of 800 respondents (400 respondents x 2 LGAs) were selected per ecological zone. Therefore, in all, a total of 1,600 respondents (800 per ecological zone x 2 ecological zones) were used in this study.

2.2. Data Analyses

The annual rainfall amount and mean temperature were computed and used to depict their annual linear trends while the monthly rainfall amount and mean temperature were computed to illustrate their seasonal distribution. Simple linear regression was used to project annual rainfall amount and mean temperature using annual rates of change of the 1961-2012 timeframe. While the projected annual rainfall amount and mean temperature for year 2030 remarkably coincide with the deadline for the realization of Sustainable Development Goals (SDGs), the values for year 2050 provide an outlook for the post-SDGs era. The climate change-induced agricultural losses, causes of food shortage and action taken to tackle food shortage and sources of food during climate change incidence were analyzed on the basis of ecological zones in order to facilitate comparison using t-test and percentage. This approach was used to reflect the disparity of climate change associated forms of agricultural losses, causes of food shortage, sources of food and adaptation strategies between the mangrove and freshwater swamp forests.

3.0. Results and Discussion

3.1. Climatic Setting

The distribution of monthly rainfall amount and mean temperature are presented in Figure 2. Correspondingly, lowest rainfall amounts occur in the months of March and November coincide with the months of highest mean temperature. The month of March in the freshwater and mangrove swamps forests often marks the period of land preparation, cultivation and germination stage of crops. Annual rainfall amount in the swamps forests is usually above 2500mm with the characteristic double maxima usually in the month of July and September during which rainfall amount is up to 450mm. Similar monthly rainfall amount and mean temperature distribution have been reported by Odigwe*et al* (2021). Mean air temperature is usually relatively lower during the wet season but may rises to 29^{o}C during the dry season, especially in

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the month of March. The annual trends of mean temperature and rainfall amount are presented in Figure (Figure 3). Annual mean temperature increased at annual rate of 0.02ºC during the 1960-2012 timeframe with projected values of approximately 27.2ºC and 27.6ºC by 2030 and 2050 respectively while annual rainfall amount declined at annual rate of -2.82mm with estimated values of approximately of 2,794.8mm and 2,738.4mm by 2030 and 2050 respectively.

The swamps forests experience heavy rainfall during the peaks of the wet season. It is therefore not surprising the swamps forests witness recurrent incidences of flood, sea level rise and salinization which often are of disastrous magnitude to agricultural activities. The peak of the wet season usually coincide with the mid or near maturity stages of most crops in the swamps forests of the Niger Delta region. Thus, flood incidence lead to the destruction farms or induces premature harvest of crops within floodplain which is capable of causing food insecurity. Apart from the flood incidences induced by heavy rainfall during the peaks of the wet season, the heavy network of rivers in the swamps forests aggravate the flood occurrences. The increasing trend of mean temperature coupled amid declining rainfall will lead to increase in evapotranspiration and consequently induce crop moisture stress (Ukhurebor, 2017), especially during the beginning of the cropping season which marks the germination and tender stage of most food crops in the forest belts of Nigeria. More so crop production makes up about 94% Nigerian's agricultural production (Okon *et al*., 2021).

