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Sea Surface Temperature Changes and Their Impacts on Agricultural Activities and Food Production in Coastal Communities of Rivers State, Nigeria

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Research Article

Keywords: sea surface temperature, agriculture, food security, NDVI, land surface temperature, salinity intrusion, coastal communities, Niger Delta

Posted Date: November 20th, 2026

DOI: https://doi.org/10.21203/rs.3.rs-11785561/v1

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Additional Declarations: The authors declare no competing interests.

Sea Surface Temperature Changes and Their Impacts on Agricultural Activities and Food Production in Coastal Communities of Rivers State, Nigeria

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Abstract

Coastal agriculture in the Niger Delta is highly sensitive to ocean-driven climatic change, yet the specific contribution of sea surface temperature (SST) variability to agricultural decline and food insecurity in Nigeria's coastal communities remains under-researched at the sub-national level. This study evaluates the impacts of SST changes on agricultural activities and food production in coastal Rivers State, Nigeria, over a thirty-year period (1995–2025). A mixed-methods design integrated satellite-derived SST records with Land Surface Temperature (LST) and Normalised Difference Vegetation Index (NDVI) change products, alongside household surveys, key informant interviews, and focus group discussions across the coastal local government areas of Bonny, Andoni, Opobo/Nkoro, Degema, and Okrika. Results show SST rose by approximately 1.5–3°C between 1995 and 2020–2025, with warming spreading from localised industrial hotspots into a regionally integrated pattern. This warming corresponds spatially with rising LST and declining NDVI across central and eastern local government areas – Obio/Akpor, Eleme, Tai, Oyigbo, and Khana – indicating reduced vegetation vigour and heightened crop stress, while limited pockets of NDVI improvement in western and central inland areas suggest localised adaptive resilience linked to freshwater access. Household data corroborate these geospatial patterns: a majority of surveyed farming households reported irregular rainfall, increased flooding, saltwater intrusion into farmland,

and declining crop yields, which they directly associated with changing sea and land temperatures. The study concludes that SST-driven climatic variability is a measurable and spatially differentiated driver of agricultural decline and food insecurity risk in coastal Rivers State, and recommends climate-smart agriculture, improved irrigation and drainage, and salinity management as priority interventions.

Keywords: *sea surface temperature; agriculture; food security; NDVI; land surface temperature; salinity intrusion; coastal communities; Niger Delta*

1. Introduction

Sea surface temperature (SST) is a principal indicator of ongoing climate change, reflecting the ocean's absorption of over 90 percent of the excess heat generated by greenhouse gas accumulation (Levitus et al., 2012; IPCC, 2021). While SST is most directly associated with marine and fisheries impacts, its influence extends into terrestrial systems through atmospheric and hydrological pathways: rising SST alters evapotranspiration rates, precipitation patterns, and coastal heat budgets, with downstream consequences for agriculture in adjacent coastal zones (Bakun, 1990; Trenberth & Fasullo, 2017).

In low-lying deltaic environments such as Rivers State, Nigeria, these consequences are amplified by geography. The state's coastal farmland sits at the interface of tidal, estuarine, and rainfall-driven hydrology, making it acutely vulnerable to salinity intrusion, altered rainfall timing, and thermal stress on crops. Agriculture, alongside fishing, forms the backbone of livelihoods in coastal communities such as Bonny, Andoni, Opobo/Nkoro, Degema, and Okrika, where households cultivate cassava, yams, cocoyam, and vegetables on limited arable land (UNEP, 2016; Nwankwoala, 2021). Yet the specific empirical relationship between SST variability and agricultural productivity in this region has not been systematically established.

This paper addresses that gap by evaluating the impacts of SST changes on agricultural activities and food production in coastal Rivers State. It draws on a thirty-year satellite record combined with community-level survey data to determine the extent, spatial distribution, and mechanisms through which SST variability has affected coastal agriculture and food security.

2. Literature Review and Theoretical Framework

2.1 SST, Climate Variability, and Agricultural Systems

The pathway linking ocean warming to agricultural outcomes is well documented in the global literature. The Energy Balance Theory (Trenberth & Fasullo, 2017) establishes that oceans regulate the exchange of heat and moisture with the atmosphere; as SST rises, evaporation intensifies and precipitation patterns shift, altering the timing and intensity of rainy seasons in adjacent coastal regions (Akinsanola & Zhou, 2019). The Coupled Ocean–Atmosphere Interaction Theory extends this by explaining how SST anomalies propagate into atmospheric convection patterns that determine the onset, duration, and intensity of rainfall (Ogallo, 2010; McPhaden et al., 2006), with direct consequences for traditional farming calendars in West Africa.

Empirically, Hossain et al. (2023) demonstrated that seawater intrusion and thermal stress in comparable coastal environments can produce agricultural yield reductions of up to 75 percent in extreme cases, while Zhang et al. (2024) confirmed that NDVI is highly sensitive to temperature and moisture stress, making it a reliable proxy for agricultural productivity under changing climatic conditions. Abbas et al. (2022) further showed that vegetation response to climatic stress is not purely climate-driven but mediated by land-use and irrigation practices, implying that localised adaptive capacity can offset some SST-linked stress even within a broader zone of decline.

2.2 Vulnerability-Resilience and Sustainable Livelihoods Perspectives

This study adopts the vulnerability-resilience framework of Turner et al. (2003) and Adger (2006), which frames agricultural vulnerability to SST-driven change as a function of exposure (proximity to salinity intrusion and flooding pathways), sensitivity (dependence on rain-fed, climate-sensitive cropping systems), and adaptive capacity (access to irrigation, drainage, and alternative livelihoods). This is complemented by the Sustainable Livelihoods Approach (Scoones, 2015; DFID, 2020), which explains how coastal farming households mobilise natural, financial, and social assets in response to environmental shocks. Together, these frameworks anticipate that SST-driven agricultural decline in Rivers State will be spatially uneven, concentrated where thermal and hydrological stress coincide with limited adaptive capacity.

3. Materials and Methods

3.1 Study Area

The study focuses on the coastal local government areas of Rivers State, Nigeria, located between latitude 4°20′N and 5°45′N and longitude 6°35′E and 7°30′E within the Niger Delta. The area falls within the tropical rainforest climate zone, with annual rainfall of 2,000–4,500 mm and average temperatures of 26–32°C. Agriculture in the coastal LGAs – Bonny, Andoni, Opobo/Nkoro, Degema, and Okrika – is characterised by smallholder cultivation of cassava, yams, cocoyam, and vegetables on low-lying, flood-prone land subject to tidal influence and seasonal saline intrusion.

