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Households' Livelihood Vulnerability to Climate Change and Climate Variability: A Case Study of the Coastal Zone, The Gambia

Joshua Amuzu[1]* Amos T. Kabo-Bah[2] Bubu Pateh Jallow[3] Sidat Yaffa[4]
1. West African Science Service Center on Climate Change and Adapted Land Use (WASCAL) Headquarters, CSIR Office Complex, Airport Residential Area, P.M.B CT 504, Cantonments Accra
2. Department of Energy and Environmental Engineering, University of Energy and Natural Resources, P. O. Box 214, Sunyani, Ghana
3. Department of Water Resources, 7, Marina Parade, Banjul, The Gambia
4. University of The Gambia, WASCAL Program, North Bank Region, Farafenni Campus

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Abstract
Climate change and its variability are negatively influencing climate-dependent activities such as agriculture and fishing in Africa, of which The Gambia is no exception. Households are vulnerable to its impacts. With the impacts of climate change and its variability in The Gambia, livelihoods of people will be negatively affected. There is the need to know which regions are more vulnerable than others are so livelihood improvement actions can be taken in areas they are needed the most in the wake of present and future climate change impacts, thus, the objective of this study. This will aid in eluding maladaptation and waste of limited developmental resources for climate change adaptation. The results of the study will also assist the Government and other development partners in making decisions that are more informed as to areas where and the kind of assistance needed between the districts in the coastal zone of The Gambia. The study employed the Livelihood Vulnerability Index (LVI) in the estimation of household vulnerability to Climate Change (CC) and its variability based on their: Socio-Demographic Profile; Livelihood strategies; Social Networks; Health; Water; Natural disasters and Climate Variability and; Knowledge and Skills. This approach is divided into the Intergovernmental Panel on Climate Change (IPCC) three main components of vulnerability, namely: Exposure; Sensitivity and; Adaptive Capacity. The primary data used is based on a survey of 355 household heads in agriculture or fishing activities in the coastal zone of The Gambia, while the secondary data used was on rainfall and temperature. Microsoft Office Excel 2016 was the software employed in estimating the livelihood vulnerability index, developing the vulnerability spider (radar) chart and the vulnerability triangle in this study. The findings of the study reveal households in Kombo South may be more vulnerable to climate change and its variability than Lower Niumi districts in the study area. The LVI revealed Kombo South district may be more vulnerable to: Health; Food and; Knowledge and Skills while Lower Niumi district is more vulnerable to: Socio-Demographic Profile; Livelihood Strategies; Social Networks; Water and; Natural Disasters and Climate Variability. The overall LVI-IPCC main components of vulnerability reveals households in Kombo South may be more vulnerable than households in Lower Niumi district in the coastal zone of The Gambia.
Keywords: Vulnerability, Climate Change, Climate Variability, Livelihood Vulnerability Index, Coastal Zone, Households, Farmers, The Gambia

1. Introduction

The Intergovernmental Panel on Climate Change, IPCC Fifth Assessment Report Technical Summary characterizes climate change vulnerability as the propensity or inclination to be antagonistically influenced by climate impacts. It correspondingly represents how much a natural or social system is powerless in supporting the destruction realized from climate change (Niang *et al*., 2014). Climate change vulnerability comprises a system's adaptive capacity, potential impacts, which are reliant on the level of exposure and sensitivity. The adaptive capacity constituent of this study identifies the capacity of systems, establishments, people, and different ecosystems to conform to potential harm, to exploit openings, or to react to varied consequences. The exposure constituent in this study entails individuals, biological systems, ecological capacities, services, assets, infrastructure, financial, or social resources in places and settings that could be unfavourably influenced by climate change (Niang *et al*., 2014). The Sensitivity component of this study identifies with how much a framework or biological system is influenced, antagonistically or usefully, either by climate change or by its variability.

Climate change and its variability are negatively influencing climate-dependent activities such as agriculture and fishing in Africa at large of which The Gambia is no exception. The IPCC, Niang *et al*., (2014) predicts with high certainty that Climate Change (CC) will amplify existing stresses on water availability in Africa. With high certainty, IPCC AR5 predicts climate change and its variability will associate with non-climate drivers and stressors to compound the defenselessness of agricultural systems, chiefly in semi-arid areas. The vulnerability of Africa to climate change and its variability is principally because of its low adaptive capacity and high poverty rate (Boko *et al*., 2007). The degree of the impact of climate change in agriculture and fisheries relies upon the level of exposure and vulnerability of farmers and fisherfolk to these impacts (Etwire *et al*., 2013). The Gambia's populace is estimated to be over 1.88 million with around 60% of the general populace living in provincial areas (GBoS, 2013). Poverty is higher in provincial regions contrasted with urban areas due to over-dependence on rain-fed agriculture as livelihood means. The Gambia has an agrarian economy with the Agriculture sector alone contributing around 30% to the Gross Domestic Product (GDP) while the fisheries sector contributes over 12% of GDP in 2015 (MOA, 2015). As of 2013, the poverty rate in The Gambia was evaluated to be 61% with the majority of the poor subject to Agriculture and fisheries for their livelihoods (MOA, 2015). With the impacts of climate change and its variability in The Gambia, livelihoods of people will be negatively affected. There is the need to know which regions are more vulnerable than others are so livelihood improvement actions can be taken in areas they are needed the most in the wake of present and future climate change impacts, thus, the objective of this study. This will aid in eluding maladaptation and waste of limited development resources for climate change adaptation. The results of the study will also assist the Government and other development partners in making decisions that are more informed as to areas where and the kind of assistance needed between the districts in the coastal zone of The Gambia.

