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Original Article

Geospatial Techniques-based Weighted Arithmetic Aggregation for Mapping Adaptation Strategies of Fishermen to Climate Change in Littoral Local Government Areas of Delta State, Nigeria

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Fishermen, Climate Change, Adaptation, Littoral, Mapping, Delta State.

ABSTRACT

This paper focused on the application of weighted arithmetic aggregation (WAA) and geospatial techniques (GTs) in mapping adaptation strategies of fishermen (ASF) to climate change (CC) in littoral local government areas (LLGAs) of Delta State, Nigeria. Data was sourced from the field sourced 165 fishermen in three LLGAs using network sampling techniques and a well-vetted questionnaire. Data analysis was carried out using GTs, descriptive and inferential statistics in SPSS 22 and Arc GIS 10.8 software. Results showed that 96.4% noticed CC/variation with an annual loss of income from fishing exerting a very severe impact on fishermen. Again, switching to other means of livelihood and/or combining different livelihood activities, increasing fishing frequency and spending more time in the river was very effective ASF. The overall ASF index showed Warri North had high adaptation while Warri South-West LGA recorded low adaptation. The paper recommended the establishment of meteorological stations and CC enlightenment in the area.

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INTRODUCTION

Over the past three decades, several concepts including, vulnerability, exposure, sensitivity, mitigation, resilience and adaptation among others have continued to dominate climate change debates globally. A shift in climate straightforwardly and obliquely ascribed to the actions of man which modify atmospheric processes as well as the noticeable natural fluctuations in global climate patterns spatially and temporarily is regarded as climate change (Intergovernmental Panel on Climate Change, IPCC, 2014). In sub-Saharan Africa' (SSA), empirical evidence shows that the continent is already experiencing a shifting precipitation regime coupled with a warming of about 0.7°C with a high probability of doubling at the end of the 21st Century (Niang et al., 2014). Widespread climate change related hazards including drought and desertification in the northern parts of Nigeria (Nnodim, 2020; Nwakaudu, 2020).

However, many fragile ecosystems including the littoral zones, communities and livelihoods in SSA have been predicted to be highly vulnerable to the impacts of climate change due pitiable household social economy. Sadly, water levels in the oceans have risen to about 3-4mm per annum and by 2100, it will most likely increase to about 15 mm (Broin, 2020). Many shorelines, coral reefs and beaches together with several low-lying settlements in the freshwater and mangrove ecosystems have been inundated with coastal and river flooding. Upsurge in disease/pest infestation coupled with disruption of wildlife's natural habitats and breeding grounds of game animals is compelling species that are unable to adapt to these alterations to migrate and/or go into extinction with a resultant reduction in forest-based biodiversity and resources (Niang et al., 2014).

In as much as climate change cannot be abated, adaptation apart from mitigation becomes the sure approach in responding to this global socio-ecological change indicator. Climate change adaptation is therefore the process and exploration of prospects essential for the readjustment of human and natural systems to the real and anticipated adverse impacts of climate dysfunctionalities (IPCC, 2014). Nevertheless, climate change adaptations are socio-ecological systems, spatial spheres, regions and livelihood specific. In other words, a climate change adaptation strategy' that is effective in 'agriculture for instance may be unworkable in the housing sector or a functional strategy in temperate regions can become ineffective in tropical ecological zones. Policy formulation and implementation may also dominate nationalized adaptation. While indigenous skills may control rural-level climate change adaptations. Again, awareness, degree of exposure, extent, of sensitivity, enthusiasm and willingness to adjust are key determinants of climate change adaptation.

Regrettably, littoral zones which are already fragile and the entire Niger Delta region of Nigeria are already being bedevilled with socio-economic and ecological predicaments heightened by natural and anthropogenic environmental stressors. Continued oil spillage, gas flaring and increased environmental pollution arising from petroleum and natural gas exploration and extraction have exposed the region to systemic vulnerabilities including poverty, under-development, poor infrastructure, joblessness, conflicts, militancy and flood risk (Peterside, 2018; Ibanga and Idehen, 2019). The climate change governance framework in the region is not only pathetic but also lacks well-coordinated and multidimensional strategies in the formulation and implementation of adaptation policy. This has led to an inability to mainstream climate change adaptation into the national, state and local development programmes by successive administrations.