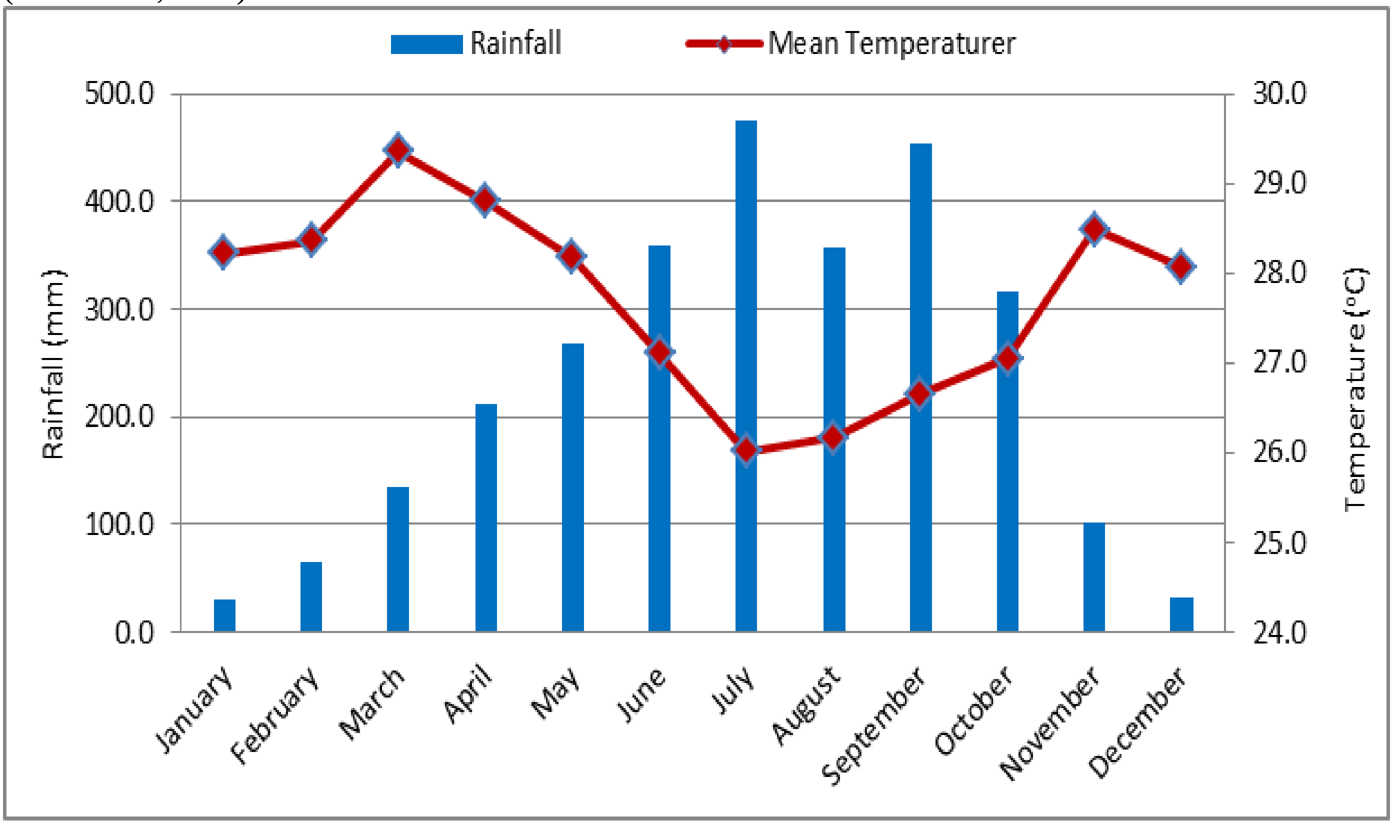

Figure 2: Mean monthly temperature and rainfall (1951-2012)