1.1. Approaches to Vulnerability Assessment

Hoddinott and Quisumbing (2003) assert that in undertaking vulnerability assessments five inquiries should be replied: what is vulnerability; who is vulnerable; what are the wellsprings of vulnerability; how do households react to climate shocks, and what gaps exist among risks and hazard management components? Regardless of these questions, vulnerability assessments embraced in diverse studies predominantly concentrate on the utilization of secondary data where Geographic Information Systems (GIS) or econometric models are used in the analysis of data (Hoddinott & Quisumbing, 2003; Naude *et al*., 2009). For instance, some econometric models utilized in assessing vulnerability to poverty include the Vulnerability as Expected Poverty (VEP); Vulnerability as Expected Utility (VEU); and Vulnerability as Uninsured Exposure to Risk (VER). These models produce more blunders when utilized for the community or individual levels, it is well suited for use at national levels (Bérgolo *et al*., 2012). Hoddinott & Quisumbing (2003) reports that with the utilization of the VEP at the local level, for instance, could lead to perverse policy outcomes that can increase risks for households.

Another vulnerability assessment method used is the Household Vulnerability Index (HVI). The HVI defines vulnerability as the "presence of factors that place households at risk of becoming food insecure or malnourished" (Moret, 2014). This is assessed on the levels of 'external vulnerability', which refers to exposure to external shocks or hazards and 'internal vulnerability', which refers to the capacity to cope with or withstand those shocks (Moret, 2014). The HVI vulnerability assessment method was used in South Africa to examine household vulnerability through the lens of the influence of HIV and AIDS pandemic on small-scale agriculture and household food security (FANRPAN, 2011). A limitation in using the HVI is, it focuses more on food security and agriculture and does not lay accentuation on the livelihood vulnerabilities at the household level (Moret, 2014). Additionally, this methodology does not highlight community participation, which may bring about restricted input and viewpoint of community members as to how their livelihoods are influenced from varied climatic stresses (Moret, 2014).

Another method utilized in vulnerability assessment is the Sustainable Livelihoods (SL) approach. The Brundtland Commission on Environment and Development, and the 1992 United Nations Conference on Environment first introduced the concept of SL as a broad goal for poverty eradication (Krantz, 2001). The concept of SL goes past the regular definitions and approaches to poverty eradication. It considers other vital aspects of poverty like vulnerability and social exclusions (Krantz, 2001). The SL approach overcomes these challenges by offering a more coherent and integrated approach to poverty eradication. For instance, it provides a more holistic view on what resources, or combination of resources, are important to the poor, including not only physical and natural resources, but also their social and human capital (Krantz, 2001). This draws attention to the multiplicity of resources people use in constructing their livelihoods. The SL approach additionally looks at the vulnerability context, which could be trends, shocks, and stresses in which these assets exist (Krantz, 2001). A noteworthy limitation of the SL approach is that it covers sensitivity and adaptive capacity in relation to stresses on assets, but does not consider exposures that make individuals vulnerable (Krantz, 2001; Hahn *et al*., 2009). This prompted the development of the Livelihood Vulnerability Index (LVI) by Hahn *et al*., (2009) to incorporate climate exposures, sensitivity and adaptive capacity comprehensively in evaluating risks resulting from climate change and its variability. This methodology is employed in this study.

1.2. The Livelihood Vulnerability Index

The LVI uses indicators to assess exposures, sensitivity and adaptive capacity to climate change and variability. Few methods have been developed for aggregating indicators in computing an index; key among them is the gap method and the weighting method. The gap method used in this study is based on the deviation of smallholder farmers and fisherfolk living conditions from predetermined standard living conditions without climate change and variability (Romieu *et al*., 2010). The weighting method used in this study is based on effectively valuing every indicator regarding its significance in adding to making smallholder farmers and fisherfolk vulnerable to climate change and its variability (Romieu *et al*., 2010; Hahn *et al*., 2009). A balanced, weighted approach is then utilized in computing the LVI in this study. This study uses primary data from household surveys and the only secondary data source it uses is that of rainfall and temperature in assessing the LVI. This helps to avoid expansive data gaps typically associated with using secondary data. It also affords the opportunity to get results more representative at the district to the household level. The LVI gives development organizations, policymakers, and public health practitioners an applied tool to comprehend demographic, social, and health factors contributing to climate vulnerability at the community level (Shah *et al*., 2013). Another essential part of the LVI is that it encourages the comprehension of the basic reasons for poverty by focusing on wide-ranging factors, at different levels, that directly or indirectly determine poor people's access to assets of different kinds, and their livelihoods (Hahn *et al*., 2009).

The LVI has been used in varied studies. For instance, Can *et al*., (2013) used this method to assess risks from flood incidence, with Mekong Delta of Vietnam as a case study. Thể and Tính (2013) used this method to examine households' vulnerability to climate change in Thua Thien Hue Province of Vietnam. Shah *et al*., (2013) applied the livelihood vulnerability index in vulnerability assessment in Trinidad and Tobago. Legese *et al*., (2016) used the livelihood vulnerability approach in Assessing climate change Impacts in the Lake Tana Sub-Basin, Ethiopia. Koya *et al*., (2017) used this method in assessing the vulnerability of coastal fisher households to climate change with Gujarat, India as a case study. Etwire *et al*., (2013) used the LVI in the assessment of vulnerability to climate change and variability in the three northern regions of Ghana.