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Besides, in SSA, climate change adaptation debate has often neglected fishing /fishermen which is one of the traditional means of livelihood. Fishing / Fishermen have often been seen as an "enemy of aquatic animals", with key drivers of climate change with unsustainable fish strategies like the use of chemicals are prime contributors to aquatic life depletion/extinction (Friant et al., 2015). Notwithstanding the fact that forest-based informal economic activity has employed a substantial number of rural dwellers in many littoral zones for centuries. Many households have also been provided with readily available animal-based protein sources, forest-based food resources, clothing, shelter, income for children's educational development, recreation as well as contribute to overall community development.

Also, disheartening is the drought in literature deploying a statistically well-grounded weighting approach through multivariate analysis of indicators and the weighted arithmetic aggregation (WAA) framework in component and index summation. Added to the above is the dearth of empirical studies exploring the capabilities of geospatial techniques (GTs) in mapping adaptation strategies of fishermen to climate change in LLGAs, Niger Delta, Nigeria. Thoughts and/or considerations need to be accorded this informal economic livelihood when policies, legislations and conventions towards biodiversity, wildlife and habitat conservations are formulated and implemented. These knowledge gaps therefore call for a GTs-based framework where adaptation strategies (largely consistent with the socio-economic approach), exposure and sensitivity (related to the biophysical approach) are integrated to form a robust decision support system.

Aim and Objectives

This paper specifically focused on the application of weighted arithmetic aggregation (WAA) and geospatial techniques (GTs) in mapping adaptation strategies of fishermen (ASF) to climate change in littoral local government areas (LLGAS) of Delta State, Nigeria. Specific objectives include to:

- Interrogate the effects/sensitivity of fishermen to climate change in littoral LGAs of Delta State.
- Explore the various climate change adaptation strategies adopted by fishermen in the littoral LGAs of Delta State.
- Deploy GTs-based WAA in mapping the adaptation strategies of fishermen to climate change in littoral LGAs of Delta State.

MATERIALS AND METHODS

The study area is made up of three littoral LGAs which include: Warri North, Warri South-West and Burutu which extends from latitude 4° 59'31.556"N- 6°9'3.227"N and Longitude 4°59'41.778" E -5°53'5.485" E (Figure 1). The area is characterised by a tropical equatorial climate (Af). Temperature is largely high and constant all through the year. The average temperature is 27°CC with an annual rainfall of about 2500mm. Nine hunting-based climate change effects/sensitivity indicators and eight adaptation strategies of fishermen were investigated in a field-based survey of 165 rural fishermen out of 180 fishermen selected using purposive and network sampling techniques from seven communities (Table 1) in the three littoral LGAs in Delta State from March to September 2022 using well-vetted and prearranged questionnaires. The research instrument was validated through a pre-test with 90 respondents in two communities namely Oporoza and Okerenkoko in Warri South West LGA of Delta State. This resulted in reliability Cronbach Coefficient alpha of 0.866 which was good, consistent and satisfactory in realizing our research objectives. Data analysis was carried out using descriptive and inferential statistics of Likert's weighted mean score (WMS), analysis of variance (ANOVA), principal component analysis (PCA) in SPSS 22 and results were transferred to ArcGIS 10.8 software where GTs-based WAA was applied in mapping FAS to CC implemented using raster calculator with weights generated from PCA-varimax rotated component scores.