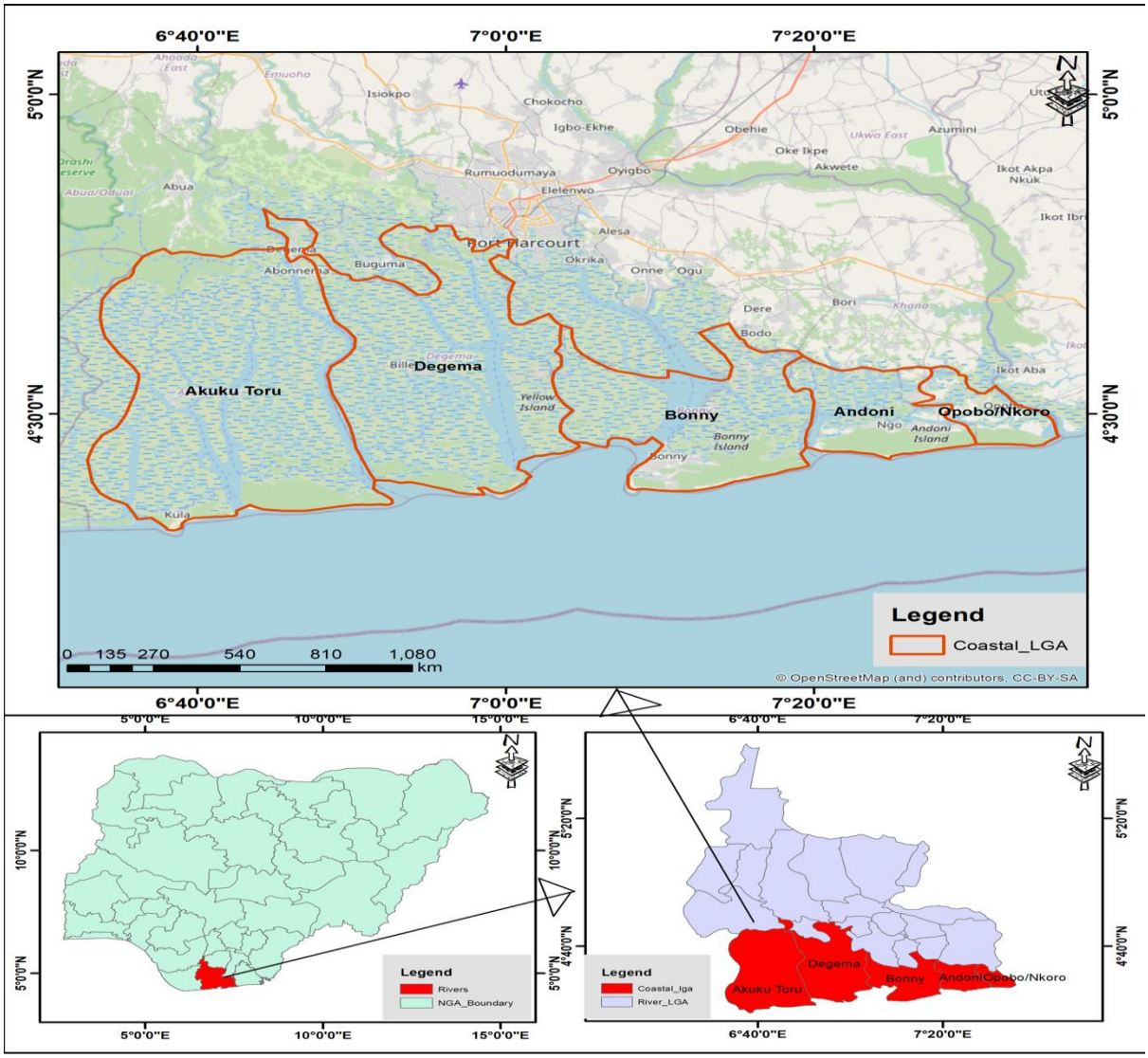


Fig. 1. Study area map showing the coastal local government areas of Rivers State, Nigeria.

3.2 Data Sources

Sea surface temperature data for 1995 and 2020–2025 were obtained from NOAA, NASA MODIS-Aqua, and the Copernicus Marine Service. Land Surface Temperature (LST) change

and Normalised Difference Vegetation Index (NDVI) change products for the 1995–2025 period were derived to assess thermal anomalies and vegetation vigour across Rivers State's local government areas, serving as geospatial proxies for agricultural productivity. Meteorological data (rainfall, air temperature, relative humidity) were obtained from the Nigerian Meteorological Agency (NIMET). These were complemented by primary data from structured household surveys, key informant interviews with agricultural extension workers, focus group discussions with farming households, and field observation of farmland conditions across Bonny, Andoni, Opobo/Nkoro, Degema, and Okrika.

3.3 Analytical Approach

SST data were analysed for long-term trend and spatial distribution to identify warming hotspots. LST and NDVI change maps were spatially overlaid with SST patterns to assess correspondence between thermal anomalies, vegetation decline, and agricultural stress across local government areas. Correlation analysis examined the relationship between SST variability and agricultural output indicators, while descriptive statistics summarised household-reported rainfall changes, flooding, salinity intrusion, and crop yield trends. Qualitative data from interviews and focus group discussions were thematically analysed to contextualise the geospatial findings.