2. Materials and Methods

2.1. Calculating the LVI: Composite Index Approach

The major components of the composite index used in this study are Socio-demographic profile, Livelihood strategies, Social Networks, Health, Water, Natural Disasters and Climate Variability, Knowledge and Skills (Table 2). These major components were sourced from Hahn *et al.,* (2009) study. The new major component, Knowledge and Skills in this study is sourced from Botero and Salinas (2013) study. The LVI further aggregates the eight major components of the composite index into the IPCC's three contributing factors to vulnerability. The other components that constitute the IPCC adaptive capacity contributing factor are; Socio-Demographic Profile, Livelihood Strategies, Social Networks, Knowledge, and Skills. The IPCC Sensitivity constituents comprise, Health, Food, and Water while the Exposure constituent cover Natural Disasters and Climate Variability. Each component was measured on a different scale; they were then standardized using Equation (1).

$$Index_{S_q} = \frac{S_q - S_{min}}{S_{max} - S_{min}} \quad (1)$$

Where: S_q is the original sub-component for District q, S_{min} and S_{max} are the minimum and maximum values respectively. After the sub-components are standardized, they are then averaged using Equation (2) to generate the index.

$$M_q = \frac{\sum_{i=1}^{n} Index_{sq_i}}{n} \quad (2)$$

Where: M_q is the major components for each district, q. The major components could be Socio-Demographic Profile (SDP), Livelihood Strategies (LS), Social Networks (SN), Health (H), Food (F), Knowledge and Skills (KS), Water (W) or Natural Disasters and Climate Variability (NDCV). $Index_{sqi}$ represents the sub-components generated from computing Equation (1), and n represent the number of sub-components that makes up each major component.

Once values for each of the seven components for a district is calculated, the respective average for each district can be calculated using Equation (3) to obtain the district-level LVI:

$$LVI_q = \frac{\sum_{i=1}^{8} W_{M_i} M_{q_i}}{\sum_{i=1}^{8} W_{M_i}} = \frac{W_{SDP}SDP_q + W_{ls}LS_q + W_{SN}SN_q + W_H H_q + W_F F_q + W_W W_q + W_{KS}KS_q + W_{NDC}NDCV_q}{W_{SDP} + W_{LS} + W_H + W_{SN} + W_F + W_W + W_{KS} + W_{NDC}} \quad (3)$$

The number of sub-components that make up each major component included ensuring that all sub-components contribute equally to the overall LVI determines the weights of each major component, W_{Mi}. In this study, the LVI is scaled from 0 (least vulnerable) to 0.6 (most vulnerable).

2.2. Calculating the LVI- IPCC: IPCC Framework Approach

Hahn *et al*., (2009) introduced a new variable in their study, LVI- IPCC based on the IPCC definition of vulnerability. The LVI-IPCC takes a different form from the LVI from Equations (1)-(3) when the major components are combined. Rather than combining the major components into the LVI after they have been standardized, averaged and weighted to form Equation (3), the major components are first combined into the three main IPCC defined components of vulnerability namely, exposure, adaptive capacity, and sensitivity using Equation (4). This form the respective IPCC defined contributing factors. Once the IPCC-defined contributing factors are calculated, they are pooled using Equation (5).

$$CF_q = \frac{\sum_{i=1}^{n} W_{M_i} M_{q_i}}{\sum_{i=1}^{n} W_{M_i}} \quad (4)$$

Where: CF_q is the IPCC-defined contributing factor for district q, M_{qi} is the major components for district q, W_{Mi} is the weight of each major component, and n is the number of major components in each CF.

$$\mathbf{LVI - IPCC_q} = (\mathbf{e_q - a_q}) * \mathbf{S_q} \quad (5)$$

Where: LVI- IPCCq is the corresponding LVI for district q expressed using the IPCC vulnerability framework, e_q is the calculated exposure score for district q, a_q is the calculated adaptive capacity for district q, s_r is the calculated sensitivity score for district q. The e_r values equal the natural disaster and climate variability major component, while the a_r values correspond to the weighted averages of the socio-demographic profile, livelihood strategies, knowledge and skills, and social networks major components. The s_q equals the weighted average of the health, food, and water major components. In this study, the LVI-IPCC values are scaled from -1 (least vulnerable) to 1 (most vulnerable). Microsoft Office Excel 2016 was the software employed in estimating the livelihood vulnerability index, developing the vulnerability spider (radar) chart and the vulnerability triangle in this study. Details of procedures for computation are further included as Appendices A and B of this study.

2.3. Study Area

The Coastal Zone (CZ) of The Gambia extends 80 km of open coast from Buniadu Point in the Lower Niumi District, northward, to the mouth of the Allahein River in the Kombo South district, southward (Figure 1). The Kombo South district which falls under the West Coast Region lies between latitude 13^0 15' North and longitude 16^0 45' West whiles Lower Niumi District, which falls within the North Bank Region lies between latitude 13^0 32' 60" North and longitude 16^0 25' 0" West. The coastal zone of The Gambia is highly characterized by low-gradient sandy beaches. Kombo South covers a land area of 299.71 km^2 with an average population of over 108,773 people while Lower Niumi District spans over 392.99 km^2 of land with over 57,358 inhabitants (GBoS, 2013). The major livelihood activities in the study area are small-scale farming and fishing.