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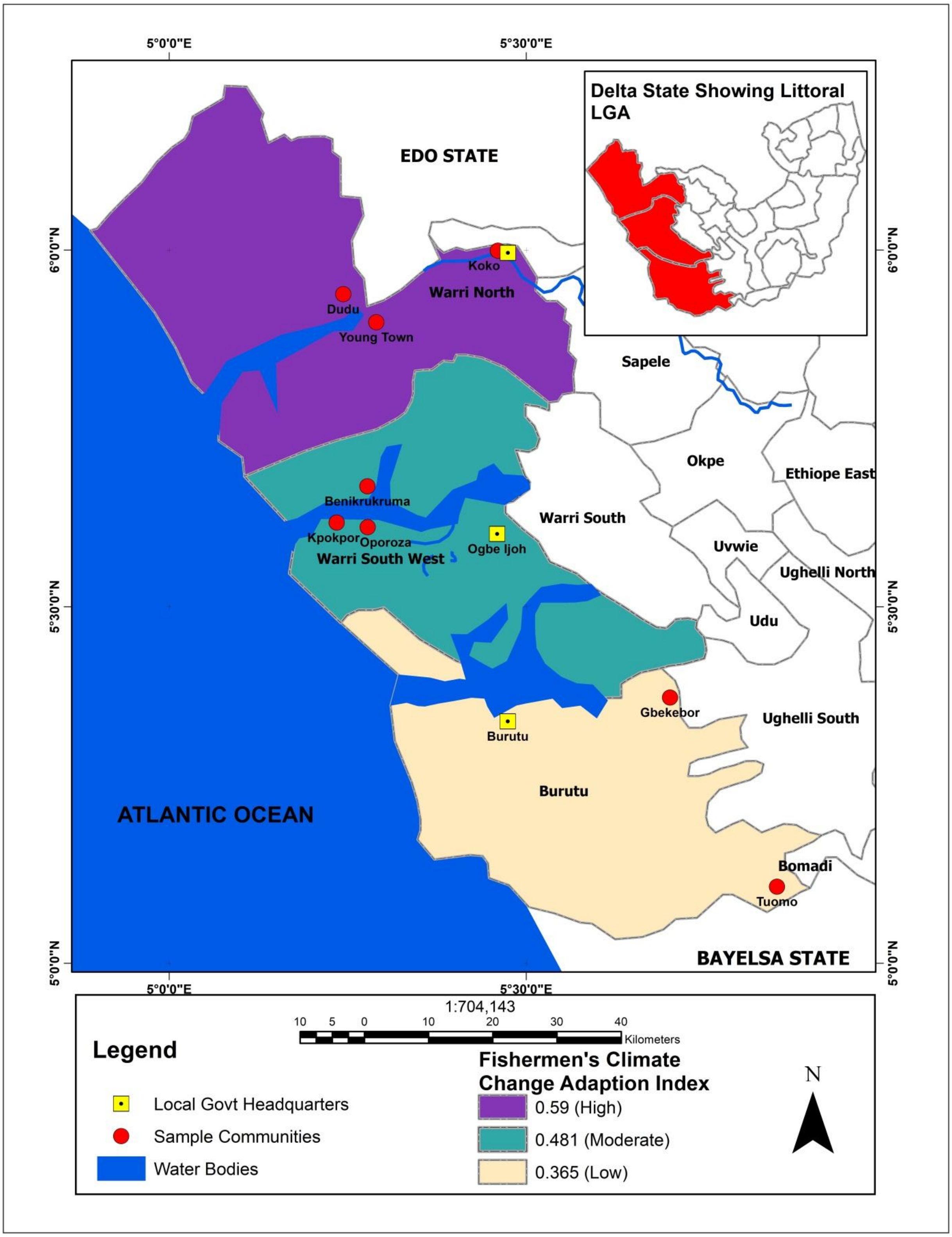
Figure 1: Fishermen's Climate Change Adaptation Index of Littoral LGA of Delta State



RESULTS AND DISCUSSION

It was found that the majority of the fishermen were male (n = 132; 80%) while 33 (20%) were female. Male domination of research participants is not surprising since fishing is generally seen as a gender-sensitive livelihood. This aligns with the findings of Santos et al. (2022) who reported 92% male engagement in fishing expeditions in the

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quasi-desert area of northeastern Brazil. Similarly, 101 (61.2%) sampled fishermen had resided in the area for up to 11- 20 years even as 124 (75.2%) spent between 21-30 years in fishing. The blend of considerable extended stay in the littoral area as well as stretched engagement in fishing are strong indications that the information divulged is not only reliable and authentic but tried and tested. This finding is consistent with that of Pattiselanno et al. (2023) who reported that dependable knowledge of fishing in Tambauw Districts, Papua Barat Province of Indonesia is based on experience over time.