4. Results

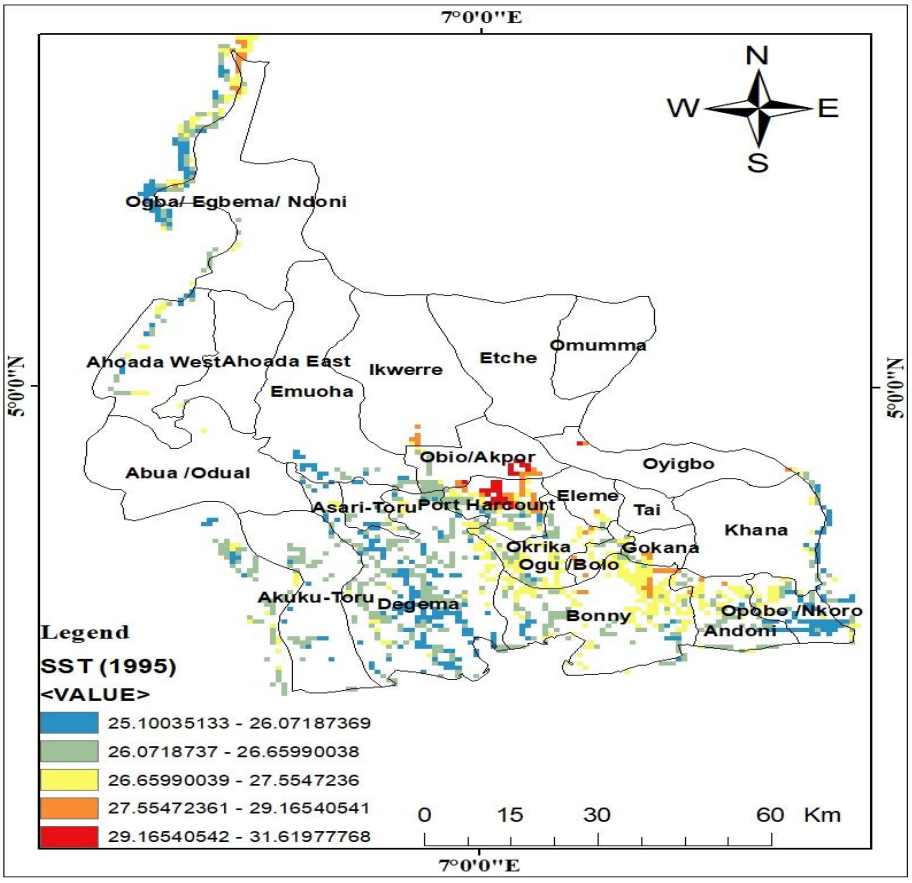


Fig. 2. Sea surface temperature of the Rivers State coastal area, 1995 baseline.

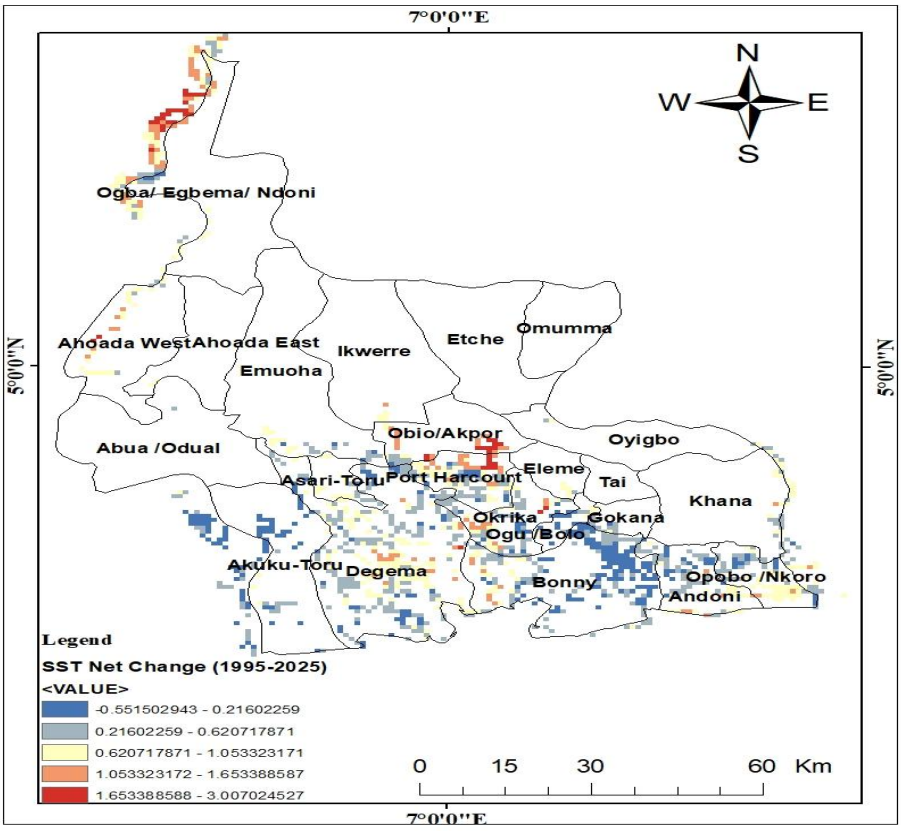


Fig. 4. Sea surface temperature net change across coastal communities of Rivers State (1995–2025).

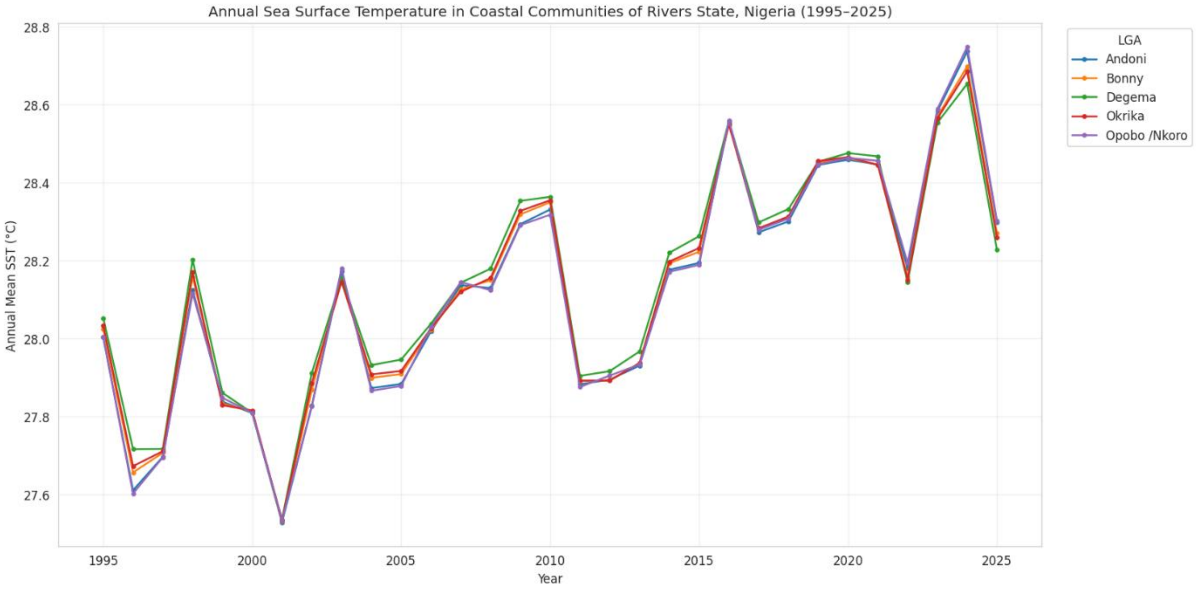


Fig. 5. Annual sea surface temperature of the coastal communities of Rivers State, Nigeria (1995–2025).