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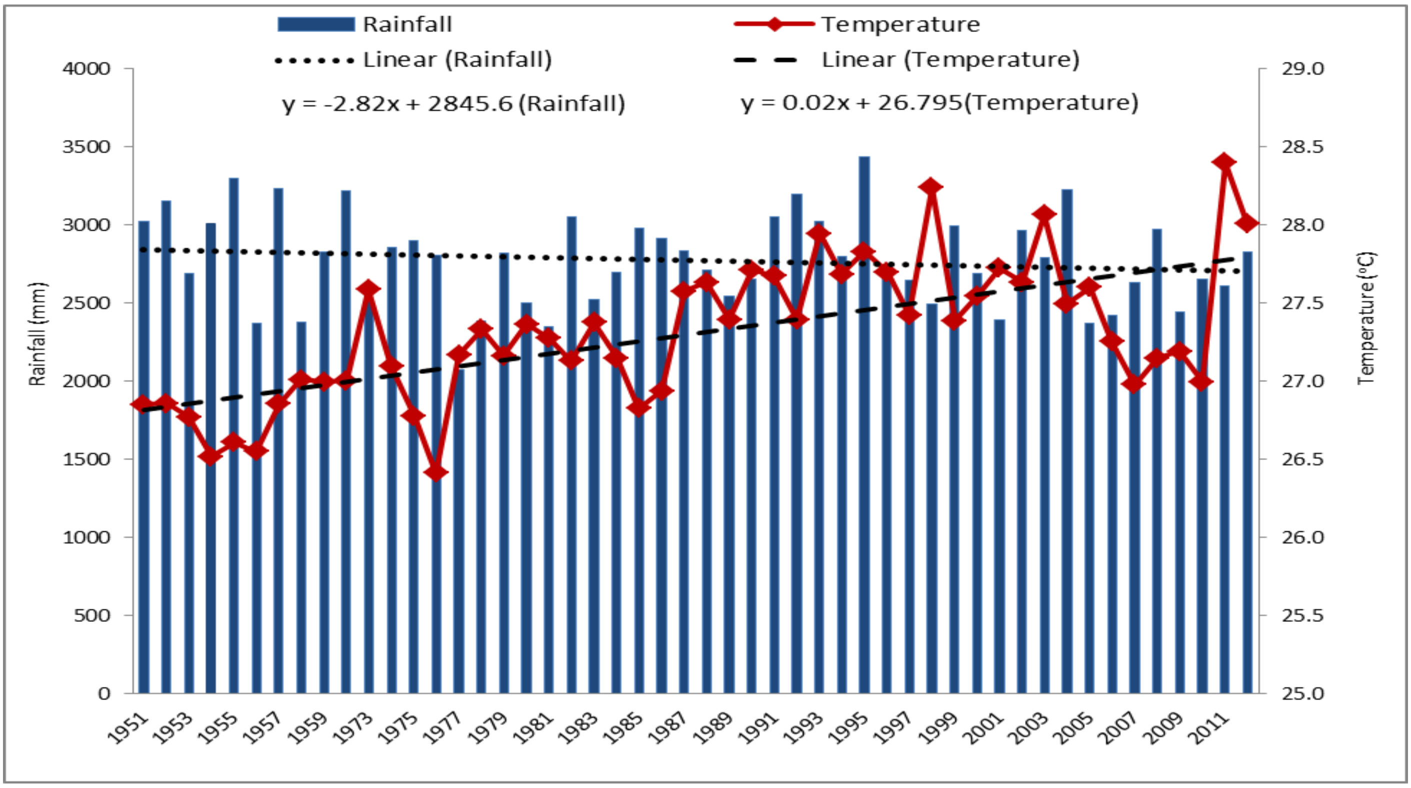


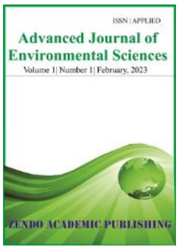
Figure 3: Annual trends of mean temperature and rainfall

3.2. Demographic Characteristics of the Respondents

The demographic features of the selected respondents are presented in Tables 1. Our analysis shows that household heads made up of males and females were relatively higher than other members of the household in the two ecological zones. Respondents within the age bracket of 41-60 years constitute the dominant class in the two ecological zones while the proportions of female respondents were in both ecological zones. A high proportion of the respondents are married while over 70% of the respondents have educational attainment of primary above.

Table 1: Demographic characteristics of the respondents

Household status of respondents (%)			
Household status	freshwater swamps forest	mangrove forest	swamps
Household head	52.25	51.75	
Other members of the household	47.75	48.25	
Total	100.0	100.0	
Age distribution of respondents (%)			
Age groups (years)	freshwater swamps forest	mangrove forest	swamps
18-40	28.4	37.1	
41-60	57.9	41.3	
61 and above	13.7	21.6	



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Total	100.0	100.0

Sex distribution of the respondents (%)

Sex	freshwater swamps forest	mangrove swamps forest
Male	40.9	45.0
Female	59.1	55.0
Total	100.0	100.0

Marital status of the respondents (%)

Marital status	freshwater swamps forest	mangrove swamps forest
Single	9.0	14.8
Married	76.5	68.9
Widowed	11.0	11.3
Separated	3.5	5.1
Total	100.0	100.0

Highest education level of the respondents (%)

Educational attainment	freshwater swamps forest	mangrove swamps forest
No formal education	19.9	10.4
Primary	33.2	16.9
Secondary	36.6	32.8
Tertiary	10.3	39.9
Total	100.0	100.0

3.3 Socio-Economic Characteristics of the Respondents

The socio-economic characteristics of the respondents (Table 2) reveal that a higher percentage of the respondents engage in farming in the freshwater swamps forest, and mangrove swamps forest respectively. The scarcity of arable land in the mangrove swamps Forest due to the coastal nature of the terrain may have accounted for the relatively lower percentage of respondents who engage in farming *vis-á-vis* the other ecological zones. Our analysis shows that over 70% of the selected respondents have engaged in their main occupation for up to 10 years and above in in the two ecological zones. This makes their knowledge of climate change and disaster risks reliable. Besides, in Africa, small-scale farmers constitute the greatest proportion of the farming population (Frimpong *et al.*, 2015). A higher proportion of the selected respondents engage in both subsistence and commercial agricultural activities in two ecological zones. While a higher percentage of the selected respondents earn above N20, 000.00 ($45.74) monthly income in the mangrove swamps forest, higher percentage proportion of the selected respondents falls within ₦10, 000.00-20,000.00 ($22.87 and 45.74) monthly income in the fresh water swamps forest.