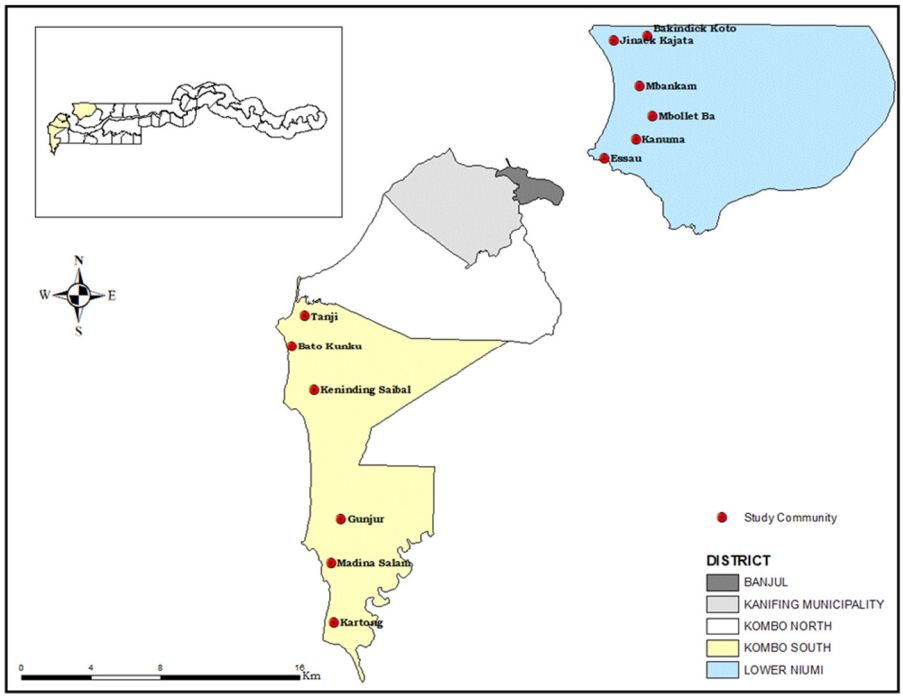

Figure 1. *Map of Study Area*

2.4. Data Source, Sampling, and Sample Size

The study used mainly primary data sources from smallholder farmers and fisherfolk with a well-structured questionnaire designed, pre-tested and administered to heads of households in the study area. The questionnaire used 34 principal variables in computing the LVI in this study. The secondary data on rainfall, minimum and maximum temperature were sourced from The Gambia's Department of Water Resources. The reference period for most questions asked during the survey is between 2009 and 2016, and that of the secondary data used is between 2010 and 2016.

A multistage cluster sampling technique was used in selecting respondents for the study. The first stage was the purposive sampling of two districts out of the five districts that make up the coastal zone of The Gambia. The Kombo South and Lower Niumi Districts were selected because of its top relatively large number of small-scale agriculture and fisheries livelihood activities compared to the other districts in the coastal zone (MOA, 2015). We argue that these farmers and fisherfolk will have more of their livelihoods impacted by climate change than the other 3 districts in the study area. The simple random sampling technique was then used to select six communities from each district for the data collection. In the last stage, simple random sampling was used to select households after a random walk through the principal streets of the community. An average of 29 household heads were interviewed in the Lower Niumi and 31 households heads interviewed in the Kombo South districts. Krejcie and Morgan (1970) sample size formula (Equation 6) is used in estimating the sample size for the study. 355 household head were interviewed for the entire study (Table 1). To obtain the number of respondents for each community, the total household number for each community is divided by the overall total household number in the study area (4,652) and then the value multiplied by 355 (Table 1).

$$\mathbf{S} = \frac{\mathbf{X^2 NP(1-P)}}{\boldsymbol{d^2(N-1) + X^2 P(1-P)}} \qquad (6)$$

Where: S is the required sample size, X^2 is the Z value (for instance, 1.96 corresponds to 95% confidence level). N is the population size, P is the population proportion (assumed to be 0.5 or 50%), d is accuracy (5%) expressed as a proportion (0.05) signifying the margin of error.

Table 1. Sample for the Study

District	Communities	Total Households	Sampled Households	Percentage (%)
Lower Niumi	Bakindick Koto	120	9	3
	Jinack Kajata	131	10	3
	Kanuma	185	14	4
	Mbankam	127	10	3
	Mbollet Ba	286	22	6
	Essau	1400	107	30
Kombo South	Bato Kunku	270	21	6
	Karthong	352	27	8
	Kenеding Saibal	61	5	1
	Madina Salaam	106	8	2
	Tanji	720	55	15
	Gunjur	894	68	19
Total	**12 Communities**	**4,652**	**355**	**100**

3. Results and Discussion

3.1. LVI: Kombo South versus Lower Niumi District

The results of the study showing the indexed Sub-components, with its corresponding major components and the overall LVI values for the study area, are given in Table 2. The estimated LVI for the study reveals that Kombo South may be more vulnerable to climate change and its variability than Lower Niumi district; the corresponding values are 0.404 and 0.391 respectively.

The major component Socio-Demographic Profile comprises six sub-components. This major component reveals a greater vulnerability for Lower Niumi (0.273) than Kombo South (0.229). The dependency ratio index for Lower Niumi (0.079) was higher than Kombo South (0.074). This implies that more households in Kombo South have a larger active working population than minors and people above the age of 65 compared to Lower Niumi district. Higher dependency ratios imply a less number of people who can actively farm and engage in other livelihood activities than areas with lower dependency ratio. There may be more financial stress on households in the Lower Niumi District than in Kombo South District. This can reduce one's resilience to climate change. The respondents reported a greater section of young female-headed households in Lower Niumi (0.2) than in Kombo South (0.15). Out of this proportion, the respondents, about 87% of household heads have access to formal education in Kombo South parallel to the 85% reported in Lower Niumi. People with some level of formal

education can better access information sources and better comprehend means to cope with and better adapt to tenacious climate change impacts than those deprived of formal education. People with formal education can also access support from wide-ranging sources and are able to embrace new technologies and techniques in coping with climatic stress. About 46% of households in Lower Niumi reported raising at least an orphan and 40% of households reported to have at least one person that requires daily care because of old age, disability or mental health challenges in Kombo South. Households caring for orphans and persons requiring daycare place extra stress on individual homes, it may reduce their resilience in coping and adapting to climate stresses. This case can vary as some orphans falling in the active working group could assist in increasing household income stream besides providing work force for farming and fishing operations.