Table 1: Spatial Attributes of Sampled Communities

LGAs	Communities	Latitude	Longitude	Elevation
Burutu	Gbekebor	5° 22'26.627"N	5° 42'44.831"E	7
	Tuomo	5° 6'29.866"N	5° 53'9.056"E	10
Warrì South West	Oporoza	5° 35'47.803"N	5° 16'51.294"E	9
	Kpokpor	5° 36'2.916"N	5° 14'1.9"E	4
	Benekrukru	5^{O} 62'22.223'N	5^{O} 38'5.155"E	6
Warri North	Koko	6°0'1.883"N	5° 28'4.562"E	7
	Dudu	5° 56'22.132"N	5° 14'39.383"E	8
	Young Town	5° 54'15.08"N	5° 17'45.388"E	7

Also, the majority (n =159; 96.4%) noticed variation/changes in climate in the locality with 145(87.9%) deriving their source of climate change knowledge from personal observation and experience over the years. This finding collaborates with that of Ogunyiola et al (2022) who argued that the effectiveness of any climate change adaptation programme is contingent upon mainstreaming indigenous skills and experiences into the agenda in SSA. It was also found that annual loss of income from fishing with a weighted mean score (WMS) of 3.32 and reduced access/increased distance to the fishing ground (WMS=3.31) were the most perceived CC effect/sensitivity indicators with very severe impact on Fishermen (Table 2). The most adopted and very effective adaptation strategies of fishermen to climate change (Table 3) were switching to other means of livelihood and/or combining different livelihood activities (WWS = 2.81) thus increasing the frequency of fishing trips and spending more time in the forest(WMS=2.8).

Table 2: Climate Change Effects/Sensitivity of Fishermen in Littoral LGAs of Delta State

Climate change effects/sensitivity indicator		Extent of effect/sensitivity				Total	WMS/Rank/Sensitivity level
		Very severe	Severe	Moderate	Not severe		
Annual loss of income from fishing	Count (%)	90(54.6)	46(27.7)	21(12.7)	8(5.0)	165(100)	3.32(1st)
	Weighted Count	360	138	42	8	548	Very severe
Reduced access/increasing distance to the fishing ground	Count (%)	88(52.9)	48(29.3)	21(12.7)	8(5.1)	165(100)	3.31(2nd)
	Weighted Count	352	144	42	8	546	Very severe
Low concentration of fishing in an area	Count (%)	85(51.3)	51(30.7)	21(12.9)	8(5.1)	165(100)	3.29(3rd)
	Weighted Count	340	153	42	8	543	Very severe
Income from fishing	Count (%)	84(51.1)	52(31.1)	21(12.7)	8(5.1)	165(100)	3.28(4th)

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Climate change effects/sensitivity indicator		Extent of effect/sensitivity				Total	WMS/Rank/Sensitivity level
		Very severe	Severe	Moderate	Not severe		
	Weighted Count	336	156	42	8	542	Severe
Number of fishes killed/caught per trip	Count (%)	83(50.4)	53(32.3)	20(12.1)	9(5.2)	165(100)	3.27(5th)
	Weighted Count	332	159	40	9	540	Severe
Sizes of fishes killed/caught	Count (%)	82(49.8)	52(31.4)	22(13.3)	9(5.5)	165(100)	3.25(6th)
	Weighted Count	328	156	44	9	537	Moderate
Distribution of species in an area	Count (%)	80(48.5)	55(33.1)	20(12.3)	10(6.1)	165(100)	3.24(7th)
	Weighted Count	320	165	40	10	535	Moderate
Fishing trips	Count (%)	73(44.3)	56(34.2)	23(13.6)	13(7.9)	165(100)	3.22(8th)
	Weighted Count	292	168	46	26	532	Not severe
Species of Fishes killed	Count (%)	81(49.2)	52(32.0)	20(11.5)	12(7.3)	165(100)	3.20(9th)
	Weighted Count	324	156	40	8	528	Not severe

The overall climate change-based fishing' adaptation index as seen in Figure 1 showed that a high level of adaptation (0.59) was recorded by fishermen in Warri North LGA. Also, the level of adaptation of Fishermen to climate change in Burutu LGA was categorized as moderate based on the index of 0.481. In contrast, Fishermen in Warri South-West LGA experienced low-level adaptation to climate change based on the index of 0.365. The variation in the level of adaptation of Fishermen to climate change in littoral LGAs of Delta State may not be unconnected to the disparities in household social economy. For instance, 60(42.7%) sampled fishermen in Warri North LGA earned between N31,000.00 to N90,000.00 on a monthly basis while 53 (32.1%) earned similar income in Burutu LGA as compared to 37 (22.4%) fishermen who make similar wages monthly in Warri South-West LGA. Household income is very vital in climate change adaptation and this finding is in agreement with that of Nor Diana et al. (2022) who argued that the likelihood of adoption of innovative measures to cushion the effect of climate change is a function of sufficient personal and household earnings.