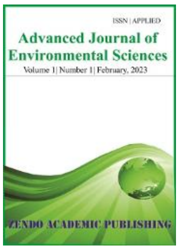

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Table 2: Economic characteristics of the respondents

Distribution of respondents according to main occupation (%)		
Main occupation of respondent	freshwater swamps forest	mangrove swamps forest
Farming	78.3	31.7
Trading	14.2	34.4
Public sector	3.7	18.5
Private sector	3.8	15.4
Total	100.0	100.0
Number of years respondents have been in their main occupation (%)		
Number of years	freshwater swamps forest	mangrove swamps forest
Less than 10	21.4	31.4
10 – 20	53.7	34.2
Above 20 years	24.9	34.4
Total	100.0	100.0
Agricultural activities (%)		
Type	freshwater swamps forest	mangrove swamps forest (%)
Subsistence	22.4	38.2
Commercial	5.8	9.4
Both subsistence and commercial	71.9	52.4
Total	100.0	100.0
Average monthly income group of respondents (%)		
Income (N)	freshwater swamps forest	mangrove swamps forest
Less than 10,000	17.2	22.4
10,000 – 20,000	43.5	24.8
Above 20,000	39.2	52.8
Total	100.0	100.0

3.4.Climate Change-InducedForms of Agricultural Losses

Agriculture is widely considered as one of the climate-sensitive sector climate influence of every stage of agricultural production such as land preparation, tillage, planting, harvesting, preservation, etc. Apart the threats such as overexploitation of natural resources, oil spill, dredging and wetland reclamation, and the ecological zones of the Niger Delta could also be threatened by climate change (Onyena& Sam, 2020). The forms of agricultural losses in the freshwater and mangrove swamps are presented in Table 3. Our analysis shows that a combination of loss of farm land, farm inputs and crop failure account for highest forms of agricultural losses due to climate change which make up 48% and about 47% of the respondents in the freshwater and the mangrove swamps. The combination of these forms of agricultural losses and others imply that diverse aspects of agriculture are responsive to the adverse impacts of climate. This agrees with

Wiréhn*et al* (2016) which reported vulnerability of agriculture to climate change based on varying climatic scenarios in Nordic countries.

Table 3: Forms of agricultural losses to climate change

Forms of losses	**Freshwater swamps (%)**	**Mangrove swamps (%)**
Loss of farm land	4.3	2.7
Loss of farm inputs	11.3	2.0
Crop failure	12.0	4.4
Loss of livestock	1.9	4.0
Loss of fish	0.3	10.9
Loss of access to non-timber forest resources	0.1	1.0
Loss of crops to fire	6.6	0.6
Loss of farm land, farm inputs and crop failure	48.0	44.6
Loss of livestock, loss of fish, and loss of access to non-timber forest resources	1.6	8.7
Not applicable	13.9	21.0
Total	100	100

3.5. Causes of Food Shortage

In the face of rapid population growth, diverse factors account for food shortages in the freshwater and mangrove swamps. Table 4 shows the main forms of causes of food shortage in the freshwater and mangrove swamps. Our findings show that the most significant cause of food shortage is flooding which account for approximately 47% and 58% of the respondents in the freshwater and mangrove swamps respectively. As earlier noted, the two ecological zones experience high rainfall amount which coupled with low-lying topography and location in downstream of river Niger increase flood incidence. Floods have been described as the most costly and wide-ranging of the entire natural disasters (Wizor&Agbabou, 2014). Thus, associated with frequent flood incidence is destruction of farms, fish ponds and other livelihood schemes (Emmanuel *et al*., 2015; Nkwunonwo*et al*., 2015) and agricultural settlements. It is therefore not surprising that a high percentage of respondents attribute it to the main cause of food shortage in the freshwater and mangrove swamps. Apart from contribution of flooding, it is also important to note that bush burning and indiscriminate grazing also induce food shortage in the freshwater and mangrove swamps, accounting for approximately 39% of the respondents in the freshwater swamps. The associated disruptions to the ecosystem could inadvertently reduce additional vital source of food (Lo *et al*., 2019) as well as reduce the impacts of extreme events and disturbance, such as wildfires, floods and droughts as well as act as veritable carbon sequester (Olalekan & Mitchell, 2011; Lo *et al*., 2019; Onyena& Sam, 2020; Filho *et al*., 2021).

