

Vulnerability of Smallholder Farmers to Climate Related Shocks in Kinakomba Ward, Tana River County, Kenya

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Abstract

According to IPCC, (2007) Vulnerability is the degree to which a system is susceptible to, and unable to cope with, adverse effects of climate change, including climate variability and extremes. It is a function of exposure, sensitivity, and adaptive capacity (Marshall et al. 2010; Wongbusarakum and Loper 2011, Mucke 2012). The study sought to determine the vulnerability to climate related shocks among smallholder farmers in Kinakomba Ward. The main purpose of the study was to assess the extent to which, exposure, sensitivity and adaptive capacity contributed to the vulnerability of the smallholder farmers on their livelihoods. The study was carried out in Kinakomba ward in Tana River County, Kenya. A descriptive survey research design was used. Stratified random sampling was employed to select 390 out of a population of 3,908 households. Data was collected using questionnaires and Focus Group Discussions. Descriptive statistics, metric of sensitivity, composite index was used to analyse sensitivity. Two methods were used to analyse exposure. Firstly the fuzzy logic in assessing susceptibility to drought involving a selection of input variables, Fuzzification, inference modelling and defuzzification and secondly DrinC Model software. The researcher used two methods to analyse adaptive capacity namely the interview with 390 farming households to gather data on farming and household characteristics and natural resources availability and secondly a panel of 15 Key Informants provided ratings of indicators of adaptive capacity using analytic hierarchy process (AHP). To understand the interaction of these variables this study analysed a quantitative Vulnerability score by using an equation which combined three contributing indices of exposure, sensitivity and adaptive capacity each normalized to 0–1 Scale (Adger and Vincent, 2005; Allison et al. 2009), the vulnerability score was obtained by adding exposure to sensitivity and subtracting the adaptive capacity. The key results from the study showed that exposure ($p=0.000066$) and sensitivity ($P=0.00038$) had a significant effect on livelihoods. These factors were also found to have a negative influence on livelihoods in the area. Further statistical findings showed that as adaptive capacity increased vulnerability decreased while when sensitivity increased vulnerability increased at the same time. The study concluded that these two dimensions of vulnerability could be modified by policy and development. The study also concluded that exposure contributed more than sensitivity and adaptive capacity to the cumulative vulnerability. The study recommended that the County and National governments and stakeholders to employ measures to adapt to climate change and variability. This study also recommended that the Government in partnership with other stakeholders develop a comprehensive disaster risk management framework to address the drought hazards and undertake mitigation and adaptation measures by equipping the smallholder farmers with knowledge on how to cope with the cyclic and vicious droughts' impacts that have led to serious irreversible harm to humans and livestock in the area. Also that the Government in partnership with stakeholders develops interventions of adaptation options and empowerment of farmers with skills in diversification of livelihoods options.

Keywords: Vulnerability, Sensitivity, Exposure, Adaptive Capacity, Fuzzification, DrinC Model software, Analytic hierarchy process (AHP)

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1. Introduction

Climate change is defined by the United Nations Framework Convention on Climate Change (UNFCCC) as 'a change of climate which is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and which is in addition to natural climate variability observed over comparable time periods.' The origin of the climate change debate was the international environmental and developmental challenge that led to different initiatives from the publication of the Brundtland Report in 1987 through to the formation of the Intergovernmental Panel on Climate Change (IPCC) in 1989, the 1992 United Nation Conference on Environment and Development (UNCED) in Rio de Janeiro, and the establishment of the United Nations Framework Convention on Climate Change (UNFCCC), (NCCRS 2010).

The evidence of climate change in the world today is unmistakable. Europe is warming faster than many other parts of the world. The European land temperature over the past decade has been on average 1.3°C higher than in the pre-industrial era, compared with a global average rise of 0.8°C. (<http://climate-adapt.eea.europa.eu/>). In Kenya since early 1960s, both minimum (night time) and maximum (day time) temperatures have been on an increasing (warming) trend (NCCRS 2010). The minimum temperature has risen generally by 0.7-2.0°C and maximum by 0.2-1.3°C, depending on the season and the region (NCCRS 2010).

Africa is likely to be the continent most vulnerable to climate change (Schneider et al. 2007). In East Africa severe drought interrupted seasonal rains for two consecutive seasons, precipitating in 2011 the worst drought in the region seen in 60 years with precipitation of less than 30% (April to June) of average of 1995 -2010 (Eastern Africa 2011). In Sahel region 15% of the population experienced a temperature increase of more than 1 °C from 1970 to 2010. The mean seasonal rainfall is also below the long-term average, and flooding has increased in frequency and severity. Since 1985, 54 per cent of the population has been affected by five or more floods in the 17 Sahel region countries (Livelihood Security Climate Change in the Sahel 2011). With the increasing frequency, duration, and severity of drought conditions across much of the African continent, smallholder farmers are looking for new ways to ensure that their harvests are secured against unpredictable rains (RoK 2013).