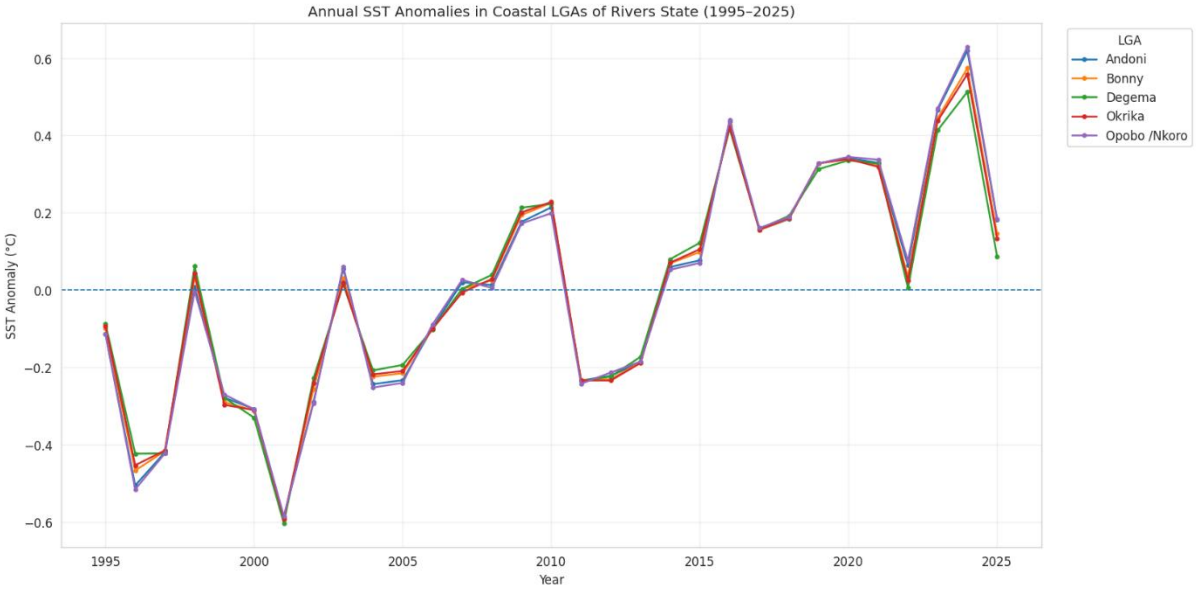


Fig. 6. Annual sea surface temperature anomalies of the coastal communities of Rivers State, Nigeria (1995–2025).

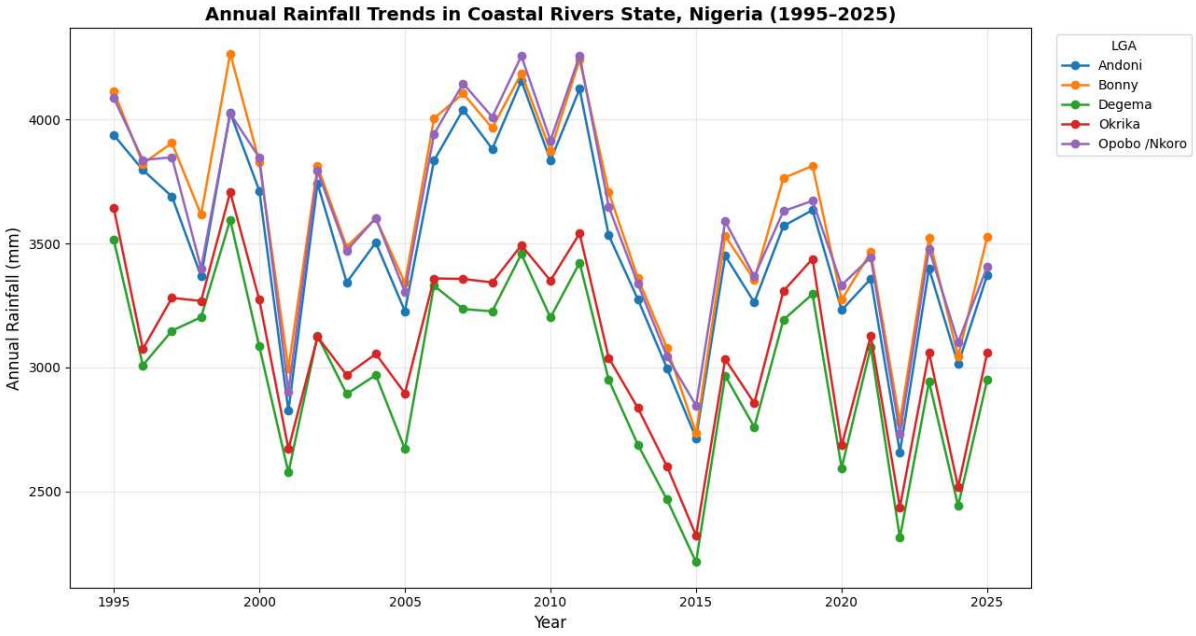


Fig. 7. Annual rainfall trends in coastal Rivers State, Nigeria (1995–2025).

The comparative SST analysis confirms a statistically and spatially significant warming trend across the coastal waters of Rivers State. At the level of individual grid cells, SST rose from a 1995 baseline of approximately 25–31°C to values exceeding 33°C in 2020–2025 (Fig. 2, Fig. 3) – an average increase of 1.5–3°C. Warming that was initially concentrated around Port Harcourt, Obio/Akpor, and Eleme has, by 2020–2025, expanded across the central and eastern coastal belt, including Okrika, Ogu/Bolo, Gokana, Khana, Opobo/Nkoro, and Andoni (Fig. 4).

Averaged annually across the five focal LGAs (Andoni, Bonny, Degema, Okrika, and Opobo/Nkoro), mean SST rose from approximately 27.5–28.1°C in 1995 to a peak of 28.75°C in 2024, before falling back to approximately 28.2–28.3°C in 2025 (Fig. 5). The corresponding SST anomaly series (Fig. 6) shows a trough of approximately −0.6°C in 2001 and a peak of approximately +0.6°C in 2024, with anomalies shifting decisively positive from around 2014 onward – indicating that the warming trend has accelerated in the most recent decade of the study period rather than proceeding at a constant rate. Over the same period, annual rainfall across the five LGAs declined from approximately 3,800–4,100 mm in 1995 to a low of roughly 2,200–2,700 mm around 2015, with partial recovery to approximately 3,000–3,500 mm by 2025 (Fig. 7), corroborating household-reported perceptions of increasingly irregular rainfall.