Another key determinant of variation in the level of adaptation of fishermen to climate change in littoral LGAs of Delta State may be literacy. This is because 44(26.7%) fishermen in Warri North LGA were educated up to primary school, 34 (20.6%) in Burutu LGA, whereas in Warri South-West, it is 29 (17.6%). The more educated the people are, the more likely they are to embrace novel strategies to boost their resilience to climate change impacts. This finding corroborates that of Walker et al. (2022) who reported that literate individuals are receptive to innovations while the uneducated are very reactive and in most cases resist change vehemently.

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Table 3: Fishermen Climate Change Adaptation Strategies in Littoral LGAs of Delta State

Adaptation Strategies		Level of Effectiveness				Total	WMS/Rank
		Very effective	Effective	Ineffective	Very ineffective		
Switching to other means of livelihood and/or combining	Count (%)	52(31.8)	50(30)	43(25.9)	20(12.3)	165(100)	2.81
	Weighted Count	208	150	86	20	464	1st
Increase the frequency of hunting trips and spending more time in the forest	Count (%)	52(31.8)	51(30.9)	39(23.2)	23(14.1)	165(100)	2.8
	Weighted Count	208	153	78	23	462	2nd
Indigenous knowledge of weather prediction	Count (%)	26(15.5)	50(30.5)	50(30.5)	39(23.6)	165(100)	2.38
	Weighted Count	104	150	100	39	393	3rd
Assessing more difficult terrain or distance hunting ground	Count (%)	32(19.5)	47(28.2)	34(20.9)	52(31.4)	165(100)	2.36
	Weighted Count	128	141	68	52	389	4th
Fishing during day time/ using dogs	Count (%)	28(16.8)	47(28.6)	44(26.4)	46(28.2)	165(100)	2.34
	Weighted Count	112	141	88	46	387	5th
Belonging to a cooperative society	Count (%)	23(13.6)	50(30,5)	33(20.4)	59(35.5)	165(100)	2.22
	Weighted Count	92	150	66	59	367	6th
Use of storage facilities	Count (%)	24(14.5)	37(22.3)	51(30.9)	53(32.3)	165(100)	2.19
	Weighted Count	96	111	102	53	362	7th
Advice from extension workers	Count (%)	24(14.5)	30(18.2)	50(30.5)	61(36.8)	220(100)	2.10
	Weighted Count	96	90	100	61	347	8th

CONCLUSION

Fishing/Fishermen are not adversaries to aquatic life and biodiversity but are indispensable partners in the intricate socio-ecological and livelihood systems. Fishing/fishermen have comparable potentialities of being susceptible to aliens as well as inherent environmental change indicators that defy their resilience. Fishermen have suffered very severe impacts ranging from an annual loss of income from fishing, reduced access/increased distance to fishing grounds to low concentration of fish in an area. Switching to other means of livelihood and/or combining different livelihood activities, increasing the frequency of fishing trips, and spending more time in the river as well as deploying indigenous knowledge of weather

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prediction were the most effective climate change adaptation strategies in the study. GTs-based WAÁ approaches proved very useful in mapping the adaptation strategies of fishermen to climate change in littoral LGAs of Delta State.

Key policy-based recommendations include the establishment of well-equipped synoptic weather stations for weather and climate monitoring in 'the area, deployment of extension personnel and investment opportunities with the provision of credit facilities to boost fishermen's resilience and adaptive capacity to climate change in the littoral areas. Intensive rural-based public enlightenment campaigns should be carried out in the area while a GTs-based WAA framework should be deployed to assess climate change exposure, sensitivity and vulnerability in littoral communities for effective policy development and implementation.

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