Vulnerability to climate related shocks

According to IPCC (2007) Vulnerability is the degree to which a system is susceptible to, and unable to cope with, adverse effects of climate change, including climate variability and extremes. Vulnerability is a function of the character, magnitude, and rate of climate change and variation to which a system is exposed, its sensitivity to climate change, and its adaptive capacity (IPCC 2001). Greg et al. (2004) say this of vulnerability “The concept of vulnerability expresses the multi-dimensionality of disasters by focusing attention on the totality of relationships in a given social situation which constitute a condition that, in combination with environmental forces, produces a disaster”

Vulnerability can also be viewed socially. According to Wolters and Kuenzer (2015) Social vulnerability is the inability of people, organizations, and societies to withstand adverse impacts from multiple stressors to which they are exposed. These impacts are due in part to characteristics inherent in social interactions, institutions, and systems of cultural values. Thus there is need to place an increased emphasis on assets and entitlements for understanding ‘catastrophe’ as opposed to solely the strength or severity of shocks

According to Vogel (1998), vulnerability is perhaps best defined in terms of resilience and susceptibility including such dimensions as physical, social, cultural and psychological vulnerability and capacities that are usually viewed against the backdrop of gender, time, space and scale (Anderson and Woodrow, 1989). Turner et al. (2003) state that vulnerability expresses the susceptibility of a system to experience harm or injury due to some level of hazard exposures.

In a climate change context Füssel (2009) submitted that the most prominent interpretations of vulnerability are contextual and outcome vulnerabilities. And O’Brien et al. (2007) state that contextual vulnerability is directly related to the propensity of a system to be subjected to harm from a wide range of hazards, while outcome vulnerability refers to the potential climate impacts and inherent capacity of a social system to effectively cope and adapt.

Vulnerability to climatic hazards is a function of the interactions between sensitivities, capacities and resilience and all these are determined by human-environmental conditions. In 2001 IPCC stated that resilience is the amount of change a system can undergo without changing state. These conditions and processes consist of demographic, social, economic, political, biophysical and ecological.

Ziervogel et al. (2008) analyzing the determinants of food insecurity in dry and drought prone areas found that income, income diversification, area of land cultivated, soil quality, household labour per hectare cultivated, and health status of household members were key factors influencing vulnerability. The study also found that external factors like existence of formal and informal social networks, availability and quality of health services, and controlling access of prices of farm inputs and outputs as important in mitigating the impacts of climate shocks

According to Adejuwon (2008) vulnerability is explained by the proportion of household members engaged in agriculture, poverty rate, and dependency ratio, access to potable water, health status and educational attainment among others. In addition to this, Nyong et al. (2008) found vulnerability to be explained by ownership of land and livestock, area and quality of land cultivated, sufficiency of annual harvest relative to household food needs, cash income, livelihoods diversification, gender of household head and connections to family and social networks. Pulhin et al. (2008) households’ vulnerability to flooding correlated with ownership of land, farm size, farm income, gender and that rich farmers are less vulnerable to flooding due to ownership of large land areas.

1.1 Statement of the Problem

In Tana River County, smallholder farmers rely either solely on farming or on farming and non-farming activities. The farmers rely on rain to carry out their farming activities. The reliance on rainfed agriculture has in many occasions led to low production consequently leading to food insecurity and worsening of factors supporting food production, including delayed rainfall, flash floods, infertile soils and lack of inputs, various progressive measures have been advanced by the Government and Non-government organizations for farmers to either adopt or adapt so as to address the negative climatic changes that have made the state of food security deplorable (Ndegwa et al. 2015). Despite these progressive measures studies on the rural households who live in Tana River County and are vulnerable to climate related shocks and adaptation options available have not been exhausted and are still

unexplored. It was imperative therefore to undertake a study on the vulnerability of Smallholder Farmers to Climate Related Shocks in Kinakomba Ward, Tana River County Kenya to inform the state and non-state actors on appropriate interventions of adaptation options available to the smallholder farmers.