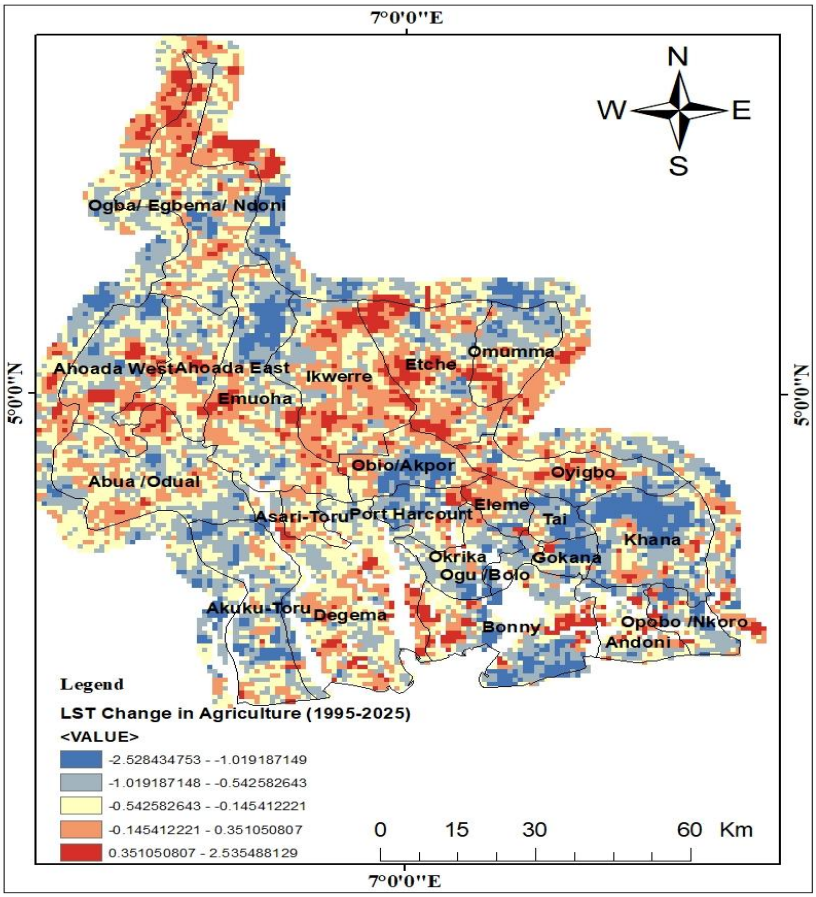


Fig. 8. LST change in agriculture across the study area (1995–2025).

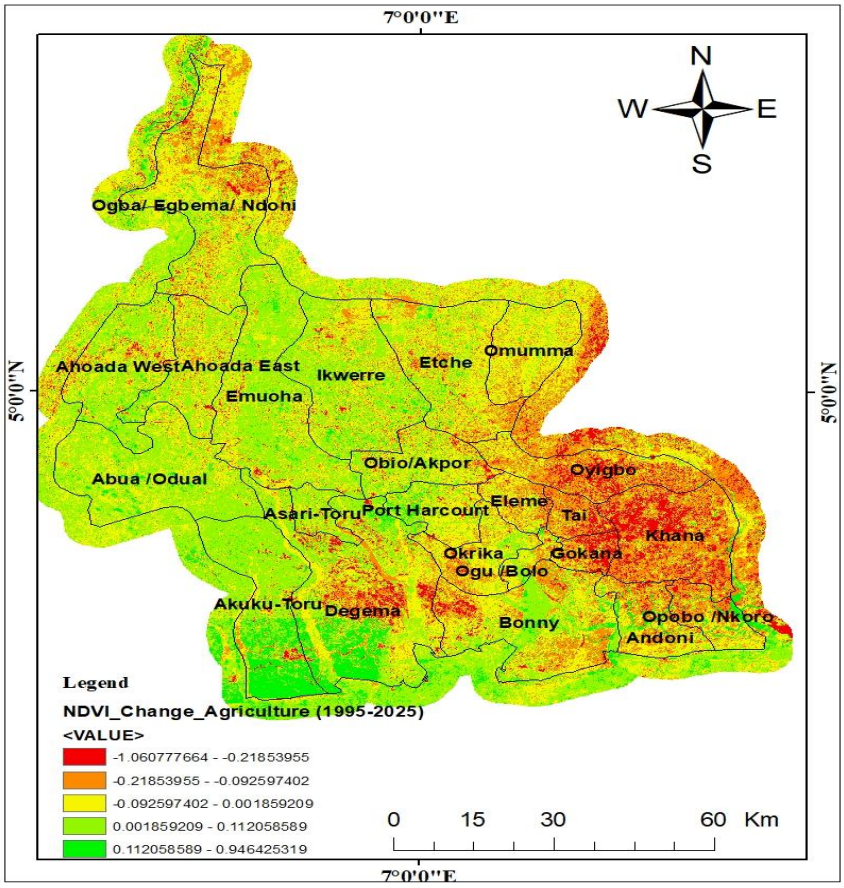


Fig. 9. NDVI change in agriculture across the study area (1995–2025).