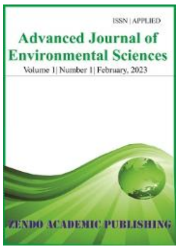

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Table 4: Main causes of food shortage

Main causes of food shortage	**Freshwater swamps (%)**	**Mangrove swamps (%)**
Flooding	47.2	58.7
Drought	1.7	2.9
Strong wind	1.5	4.5
Bush burning	12.9	1.4
Indiscriminate grazing	16.5	1.4
Water pollution	0.9	3.2
Outbreak of pests and diseases	4.4	1.8
Change in rainfall pattern	4.5	1.9
Not Applicable	10.4	24.1
Total	100	100

3.6. Source of Food during Climate Change Incidence

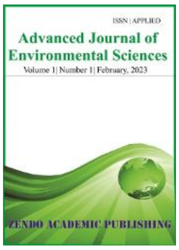
The sources of food during climate change incidence in the two ecological zones are presented in Table 5. Findings show that food purchased within community make up the main source of food during climate incidence representing approximately 53% and 42% of the respondents in the mangrove and freshwater swamps respectively. Another key source of food, especially in the freshwater swamps is food purchased outside the community. This source accounts for about 40% and 21% of the respondents in the freshwater and mangrove swamps respectively. Thus, over 80% and 74% of the selected respondents purchase food within and outside the community in the freshwater and mangrove swamps respectively during climate change incidence. It is important to note that trading in food stuff flourishes in the Niger Delta region. It is likely that food stuff sold within the community during adverse climatic condition are purchased from outside. Fairly, a significant percentage of the selected respondents depend on self-grown food during climate incidence. Self-grown crops such as plantain, yam, cocoa yam and maize flourish throughout the ecological zones of the Niger Delta region. Apart from farms, these crops are also cultivated in gardens around homes, thus making them important sources of food to numerous households. The low proportion of respondents who receive food through donations implies low inflow of aids during food shortage.

Table 5: Main source of food during climate change incidence

Main source	**Freshwater swamps (%)**	**Mangrove swamps (%)**
Donations	0.5	4.4
Purchased from outside the community	40.3	21.3
Purchased within the community	42.2	53.5
Self-grown	17.0	20.8
Total	100.0	100.0

3.7. Climate Change-Induced Food Shortage Adaptation Strategies

Agriculture remains widely considered as a climate-sensitive livelihood with no stage of agricultural production spared. Nevertheless, adoption of appropriate adaptation strategies is capable of reducing vulnerability to the vagaries of climate change. Prominent among the measures taken to deal with climate



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change-induced food shortage in the freshwater swamps are dietary adjustment, occupational change and livelihood diversification which account for 41%, approximately 24% and 17% of the respondents respectively. Important among the adaptations measures for combating food shortage in the mangrove swamps are dietary adjustment, out migration and relief materials from government which represent approximately 28%, 14% and 24% of the respondents respectively (Table 6). Remarkably, dietary adjustment ranks highest amongst the measures adopted by the respondents to tackle food shortage in the two ecological zones. During climate change-induced food crises, children, elderly and sick members of households are usually given preference. Households also opt for lowpriced food substitutes and home-grown food during climate change-related food shortage. Livelihood diversification broadens income base and reduces the risks faced by farmers since climate change impacts livelihoods distinctly. Thus, what constitutes climate change stressor to a particular livelihood may not be adverse to another livelihood. Livelihood diversification amongst farmers as a coping strategy against climate change in Nigeria has been widely reported (Adesina &Odekunle, 2011; Olayide & Tetteh, 2017). Having multiple livelihoods can boost individual's income and capacity to purchase food to augment deficits induced by the adverse impacts of climate change. However, although local farmers have forged adaptation measures against climate change over the years, the need to teach them scientifically tested agricultural practices suitable for unfolding climatic scenarios remain imperative. This may have generated calls for intensification of extension services to bridge the gap between locally evolved farming practices and scientifically tested practices, especially those in
response to climate change events (Zacarias, 2019; Pawlak & Kołodziejczak, 2020).