1.2 Theoretical Framework

The social-ecological system theoretical framework

This study used the Social Ecological Systems (SESs) theoretical framework initially proposed by Ostrom, (2007) and has since been improved. The system was built to provide common vocabulary and logical linguistic structure to facilitate understanding of the sustainability of SESs. According to Ostrom (2005) a Framework provides the basic vocabulary of concepts and terms used to construct explanations of a theory. On the other hand a model constitutes a manifestation of a theoretical explanation of the functional relationships among independent and dependent variables important in a particular setting (McGinnis & Ostrom 2014). The SES framework is designed to identify basic working parts and their relationships to one another.

Originally SES framework was designed for application to situations in which resource users extract resource units from a resource system. The resource users provide for the maintenance of the resource system according to rules and procedures determined by a governance system and in context of related ecological systems and broader social, political, economic settings Ostrom (2007, 2009) initial work. Located at the centre of that framework as most important forms of interactions and outcomes were the processes of extraction and maintenance. In this ontological framework resource users, resource units, resource system, governance system, related ecological system and broader social-political-economic settings form first tier categories of SES framework (McGinnis & Ostrom 2014).

The initial versions of the SES framework (Ostrom 2007, 2009) implicitly incorporated the action situation within interactions and outcomes. In 2010, Ostrom changed the label of the Interaction and Outcomes to also explicitly include the broader term Action Situations. This single step cemented a close connection between decades of work on the Institutional Analysis and Development (IAD) framework and the newly established SES framework (McGinnis & Ostrom, 2014). This effectively enabled the other components of the SES framework constitute a fuller elaboration of the relevant contextual factors that contribute to a definition of the situation confronting actors located within an SES. In both the IAD and SES frameworks, feedback paths link outcomes of action situations back to the contextual variables conveying an explicitly dynamic structure to both frameworks and consequently showing how a complex system changes over time. According to McGinnis and Ostrom (2014) the SES framework is an ontology, in the sense that it defines a language of terms and specifies a series of logical relationships among these terms.

In the SES literature slight variations occur in the second-tier governance system variables as Ostrom and Cox (2010) highlight rules, property systems and network structures as the key characteristics of governance systems. On the third-tier McGinnis and Ostrom (2014) have expanded the governance system to include private corporations, community-based organizations and hybrid organizational forms that combine aspects of public, private and voluntary organizations.

Thus the SES framework offers knowledge relevant to diagnosis of properties of specific SESs to different situations. To apply the SES framework to a particular case three questions are important: what types of interactions and outcomes related to a particular resource system, resource units are most relevant to the diagnostic concerns? What types of actors are involved? Which governance systems influence the behavior of these actors? (McGinnis & Ostrom 2014).

The research design is key because the researcher selects the cases and what kind of observations of these cases can best provide the interactions needed to be able to draw valid inferences from the research project. Secondly in any application of the SES framework, the researcher selects which variables should be measured and how indicators will be implemented. Thirdly the SES framework facilitates the communication of results across research communities (McGinnis & Ostrom 2014).

1.3 Conceptual Framework

The theoretical framework is conceptualized for indicators focusing on the vulnerability of the Kinakomba Ward SESs. Kloos et al. (2015) developed a multi-hazard risk assessment framework looking at potential impacts of single and multiple hazards affecting SES. Garschagen (2014) integrated framework for vulnerability and adaptation analysis. Mansur et al. (2016) did a conceptual model of vulnerability specifically for the urban areas applying it in context of flood risk. Existing methods for indicator-based vulnerability assessment range from global (UN 2009, 2011, 2013) and (Birkmann et al. 2014) to participatory assessments at the local level (Bollin and Hidajat 2006; Asare-Kyei et al. 2015). In Kinakomba Ward the drought hazard was assessed. In this work the Resource System (RS) is the smallholder farming sector and the Resource Units are the resources harvested by the smallholder farmers. The Governance System (GS) includes characteristics pertaining to the national and county governments and factors shaping rules and governance arrangement in Kenya. These determine incentives and

behaviour for Actors (A) involved in the agricultural sector. These are the smallholder farmers, non-governmental organizations, government officials and researchers. The social, economic, and political setting(S) is the Kinakomba Ward context, in Tana River County. The nature and magnitude of drought as well as the vulnerability of the SES determines the impacts experienced by the SES (community) and its sub-systems and also the risk to experience harm (Sebesvari et al. 2016). Hazards might originate within a given SES or could be generated outside an SES. According to Sebesvari et al. (2016) these interactions from outside and SES internal processes might lead to transformations and tipping processes which greatly influence the vulnerability context.