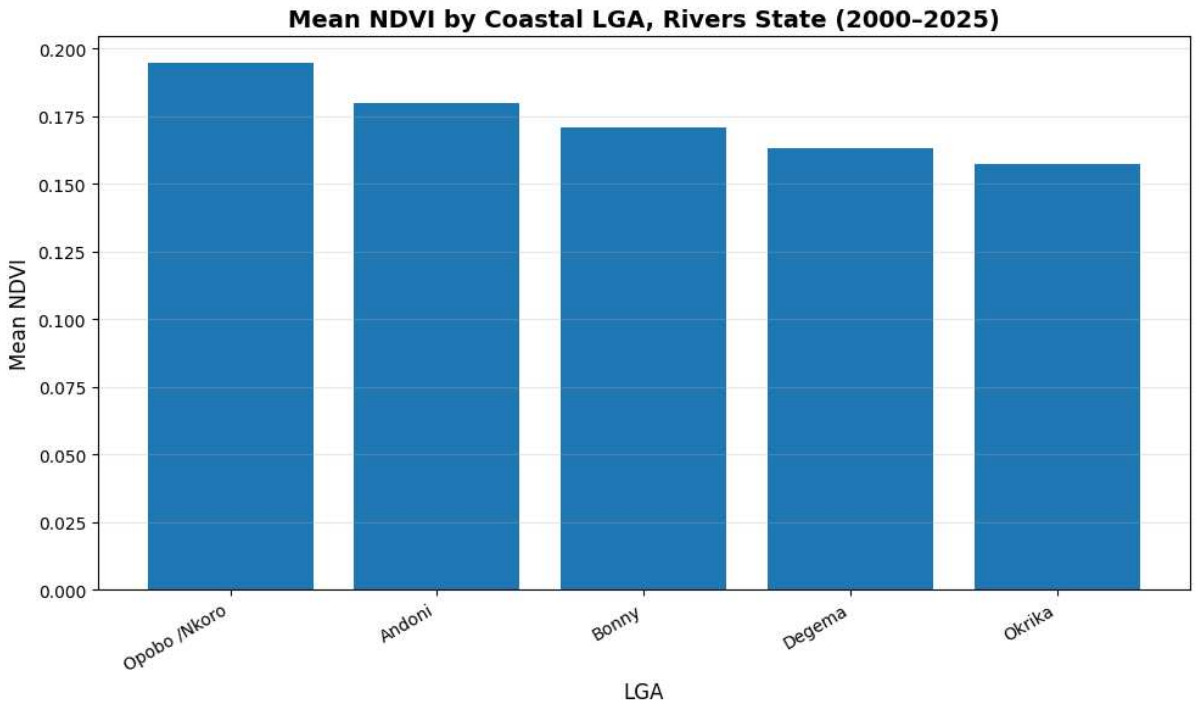


Fig. 10. Mean NDVI by coastal local government area, Rivers State (2000–2025).

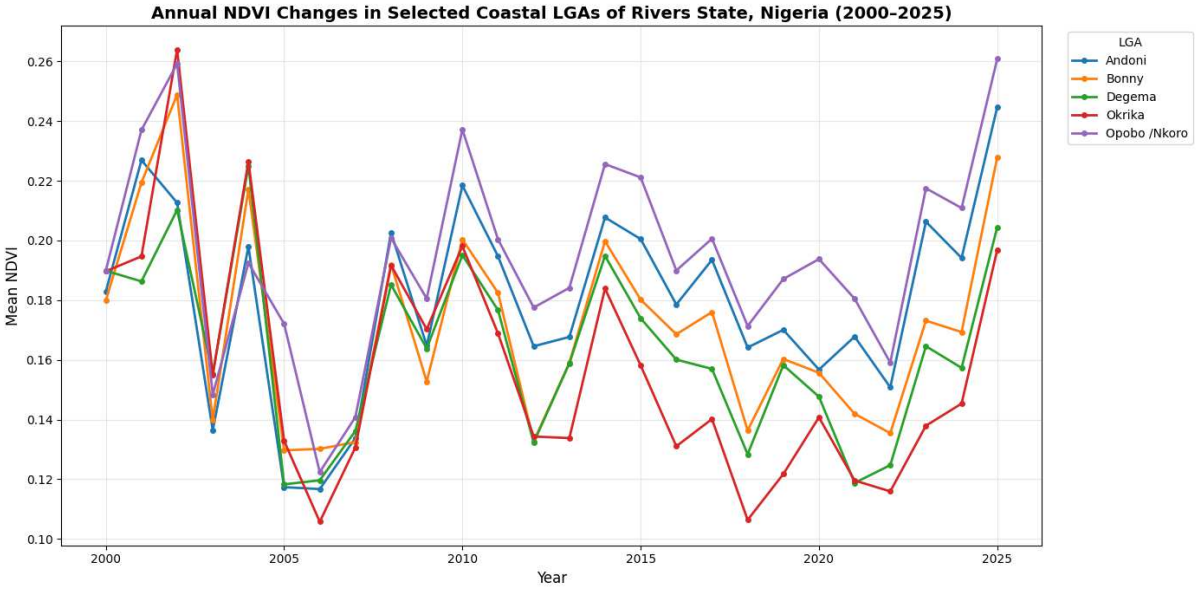


Fig. 11. Annual NDVI changes in selected coastal local government areas of Rivers State (2000–2025).

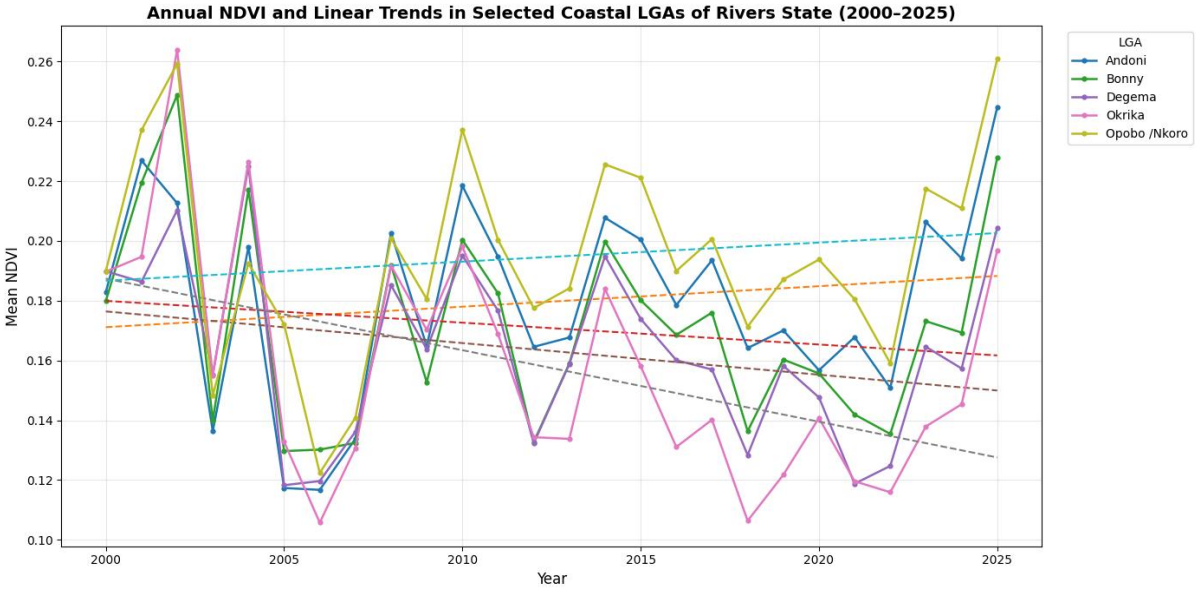


Fig. 12. Annual NDVI and linear trends in selected coastal local government areas of Rivers State (2000–2025).