The major component Livelihood Strategies comprises three sub-components. This component reveals a greater vulnerability for Lower Niumi (0.501) than Kombo South (0.495). The households in Kombo South reported a larger proportion, 90% of people who depend on Agriculture as the major source of income than Lower Niumi, 76%. This agrees with MOA (2015) report that the agriculture sector is responsible for over 70% of direct and indirect jobs. Of this number, over 75% of households depend on the crop sub-sector for household income in The Gambia (MOA, 2015). A similar response was observed in the average agricultural livelihood diversification of the respondents as Kombo South reported 0.003 while Lower Niumi reported 0.002. The diversification of crops and fisheries helps in reducing risks from total crop failures, this is an approach to building resilience to cope with and better adapt to varied climatic stress (Pingali & Rosegrant, 1995). Most households were involved in other livelihood activities like collecting and sale of natural resources like wood, raising animals, processing of fish, and keeping a grocery shop. Increase in livelihood strategies helps to increase people's level of income to build more resilience to the impacts of climate change and its variability. The respondent's in Lower Niumi, 74% reported a larger number of people travelling to other communities to work compared to the 57.6% reported in Kombo South. Most people travelling from the provinces migrate to the capital cities to seek greener pastures of which some return with societal ills that may serve as a disincentive to engage the active working population on farming and fishing activities. This notwithstanding, some people send remittances to relatives, which helps in building their resilience to climate change impacts (UNDP, 2012; WFP, 2016).

The major component Social Networks comprises three sub-components. This component reveals a greater vulnerability for Lower Niumi (0.501) than Kombo South (0.453) in social networking. Most households in the study area reported they were not going to their local government for any assistance in cash or in kind. This can be observed in the responses reported, as Lower Niumi recorded 95% of households relative to Kombo South (85%). Most households lacked the drive to seek assistance from their local government offices owing to the low level of awareness on laid down procedures from such outfits, among other reasons. The majority of the households reported to have received less assistance from friends and family members relative to the help they gave out to these people; Kombo South recorded 0.106 slightly lower than the 0.134 recorded for Lower Niumi. Some of the assistance offered were: manual labour during planting and harvesting, seed, pesticide and cash donations. Most households recorded a lower number of people who borrowed money from friends and family proportionate to those who lend money to family and friends. This result deviates from the World Food Program, WFP (2016) report revealing that most households in rural areas borrow more than they lend to others. This deviation may be because of the relatively large family size and the predominate extended family system which offers more manpower relative to the size of farms in the study area in contrast with other districts in The Gambia.

The major component, Health comprises four sub-components. Under this component, households in Lower Niumi spend an average longer time to access the nearest health facility compared to households in Kombo South. A long time in accessing health facilities increasingly exposes farmers and fisherfolk to health vulnerabilities. Easy access to health facilities enhances the physical well-being of farmers, enhancing productivity at work (Cockburn *et al*., 1999). More people in Kombo South, 84% reported cases of ill health from malaria over the past 6 months than Lower Niumi (69%). Similarly, a larger proportion of households recorded incidence of family members having to miss school or work over the past 6 months due to ill health in Kombo South (0.58) than in Lower Niumi (0.49). This contributed to households in Kombo South being more vulnerable to malaria than in Lower Niumi giving an average malaria exposure, prevention index of 0.132 and 0.024 respectively. When the sub-components are pooled, the overall Health vulnerability score for Kombo South (0.435) was higher than Lower Niumi (0.384) district. These findings are supported by claims by Conway (2004) study.

The major component, Food comprises five sub-components. Kombo South households reported 98% of people who depend solely on Agriculture and fishing for food matched with 59% in Lower Niumi. Granting the majority of the households depend on agriculture and fishing for food, the average number of months people have challenges attaining food from these sources are 3.7 months (0.304) in Kombo South and 3 months (0.247) in Lower Niumi. During the dry season, most smallholder farmers encounter challenges growing crops, as most farming activities are rainfall reliant. Households able to get consistent access to food all-year round are persons with access to irrigation water sources or have wide-ranging income sources (Jeločnik & Zubović, 2017). Others can adapt by planting drought-resistant crop varieties, preserve and store food to be expended in the lean season.

This seems to be the case in the study area as more households in Lower Niumi (57%) and Kombo South (25%) consume food harvested without saving some to be consumed another time. Congruently, household heads in Kombo South (75%) recounted saving more seeds to be planted in the next planting season than Lower Niumi (47%). Lower Niumi respondents reported a higher proportion of households that undertake crop diversification practices with relatively more diverse crops and or fishes caught than in Kombo South. When the sub-components are merged, the overall Food vulnerability score for Kombo South (0.537) was higher than Lower Niumi (0.347). This result agrees with the findings from the World Food Program, WFP (2016) report and the National Drought operations plan of The Gambia (GoG, 2015).