This conceptual SES framework aims to synthesize the following key elements; i. Focusing on the socioeconomic characteristics of the smallholder farmers in Kinakomba Ward for the social system ii. Focusing on the SES and acknowledging the influence of climate related shock patterns on the livelihoods of the smallholder farmers in Kinakomba Ward for the ecosystem iii. Focusing on determining the vulnerability to climate related shocks among the smallholder farmers in Kinakomba Ward iv. Focusing on the adaptive capacity index of the smallholder farmers in Kinakomba Ward. The theoretical framework is conceptualized as shown in figure 1.0 below

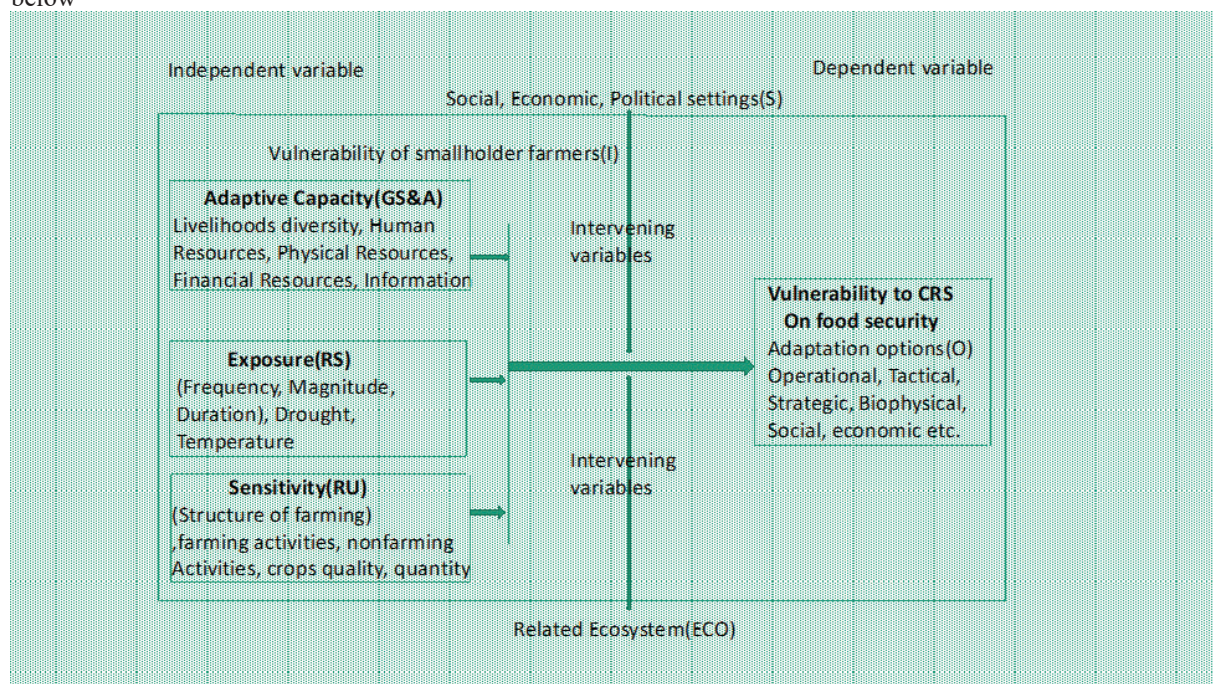


Figure 3 The conceptual framework

The scope of the conceptual framework

The scope of the conceptual framework is based on vulnerability as the function of sensitivities, exposure and adaptive capacities. This framework is a conceptual model to analyse the sustainability of Socio-Ecological Systems. It was used for the study and comparison of these systems by providing a common vocabulary that enabled identify and organize the variables relevant in SES analysis into a multitier hierarchy (Ostrom 2007, 2009) and (McGinnis and Ostrom 2014). The three solid boxes in the one big box to the left denote first-tier categories RS, RU, GS, and A are the highest-tier variables that contain multiple variables, at the second tier and lower tiers and within the boxes there is action situations to each of the top-tier categories. The main box containing the interior elements of the figure indicates that the focal SES can be considered as a logical whole, but that exogenous influences from related ecological systems (ECO) and social-economic-political settings (S) can affect any component of the SES. These exogenous influences might emerge from the dynamic operation of processes at larger or smaller scales than that of the focal SES. The use of this framework is in three steps as suggested by McGinnis and Ostrom (2014). First step is selection of a focal situation of analysis in Kinakomba Ward where the researcher identified components of the vulnerability system and how there are interacting. Secondly the researcher identified the potential variables and their indicators namely that vulnerability is a function of exposure, sensitivities and adaptive capacity. The third step was the analysis of the interactions of these variables and communication and dissemination of the results that were obtained. Thus this framework facilitated exchange of knowledge acquired at the end of that process.