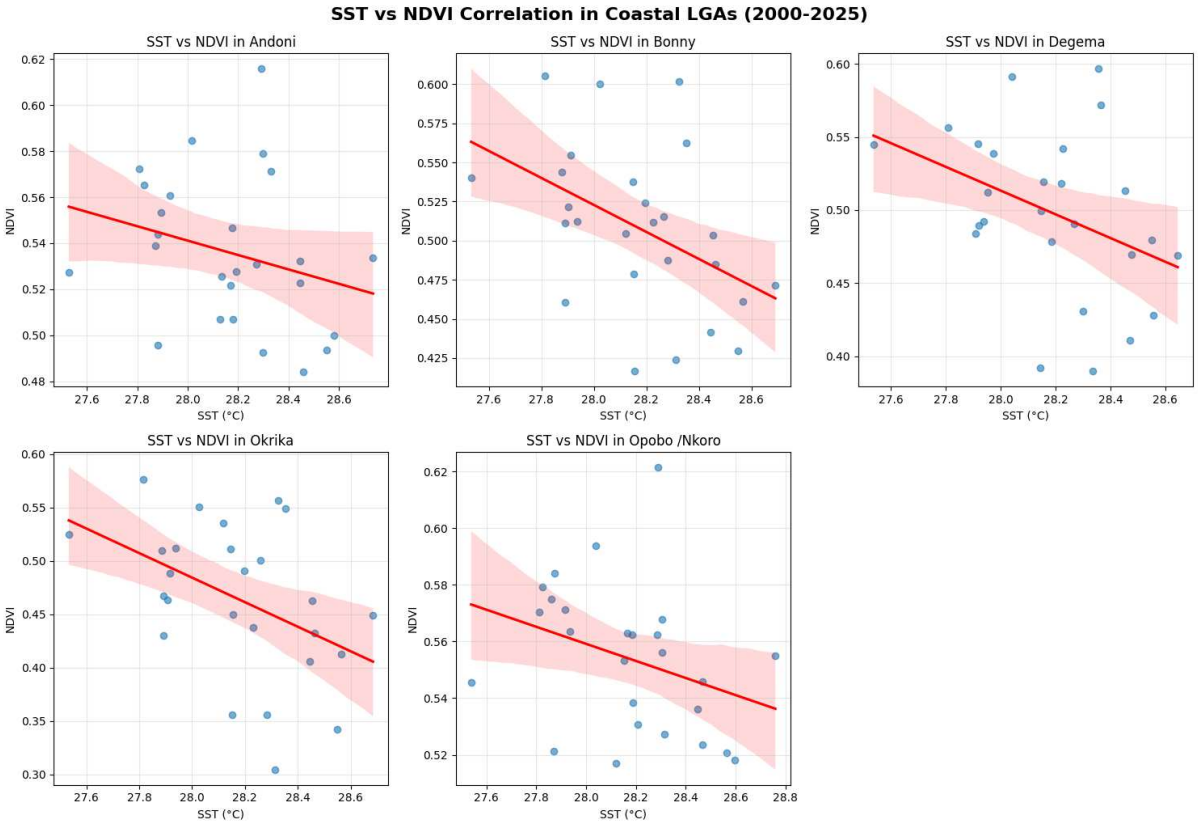


Fig. 13. SST vs. NDVI correlation across coastal local government areas (2000–2025).

The integrated LST and NDVI analysis shows pronounced spatial heterogeneity in agricultural response to this warming. Positive LST anomalies (0.35°C to over 2.5°C) dominate the central and eastern local government areas – Obio/Akpor, Eleme, Tai, Oyigbo, Khana, and parts of Etche – indicating significant warming over the study period, while negative LST anomalies (cooling) are more prevalent in the southern coastal fringe (Bonny, Andoni, Okrika) and western axis (Degema, Akuku-Toru), reflecting the moderating influence of oceanic proximity (Fig. 8). Correspondingly, NDVI decline (values between −1.06 and −0.21) is concentrated in the eastern coastal corridor – Khana, Gokana, Oyigbo, and Opobo/Nkoro – coinciding with zones of elevated LST and indicating reduced photosynthetic vigour and crop stress (Fig. 9).

Localised NDVI improvement was observed in parts of the western and central inland areas – Ahoada West, Abua/Odual, and Emuoha – suggesting adaptive resilience associated with better freshwater availability, lower salinity exposure, and improved land management. However, these positive trends remain spatially limited relative to the widespread decline recorded in the high-temperature eastern and central zones. Averaged over 2000–2025, mean NDVI was highest in Opobo/Nkoro (approximately 0.195) and Andoni (approximately 0.18), intermediate in Bonny (approximately 0.171), and lowest in Degema (approximately 0.164) and Okrika (approximately 0.158) (Fig. 10) – a ranking that does not map directly onto SST exposure

alone, reinforcing the role of local hydrological and land-management factors highlighted in Section 2.2. The annual NDVI series for these five LGAs (Fig. 11, Fig. 12) shows substantial interannual volatility, with a shared trough around 2005–2006 and a shared peak around 2010, superimposed on gently diverging long-term trend lines across LGAs – three of the five LGAs show a modest upward linear trend over 2000–2025 despite the interannual volatility, while two show a modest downward trend, consistent with the spatially uneven pattern of resilience and decline described above.

Scatterplot analysis of SST against NDVI for each of the five focal LGAs confirms a consistent negative relationship between the two variables over 2000–2025 (Fig. 13): in every LGA examined, the fitted trend line slopes downward, indicating that NDVI tends to decline as SST rises. The steepness of this relationship varies by location – Okrika and Opobo/Nkoro display comparatively steep negative slopes alongside wide confidence intervals, indicating both a strong average association and considerable year-to-year scatter, while Degema shows a shallower slope, consistent with the comparatively moderate NDVI decline observed for that LGA elsewhere in the analysis. This spatial variation in the strength of the SST–NDVI relationship is consistent with the vulnerability-resilience framework adopted in Section 2.2, whereby local adaptive capacity moderates the extent to which thermal stress translates into vegetation decline.