The major component, Water comprises five sub-components. The majority of Gambian households (91%) uses an improved source of drinking water, mostly from a pipe tap (WFP, 2016). This component reveals a greater vulnerability for Lower Niumi (0.31) than Kombo South (0.262). The respondents in Kombo South (0.31) have a grander proportion of people without access to the water supply on a daily basis matched with households in Lower Niumi (0.30). Households in Kombo South (48%) reported more concerns about water conflicts than in Lower Niumi (43%). Women and girls are customarily charged with the supply of water for household consumption; when the water supply is not reliable, more time is spent travelling over long distances (Alston & Kent, 2006). This phenomenon affects the time spent on livelihood activities by women besides children's attendance and performance in schools. Because of these water challenges, 43% of respondents in Lower Niumi access water through a natural water source using local rainwater-harvesting techniques compared to Kombo South (30%). These households may be water insecure besides their increased vulnerability to contracting waterborne diseases. Households in Lower Niumi walk an average distance of 41.1 minutes to access water from wells and community pumps compared to 26.38 minutes in Kombo South. Jaiteh and Sarr (2010) study support these findings.

The major component, Natural Disasters and Climate Variability comprise six sub-components. The majority of respondents reported not to have received any warnings about potential floods and drought incidence; Lower Niumi respondents reported 87% while 78% was recorded in Kombo South. Information on future natural disasters and extreme climatic events is essential as it allows people to build more resilience and minimize the exposure to such impacts when they occur. It is also essential these messages be translated into local languages so people with no formal education can also build their adaptive capacity in anticipation of extreme events (Sheppard, 2012). The average proportion of households that reported at least one incidence of floods or drought over the past 7 years was higher in Kombo South (0.107) than in Lower Niumi (0.095). This may be attributed to Kombo South characteristic climate, which receives more rainfall than Lower Niumi that lies in the northern belt with less vegetation and forests. Additionally, Kombo South is at a geographical elevation lower than the Lower Niumi district predisposing it to fewer flash floods. Out of the households that recorded incidence of floods, more cases of injury and or death were recorded in Kombo South (47%) than in Lower Niumi (41%). The values for the other sub-components like mean, standard deviation for minimum and maximum temperatures and average precipitation must be used with caution as some missing data values were recorded in the dataset. Nevertheless, when the sub-components were combined the overall Natural Disasters and Climate Variability score for Kombo South (0.441) was higher than Lower Niumi (0.441).

The major component, Knowledge and Skills comprise five sub-components. More respondents in Kombo South (60%) reported having a television set at home compared to households in Lower Niumi (53%). The reverse is the case with households owning a radio set at home with Lower Niumi having numbers higher than Kombo South households. The number of respondents that do not belong to any fishing or farmer-based organization and do not share experiences and knowledge with others on improving farming and fishing practices in Kombo South was 93% and 69% respectively while Lower Niumi reported lower values of 80% and 54% respectively. The establishment and strengthening of fisherfolk or farmer-based organizations make it easier for small-scale farmers and fisherfolk to access soft-loans from financial institutions to expand production on top of increasing their adaptive capacity to climate impacts (Sheppard, 2012). It also makes it easier for concerns and challenges faced in this sector at the community level to be channelled to the right authorities for a more timely intervention to be made by local government, Non-Governmental Organizations (NGOs) and other development partners (Asante *et al*., 2011). The respondents of Lower Niumi are more aware of the term 'climate change' as compared to respondents in Kombo South. Households with more radio and television sets can access weather forecast information and other expert advice on current and future trends in the domain of agriculture and fishing than those who do not have. These platforms additionally afford smallholder farmers and fisherfolk the opportunity to listen to educational programs in their local dialect on other livelihood activities they can adopt to increase their resilience towards climate change and its variability. When the sub-components are combined the overall Knowledge and Skills vulnerability score for Kombo South (0.469) was higher than Lower Niumi (0.409).

The results of all the eight major components are summarized in Figure 2. The vulnerability spider diagram of the study ranges between 0 (least vulnerable) and 0.6 (most vulnerable). Kombo South is more vulnerable to Health, Food, Knowledge and Skills. Lower Niumi is more vulnerable to Socio-Demographic Profile, Livelihood Strategies, Social Networks, Water and Natural Disasters and Climate Variability.

Table 2: Indexed Sub-components, Major Components and Overall LVI for the Study area

SUB-COMPONENT	Kombo South	Lower Niumi	MAJOR COMPONENT	Kombo South	Lower Niumi
Dependency Ratio	0.074	0.079	**Socio-Demographic Profile**	0.229	0.273
Percentage (%) of Female-Headed Households	0.150	0.200			
Average Age of Female Household Head	0.411	0.350			
% of Households Heads with no formal Education	0.130	0.150			
% of Households with Orphans	0.277	0.460			
% of Households with Persons that require daily care from old-age, disability or Mental Condition	0.330	0.400			
% of Households with Family Members working in a different Community	0.576	0.740	**Livelihood Strategies**	0.495	0.501
% of Households that Depend Solely on Agriculture as Major source of Income	0.907	0.760			
Average Agricultural Livelihood Diversification Index	0.003	0.002			
Average Receive: Give Ratio	0.106	0.134	**Social Networks**	0.453	0.501
Average Borrow: Lend Money Ratio	0.402	0.419			
% of Households that have not gone to local Government for assistance	0.850	0.950			
Average time to health facility	0.187	0.331	**Health**	0.435	0.384
% of Households that have been ill from Malaria	0.840	0.690			
% of Households with Family Members miss school or work due to illness	0.580	0.490			
Average Malaria Exposure, Prevention Index	0.132	0.024			
% of Households Depending Solely on Agriculture or Fishing for food	0.980	0.590	**Food**	0.537	0.347
Average number of Months Households have challenges getting food	0.304	0.247			
Average Crop Diversification Index	0.082	0.178			
% of Households that do not Save Crops	0.570	0.250			
% of Households that do not Save Seeds	0.750	0.470			
% of Households that have water conflicts	0.480	0.430	**Water**	0.262	0.31
% of Households that use a natural water source	0.300	0.400			
Average Distance to Water Source	0.218	0.416			
% of Households that do not have consistent Access to Water Supply	0.310	0.300			
Inverse of the Average Number of Litres of water stored per household	0.003	0.003			
Average Number of Flood and Drought over the past 7 years	0.107	0.095	**Natural Disasters and Climate Variability**	0.441	0.491
% of Households that did not receive any warning about upcoming Natural Disaster	0.780	0.830			
% of Households with an injury or death as a result of natural disasters	0.470	0.410			
Mean Standard Deviation (SD) of monthly average of average Maximum daily temperature (2010- 2016)	0.190	0.762			
Mean SD of monthly average of average Minimum daily temperature (from 2010- 2016)	0.412	0.353			
Mean SD of monthly average precipitation (from 2010- 2016)	0.684	0.497			
% of Households not having TV at home	0.600	0.530	**Knowledge and Skills**	0.469	0.409
% of Households not having radio at home	0.040	0.060			
% of Households do not participate in knowledge exchange with others	0.690	0.540			
% of Households that do not belong to any Fishing or Farmer based Organization	0.930	0.800			
Average climate change Awareness Index	0.085	0.116			
Overall LVI				**0.404**	**0.391**