Independent variable

The independent variables here represent the causes to climate related shocks. It is these variables that were tested

to see if there were the real causes of the climate related shocks. In this case these were exposure, sensitivity and adaptive capacity. Vulnerability to climatic hazards is a function of the interactions between exposure, sensitivity and adaptive capacity which are all determined by the human-environmental conditions and processes. It is recognized that the climate related shocks include increased frequency of severe drought, flood impacts, heat waves, and accelerated glacier retreat, hurricane intensity, and sea level rise (Adger et al. 2007).

Dependent variables

The dependent variables were the effect of the climate related shocks. It is these effects that were tested to see if there were the output of the climate related shocks. In this case the climate related shocks produced these effects. If the smallholder farmers had a good capacity then their vulnerability was low and the opposite was also the case.

Intervening Variables

There were also the extraneous variable or the moderating factors. These were not the focus of the experiment or survey so there were not tested. Intervening variables were kept constant or monitored to try to minimize their effects on the experiment. If these had been included in a regression as independent variables they would have aided the researcher with accurate response parameter estimation and goodness of fit but they were not under examination. In that case these were related ecological systems and social, economic and political, settings.

The interaction of variables

The independent variables were measured under the following parameters: For exposure the parameters were selection of input variables, Fuzzification, inference modelling and defuzzification. For sensitivity the parameters were a metric of sensitivity developed using surveys of 390 households, the ratio of farming to non-farming related activities was established and the extent to which households dependent on farming also engaged in non-farming livelihood activities established linkage between different sectors. Then directionality of linkages between farming and non-farming activities was also established. For adaptive capacity the parameters was a panel of 15 Key Informants provided ratings of indicators of adaptive capacity using analytic hierarchy process (AHP), then an interview was conducted to the 390 farming households to gather data on farming and household characteristics for the adaptive capacity indicators. Based on that approach adaptive capacity was determined by ownership and access to resources, information and technology and ability to diversify livelihoods to cope with climate related stresses. For dependent variable which was adaptation to climate change the parameters were stakeholders, information, environmental changes.

1.4 Objectives for the Study

The objective of the study was to determine the vulnerability of the smallholder farmers to climate related shocks in Kinakomba Ward. The study was also guided by the following null hypothesis: H_0 The vulnerability of the smallholder farmers is not significantly related to their exposure, sensitivity and adaptive capacity to climate related shocks in Kinakomba Ward.

2. Research Methodology

2.1 Research Design

The study adopted a descriptive research design which allowed collecting data in order to answer questions on current status of the subjects of the study. It was used to collect information about people's attitudes, opinions or habits Kombo and Tromp (2006). Kothari (2004) recommended descriptive design as it allows the researcher to describe, record, analyze and report conditions that exist or existed. Multi-stage random sampling procedure was used to sample 390 households from accessible population of 3,920 households who are subjected to climate change shocks in Kinakomba Ward. A sample size of 10% - 30% of the accessible population is adequate to serve as a study sample (Mugenda and Mugenda 2005). First multi-stage random sampling was used to select Kinakomba Ward out of the fifteen administrative Wards in Tana River County. The selected Kinakomba Ward has five administrative Locations which are Gwano, Jamhuri, Kinakomba, Ndura and Mazuni. In the second stage the researcher selected eleven Sub-Location areas (ESLs) from each of the Locations. The ESLs that was Hara, Maroni and Wenje from Gwano Location, Bububu from Jamhuri Location, Majengo and Masalani from Kinakomba Location, Gafuru, Mazuni and Mkomani from Mazuni Location and Bondeni and Handampia from Ndura Location. Sample frame was obtained by listing the villages under each of the ESLs from where samples were taken. The strata was based on the smallholder farmers in the listed village. Stratified random sampling was used to sample households to participate in the study. The 10% of the households sampled was proportionately distributed in the strata and calculated as shown in Table 1.0.

Table 1.0 Sample Frame

Location	Number of households	10% of accessible
Gwano	952	95
Hara	322	32
Maroni	229	23
Wenje	405	41
Jamhuri	654	65
Bububu	654	65
Kinakomba	912	91
Majengo	614	61
Masalani	297	30
Mazuni	542	54
Gafuru	256	26
Mazuni	128	13
Mkomani	159	16
Ndura	842	84
Bondeni	492	49
Handampia	352	35
Total	3,902	389

Households were selected by firstly using 10 landmarks i.e. Mosque, Church, Shop, school, Village water point, Posho mill, Village meeting baraza park, junction, electricity pole and Chief's camp and then from each point visiting households until 6 to 10 completed interviews were achieved. At the household level, the interview was with the head or spouse ensuring adequate representation of women.