Table 6: Action taken to deal with climate change-induced food shortage

Action taken	**Freshwater swamps (%)**	**Mangrove swamps (%)**
Dietary adjustment	41.0	28.1
Out migration	2.1	14.1
Relief materials from government	1.6	23.5
Increase in production scale	4.3	4.2
Change of occupation	23.8	3.3
Livelihood diversification	16.8	2.4
Not Applicable	10.4	24.3
Total	100.0	100.0

3.8. Variations of Forms of Agricultural Losses, Causes of Food Shortage, Sources of Food and Adaptation Measures

Table 7 shows the results of the t-test analyses of difference in climate change-induced forms of agricultural losses, causes of food shortage and sources of food as well as adaptation measures against climate change between the freshwater and mangrove swamps. The results reveal insignificant difference in all the variables between the two ecological zones. Although the outcomes imply similarity in the variables in the two ecological zones, the percentages of the measures taken against climate change-induced food shortage with the exception of dietary adjustment are mainly change of occupation and livelihood diversification in the freshwater swamps while in the mangrove swamps, out-migration and relief materials from government are key. These isolated disparities could inform ecological zonespecific intervention strategies.

Table 7: T-test analysis of difference between the ecological zones

Variables	t	df	sig. (2-tailed)
Forms of agricultural losses	0.005	9	0.996
Causes of food shortage	0.456	8	0.660
Main Sources of food	0.000	3	1.000
Adaptation measures	0.002	6	0.998

4.0. Conclusion

The paper examined climate change related agricultural losses, food shortage and coping strategies in the freshwater and mangrove swamps ecological zones of the Niger Delta region. Sustaining food security remains a dilemma that severely distresses economies with low per capita GDP levels with associated adverse agricultural circumstances (Pawlak & Kolodziejczak, 2020). One of the critical measures for realizing zero hunger (SDG 2) and by extension good health and wellbeing (SDG 3) is vigorous pursuit of food security for all. The study reveals that a combination of loss of farm land, farm inputs and crop failure more decisively account for the for agricultural losses to climate change in both ecological zones whereas flooding is the main cause of food losses to climate change in both ecological zones. Food is primarily sourced through purchase within and outside the communities in the freshwater and mangrove swamps respectively during climate change incidence. The study reveals that whereas a mixture of dietary management, change of occupation and livelihood diversification largely account for coping strategy against climate change-induced food shortage in the freshwater swamps, dietary management, out migration and relief materials together constitute the key coping strategy in the mangrove swamps.

Considering the proximity of the mangrove swamps to the Atlantic Ocean and the associated threats of sea level rise, salinity and coastal erosion, timely provision of relieve materials should be intensified, especially during extreme climate change events. While provision of nutrition education for households is advocated in the freshwater and mangrove swamps, especially on how to access and prepare low cost healthy food during climate change-induced food crises, ecological zone-specific interventions against climate change-induced agricultural losses and food shortages are recommended for the Niger Delta region. To this end, further studies should be conducted in the ecological zones toward identifying specific climate-resilient livelihoods options vis-à-vis available environmental resources. This could curb out-migrations which often make household members left behind more vulnerable.

Acknowledgements

The authors are grateful to the Nigerian Meteorological Agency (NiMet) for the climatic data used in this study and International Development Research Centre (IDRC) Canada for funding Project Number 108974-001 titled “Empowering women as key leaders in promoting community-based climate change adaptation and disaster risks reduction initiatives in Niger Delta region”.

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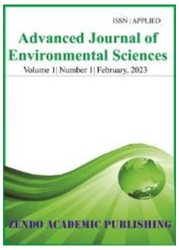

Advanced Journal of Environmental Sciences (AJES)
Volume.1, Number 1; February-2023;
Published By: Zendo Academic Publishing
https://zapjournals.com/Journals/index.php/ajes/index
14131 Alder St NW, Andover, Minnesota, USA
zapjournal@gmail.com, editorial@zapjournals.coom

Venus T.E., Bilgram T., Sauer J. and Khatri-Chettri A. (2022) Livelihood vulnerability and climate change: a comparative analysis of smallholders in the Indo-Gangetic plains. Environment, Development and *Sustainability*, 24, 1981–2009. https://doi.org/10.1007/s10668-021-01516-8

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