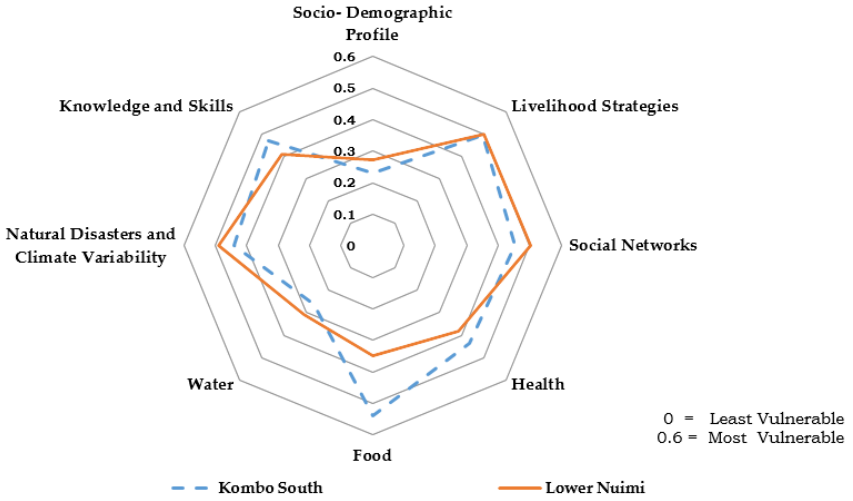

Figure 2. Vulnerability Spider Diagram of the Major Components of the LVI for Kombo South and Lower Niumi District, The Gambia

3.2. LVI- IPCC: Kombo South versus Lower Niumi

The LVI-IPCC main component is estimated by grouping the eight major components into three IPCC components that make up vulnerability namely, Exposure, Sensitivity and Adaptive Capacity; these are termed Contributing Factors (CF). The Adaptive Capacity's CF comprises scores from Socio-demographic Profile, Livelihood Strategies, Social Networks, Knowledge, and Skills. The Sensitivity's CF comprises scores from Health, Food, and Water whereas the Exposure's CF is only made up of Natural Disasters and Climate Variability. The study reports a higher Adaptive Capacity and Exposure to climate change and variability in Lower Niumi district (0.393 and 0.451 respectively), compared to Kombo South district (which has 0.386 and 0.441 respective values). This notwithstanding, Kombo South reports a higher Sensitivity value to climate change and its variability compared to Lower Niumi. The overall LVI-IPCC scores indicate that households in Kombo South may be more vulnerable than those in Lower Niumi district; this corresponds to 0.023 and 0.02 respectively. The results of the LVI-IPCC are summarized in the vulnerability triangle in Figure 3.

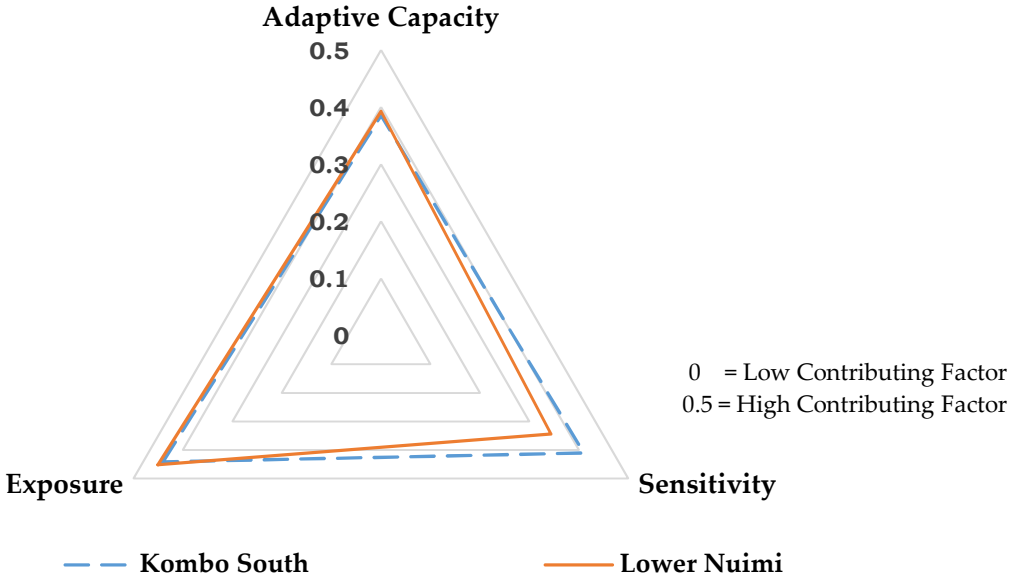

Figure 3. Vulnerability Triangle diagram of the contributing factors of the LVI-IPCC index for Kombo South and Lower Niumi, The Gambia.