The study took place in Kinakomba Ward, Galole Sub-County of Tana River County. Tana River County is subdivided into three Sub-Counties of Bura, Galole and Garsen with a total area of 35,375.8 KM² (13,658.7 sq. miles) whereby Trust land forms the bigger portion of the County with over 90% of the land. Galole Sub-County has four Wards of Wayu, Chewani, Mikinduni and Kinakomba. Kinakomba Ward is 556.9 square KM with 5 locations and 11 sub locations.

Kinakomba Ward has a population of about 18,000 people (3908 HH) which is about 7% of the total population of the whole County. The Ward as a whole falls within the Coast low land climatic Zone CL₃, CL₄ and CL₅. These zones are characterized by scarce rainfall ranging between 300mm – 600mm per annum only. The rainfall is erratic and unreliable resulting in persistent moisture stress in the soil profile. It is characterised by a flood plain along the banks of river Tana prone to flooding whenever the river bursts its banks. Apart from river floods the area is also sometimes affected by floods from the hinterland through seasonal rivers. The community lives in the floods plain and cultivate on the river banks making them very vulnerable to flash floods disasters because they have left the ground bare and the river banks are eroding at an alarming rate causing the river to change its course in many places frequently. The floods disasters experienced in Kinakomba Ward are on annual basis causing untold suffering, displacement of households and death of livestock. Being also in a Semi-Arid Area the community is confronted by immanent, persistent and prolonged droughts every second year and the frequency is increasing fast. The weather condition exhibits very high evaporation demand. From wood-head maps, the average evapo-transpiration during the dry and sunny months with a crop factor of 0.9, is 5.2mm/day CIDP II (2018-2022). Average annual temperatures are about 30⁰C with the highest being 41⁰C around January-March and the lowest being 20.6⁰C around June-July.

The area is between 70– 100m above sea level. Slopes are within the range of 0.05%-0.15% with local surface undulations. The soils range from sandy, dark clay and sandy loam to alluvial deposits. The soils are deep around the riverine environments but highly susceptible to erosion by water and wind. Soils in the hinterlands are shallow and have undergone seasons of trampling by livestock, thus are easily eroded during rainy seasons CIDP II (2018-2022). The vegetation ranges from scrubland to thorny thickets within the riverine area. Main crops grown are mangoes, bananas, maize, green grams, cowpeas, tomatoes, vegetables and melons while main livestock kept are cattle, sheep and goats. The study site is as shown in Figure 2 below.