Household survey data reinforce these geospatial findings. A significant proportion of farming respondents reported irregular rainfall patterns, increased flooding events, and declining crop yields, which they associated with changing water and air temperatures. Cross-tabulation between SST-related perception questions and agricultural outcome questions showed a strong co-occurrence of responses, indicating that households experience SST-linked climatic change as a compounding, rather than isolated, threat to farm output and food security.

5. Discussion

The results demonstrate that SST variability influences coastal agriculture in Rivers State through at least three interacting mechanisms. First, rising SST elevates atmospheric temperature and evapotranspiration in adjacent coastal zones, reducing soil moisture availability and disrupting traditional planting calendars (Trenberth & Fasullo, 2017; Ogallo, 2010). Second, SST-linked sea-level rise and altered tidal dynamics drive saltwater intrusion into low-lying farmland, degrading soil quality and suppressing crop growth – a pathway consistent with the substantial yield losses documented in comparable coastal settings by

Hossain et al. (2023). Third, SST-driven changes in precipitation timing and intensity increase the frequency of both flooding and dry-spell stress, shortening effective growing periods and elevating the risk of crop failure.

The spatial pattern observed – concentrated NDVI decline in the central and eastern coastal corridor, against localised resilience in western and central inland areas with better freshwater access – supports the vulnerability-resilience expectation that agricultural sensitivity to SST-driven change is mediated by local hydrological and land-management conditions rather than thermal exposure alone (Abbas et al., 2022; Turner et al., 2003). This implies that adaptive interventions targeting irrigation, drainage, and salinity management have real potential to offset SST-linked agricultural stress, even in a context of continued regional warming.

These findings carry direct food security implications. Because coastal households in Rivers State depend heavily on local crop production, the observed decline in vegetation vigour and household-reported yield loss point toward a gradual erosion of food production capacity in the most exposed local government areas. Left unaddressed, this trajectory is consistent with broader projections that ocean-driven climate change will significantly reduce agricultural productivity in vulnerable coastal regions in the absence of adaptive intervention (IPCC, 2023).

6. Conclusion and Recommendations

This study evaluated the impacts of sea surface temperature changes on agricultural activities and food production in coastal communities of Rivers State. The evidence establishes a coherent, thirty-year relationship between SST warming and agricultural stress: SST rose by 1.5–3°C between 1995 and 2020–2025, and this warming corresponds spatially with rising land surface temperature and declining vegetation vigour across the central and eastern coastal corridor, corroborated by household-reported declines in rainfall reliability, crop yield, and food security. Localised resilience in areas with better freshwater access indicates that the relationship between SST and agricultural outcomes is mediated by local adaptive capacity, offering a practical entry point for intervention.

The study recommends: (i) promotion of salt-tolerant and shorter-duration crop varieties suited to the coastal LGAs most affected by salinity intrusion; (ii) expansion of small-scale irrigation and improved drainage infrastructure to reduce dependence on increasingly erratic rainfall; (iii) targeted agricultural extension support directed at the central and eastern coastal corridor identified as the primary zone of NDVI and yield decline; and (iv) integration of SST and

NDVI-based agricultural monitoring into Rivers State's climate adaptation planning to allow early identification of emerging risk areas.

References

Abbas S., Nichol J.E., Zhang J., and Fischer G.A. (2022). The Impact of Land Use/Land Cover Dynamics and Climate Variability on Vegetation Greenness in South Asia, Environmental Monitoring and Assessment, 194(3), (pp. 1 – 18).

Adger W.N. (2006). Vulnerability, Global Environmental Change, 16(3), (pp. 268 – 281). DOI: 10.1016/j.gloenvcha.2006.02.006.

Akinsanola A.A., and Zhou W. (2019). Projections of West African Summer Monsoon Rainfall Extremes from Two CORDEX Models, Climate Dynamics, 52(3–4), (pp. 2017 – 2028).

Bakun A. (1990). Global Climate Change and Intensification of Coastal Ocean Upwelling, Science, 247(4939), (pp. 198 – 201). DOI: 10.1126/science.247.4939.198.

Hossain M.S., Uddin M.N., and Fakhruddin A.N.M. (2023). Impacts of Salinity Intrusion on Agriculture and Food Security in Coastal Regions: A Review, Science of the Total Environment, 857, (pp. 159 – 172).

Intergovernmental Panel on Climate Change, IPCC (2021). Climate Change 2021: The Physical Science Basis, Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change, Cambridge University Press, Cambridge.

Intergovernmental Panel on Climate Change, IPCC (2023). Climate Change 2023: Synthesis Report, Sixth Assessment Report (AR6), IPCC, Geneva.

Levitus S., Antonov J.I., Boyer T.P., Baranova O.K., Garcia H.E., Locarnini R.A., et al. (2012). World Ocean Heat Content and Thermosteric Sea Level Change (0–2000 m), 1955–2010, Geophysical Research Letters, 39(10), L10603. DOI: 10.1029/2012GL051106.

McPhaden M.J., Zebiak S.E., and Glantz M.H. (2006). ENSO as an Integrating Concept in Earth Science, Science, 314(5806), (pp. 1740 – 1745).

Nigerian Meteorological Agency, NIMET (2021). Nigeria Climate Review Bulletin, Federal Ministry of Aviation, Abuja.

Nwankwoala H.O. (2021). Geology and Hydrogeology of the Niger Delta: Implications for Water Resources Management, Earth Science Research Journal, 25(1), (pp. 55 – 68).

Scoones I. (2015). Sustainable Livelihoods and Rural Development, Practical Action Publishing, Rugby.

Trenberth K.E., and Fasullo J.T. (2017). Atlantic Meridional Heat Transports Computed from Balancing Earth's Energy Locally, Geophysical Research Letters, 44(4), (pp. 1919 – 1927).

Turner B.L., Kasperson R.E., Matson P.A., McCarthy J.J., Corell R.W., Christensen L., et al. (2003). A Framework for Vulnerability Analysis in Sustainability Science, Proceedings of the National Academy of Sciences, 100(14), (pp. 8074 – 8079). DOI: 10.1073/pnas.1231335100.

United Nations Environment Programme, UNEP (2016). Environmental Assessment of Ogoniland, UNEP, Nairobi.

Zhang Y., Peng C., Li W., Fang X., Zhang T., Zhu Q., and Zhao P. (2024). Vegetation Dynamics and its Response to Climate Change in Global Ecosystems, Scientific Reports, 14.