4. Conclusions and Recommendations

The findings of the study reveal households in Kombo South may be more vulnerable to climate change and its variability than Lower Niumi district in the study area. Households in Kombo South may be more vulnerable than Lower Niumi in their agriculture or fishing livelihoods activities. Households in Kombo South district are reported

more vulnerable regarding Sensitivity to climate change and variability than the Lower Niumi District. However, households in the Lower Niumi district may be more vulnerable only in terms of Adaptive Capacity and Exposure to climate change and variability.

The study suggests that the Government and key stakeholders should give more priority to Kombo South in terms of interventions aimed at addressing food security and livelihood enhancement issues. More climate-smart agricultural technologies and techniques should be introduced into this district to help increase their resilience to climate change. It is imperative that relevant stakeholders, NGOs and the private sector introduce more food processing and preservation technologies in the study area. This will help to preserve food crops over longer periods so farmers can take advantage of future price upturns.

It is imperative that more community health facilities like clinics and Compound Health Improvement Services (CHIS) be provided in the Kombo South District to reduce the time to access quality healthcare in the district. This will help reduce the health vulnerabilities of smallholder farmers and fisherfolk in the study area.

The Government and other development partners should give more priority to the Lower Niumi district by expanding access to more potable water sources like tape pipes and the sinking of boreholes in this district. This will help reduce the time taken to access water and address water insecurity issues in this district.

It is imperative that other viable livelihood options be introduced and promoted in the Lower Niumi district. Some opportunities could be beekeeping, poultry rearing, basket weaving, pottery- making, among others. This will help moderate out-migration of persons besides increasing their livelihood strategies, build on social networks among farmers and fisherfolk, to better adapt to and cope with impacts realized from climate change and variability.

We suggest the establishment of new and strengthening of existing early-warning system for the prediction and detection of extreme climatic events and natural disasters more precisely in the Lower Niumi district. This will aid in reducing household's vulnerability to Natural Disasters and Climate Variability in the district. Since more people had access to radio sets than television sets, it is imperative that more climate change information should be broadcast using radio programs. To enhance comprehension and increase content usage among targeted end-users without formal education, climate information should be translated into various local dialects.

The study suggests that farmers and fisherfolk work in partnership to establish a working fisher or farmer-based organization (FBO) in the study area. This will allow farmers to meet and share experiences, get more support from Government and other private stakeholders in training, access more farm implements, improved seeds and technologies to reduce their vulnerability to climate change. Although most respondents know of the term 'climate change', the scores obtained were below average. Thus, we suggest key stakeholders embark on more climate change awareness outreaches and workshops in the Kombo South District than in the Lower Niumi district.

APPENDIX A

Calculating the Social Network Major Component for LVI for Kombo South (KS)

Sub-component	Unit	Values	Maximum Value	Minimum Value (Combined)	Indexed Value (Combined)	Major Component
Average Receive: Give Ratio	Ratio	1.01	7	0.3	0.106	0.453
Average Borrow: Lend Money Ratio	Ratio	1.04	2	0.4	0.402	
Percentage (%) of Households that have not gone to their local Government for assistance	%	85	100	0	0.850	

Step 1 (repeat for all sub-component indicator): $Index_{SN} = \frac{S_q - S_{min}}{S_{max} - S_{min}} = \frac{1.01-0.3}{7-0.3} = 0.106$ (A1)

Step 2 (repeat for all major components): $SN_{ks} = \frac{\sum_{i=1}^{n} Index_{sqi}}{n} = \frac{0.106+0.402+0.850}{3} = 0.453$ (A2)

Step 3 (repeat for all districts):

$$\boldsymbol{LVI_{ks}} = \frac{\sum_{i=1}^{8} W_{M_i} M_{q_i}}{\sum_{i=1}^{8} W_{Mi}} = \frac{6*0.229+3*0.495+3*0.453+4*0.435+5*0.537+5*0.262+6*0.441+5*0.469}{6+3+3+4+5+5+6+5} = 0.404 \quad \text{(A4)}$$

APPENDIX B

Computation of LVI-IPCC for Kombo South (KS)

Contributing Factors	Major Components	Major Component Value	Number of Sub-components per major component	Contributing Factor values	LVI-IPCC value of KS
Sensitivity	Health	0.435	4	0.41	0.023
	Food	0.537	5		
	Water	0.262	5		

$$\boldsymbol{Sensitivity_{ks}} = \frac{\sum_{i=1}^{n} W_{M_i} M_{q_i}}{\sum_{i=1}^{n} W_{M_i}} = \frac{4 * 0.435 + 5 * 0.537 + 5 * 0.262}{4 + 5 + 5} = 0.41 \quad \text{(B1)}$$

Step 3 (Repeat for all districts):

$$\mathbf{LVI - IPCC_{KS}} = (e_{KS} - a_{KS}) * S_{KS} = (0.386 - 0.441)(0.41) = 0.023 \quad \text{(B2)}$$

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