2.2 Study area

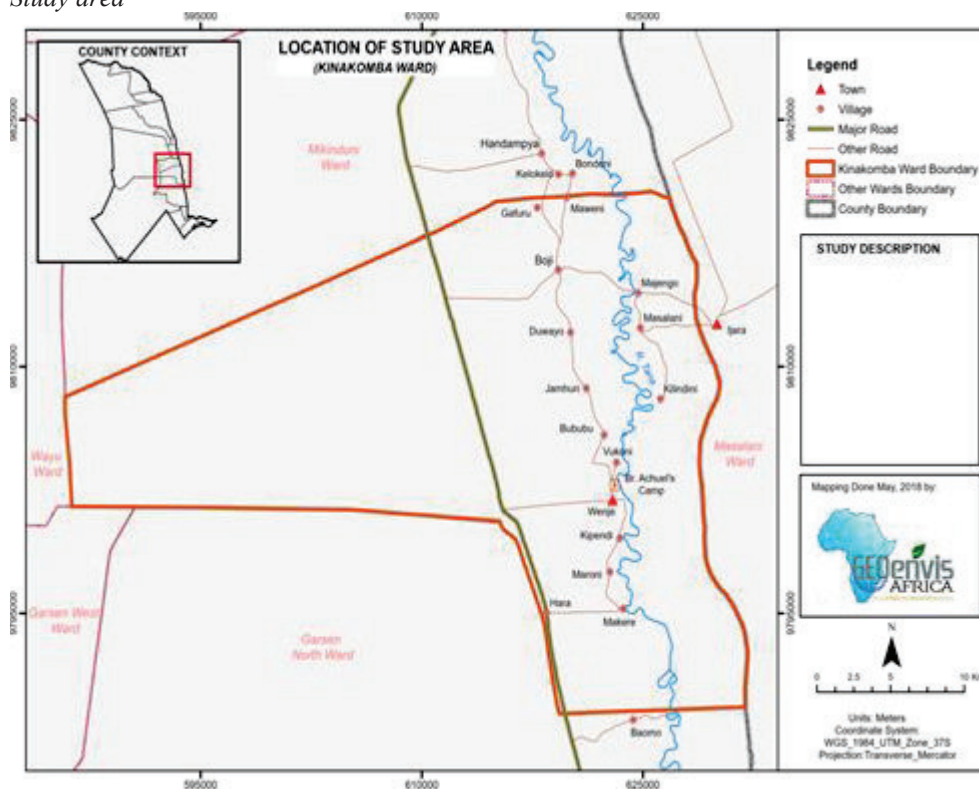


Figure 2 The map of Kinakomba Ward

2.3 Data Collection Instruments

2.3.1 Questionnaire

In this study, the researcher used questionnaires and an observation checklist to collect data. Three sets of questionnaires were developed and administered to the respondents. The researcher developed these questionnaires for the purpose of gathering information from respondents (Mugenda and Mugenda 2010). Observation overcomes one of the key disadvantages of interviews and questionnaires that is, that the responses provided may not be accurate (Dawson 2009). The questionnaire for the smallholder farmers had two sections structured and semi structured covering exposure, sensitivity and adaptive capacity.

Semi structured questions assisted in generating in-depth and explanatory qualitative information. This method allowed flexibility, follow up to original questions and pursuing of new lines of questioning, two-way interaction and facilitates exchange of information between the interviewer and interviewee making the atmosphere more relaxed. The use of both questionnaires and semi-structured questions is necessary in order to get as much information as possible from the community members. Administration of questionnaire to Key informants was done with people with vast experience and knowledge who can provide extensive insight into bio-socio-cultural aspects of the community.

2.3.2 Focus Group Discussions

To allow probing, Focus Group Discussions was developed and used. Focus Group Discussion was used to collect information on Exposure, Sensitivity and Adaptive Capacity. A panel of fifteen key informants drawn from the line ministries, involved in this area, was purposively chosen, to provide ratings on the relative importance of the different indicators of exposure, sensitivity and adaptive capacity used to measure important aspects of this capacity. The discussants were in groups of 8 - 12. .

2.3.3 Observation schedule

An observation was prepared and shared. That involved transect walks across the village and interacting with the villagers freely. That gave the feeling of the situation as was on the ground.

2.4 Validity and reliability of the Instruments

Validity

Validity of the instruments was determined before being used for data collection in the field. This was done by experts from the department of Environmental Studies- Community Development of Pwani University, to assess the face, content and construct validity of the instrument. That reduced biasness of the data collected (Abbott &

Bordens 2011).

Reliability of the Instrument

To test the reliability of the instruments the study used test-retest technique. Test-retest reliability is measured by administering a test twice at two different points in time. Reliability was also checked by comparing informant's responses with those of other informants and sources. Pre-test was used to improve the questionnaire, semi-structured questions and focus group interviews. A pilot study was carried out to test for reliability of the instruments on a sample of household with similar characteristics to those of the study sample and was not involved in the main study. Piloting was carried out for 39 households which make 10 percent of the study sample. According to Orodho (2004) the number in the pre-test should be 10 percent of the entire sample. Cronbach's alpha was used to determine the internal consistency of items in the questionnaire to gauge its reliability. According to Cronbach (1957) a coefficient of between $0.7 \leq \alpha < 0.9$ is taken to be good while that of $\alpha \geq 0.9$ is taken to be excellent George (2003).

2.5 Data collection procedure

A letter of approval for the proposed research from the ethical review panel of Pwani University and an introductory letter from Pwani University Graduate School was obtained. The letter was presented to the Tana River Governor's office to obtain permission to conduct the research in the area. Then various locations were visited personally in order to get consent from the chiefs and village elders to administer the instruments. This enabled the researcher to familiarize with the respondents and establish rapport. Two enumerators were selected and trained for five days before the data collection exercise. Then the questionnaire was administered to the participants. The respondents were assured of strict confidentiality in dealing with the responses. An informed consent form was availed to the respondents which they duly signed. Data was collected on the following variables. *Exposure* the researcher assessed defenselessness to drought. That included getting the indicators to quantify and measure proneness according to (Acosta-Michlik et al. 2008; Kro'mker et al. 2008) and Ta'nzler and Carius (2008). From the questionnaire the researcher got data to derive membership functions for different categories of the indicator of Negative consequences of drought. The researcher asked the participants to appraise eight classes of possible negative consequences of drought.

Sensitivity the researcher developed a metric of sensitivity based on the level of dependence on farming according to (Allison et al. 2009; Marshall et al. 2010). In developing the sensitivity metric, the respondents were asked to list all livelihood activities that brought in food or income to their household and ranked them in order of importance. That metric narrowed down the farm and non-farm activities

Adaptive Capacity the researcher used two sets of respondents. One was a panel of fifteen key informants to provide ratings on the relative importance of the different indicators of adaptive capacity. The ratings were elicited using the pairwise comparison questionnaire, coming with the method of Analytic Hierarchy Process. These key informants ratings were used to generate the weights of each indicator using analytic hierarchy process (AHP) (Saaty 2008). The second set of respondents consisted of 390 farming households selected through proportionate random sampling. To form the adaptive capacity index a questionnaire was conducted on these respondents to gather data on farming and household characteristics using five indicators of adaptive capacity that was physical, financial, information, human and livelihood diversity.

The researcher selected four assistants from the local area to ensure local customs are respected. That enabled creation of a rapport with the community. Two weeks were taken to explain the objectives of the study to the community, adequate time was spent explaining the objectives and enough chance given to community for seeking clarification. To minimize biases information notes was taken and later used to enrich the questionnaires. The questionnaires used had specific questions with limited answers creating a possibility to get the quantitative data that could be analysed statistically. The meetings took between 3 - 4 hours and they were done in all the five locations with the permission of the area administrator (chief).

Data Analysis Method

This study Analysed a quantitative Vulnerability score by using an equation which combined three contributing indices of exposure, sensitivity and adaptive capacity each normalized to 0–1 Scale (Adger and Vincent, 2005;Allison et al. 2009):

Vulnerability= exposure + sensitivity - adaptive capacity

For measuring exposure using fuzzy methodology.

In assessing inclination to drought the researcher was finding out

- a) Which indicators were used to quantify and measure this inclination
- b) How these indicators were interpreted
- c) How the relationship between different factors for this inclination was described and quantitatively modelled

- d) How a single numerical index would be computed for comparing this inclination between different villages and social groups

This then lead to a four step methodology according to (Acosta-Michlik et al. 2008, Krõmker et al. 2008) and Tãnzler and Carius (2008) as follows:

i) *Selection of input variables*: Here the researcher used a questionnaire to get data to derive membership functions for different categories of the indicator ‘Consequences when drought occurs’. The researcher asked the participants to appraise eight classes of possible consequences of drought. When there is drought ; ‘We will not have enough food to eat’, ‘We will have little or no rains at all’, ‘Our farms will not be able to yield any harvests’, ‘We will be forced to burn charcoal more often’, ‘We will be forced to seek food aid from government and NGOs’, ‘We will not have enough drinking water’, ‘We will be forced to leave our home’, and ‘We will become ill more often’

ii) *Fuzzification* Alcamo et al. (2008): Membership functions created above allowed the researcher to quantify linguistic term and represent a fuzzy set graphically. A membership function for a fuzzy set A on the universe of discourse X was defined as $\mu_A: X \rightarrow [0, 1]$. So each element of X was mapped to a value between 0 and 1. That was the membership value or degree of membership. It quantified the degree of membership of the element in X to the fuzzy set A . Thus x axis represented the universe of discourse while y axis represented the degrees of membership in the $[0, 1]$ interval. Thus translation from numerical data to linguistic categories, was the ‘Fuzzification’ and was accomplished through membership functions which defined the degree of membership of each indicator in each category. So in the questionnaire the researcher asked the participants to rate each of the 8 consequences according to: 1 = ‘likely’, 0 = ‘partly likely and partly unlikely’, -1 = ‘unlikely’. Then the sum of the different consequences was used to define the membership functions.

iii) *Inference modelling* Krõmker et al. (2008): The core of this approach for quantifying exposure to drought was the construction of an inference model. This model consisted of a rule system made up of linguistic statements, in turn made up of variables described by fuzzy logic (Roberts 1996), Wu et al. (1996), Silvert (2000), Mackay and Robinson (2000) and Kangas and Kangas (2004). The rule system defined the relationship between a given combinations of indicators. A rule was needed for all variables and all their categories. Here there were two steps:

Step1: Construct knowledge base rules

The researcher created this

Step 2: Obtain fuzzy value

Fuzzy set operations perform evaluation of rules. The operations used by the researcher was AND. The researcher combined all the results of evaluation to get the final result which was the fuzzy value.

iv) *Defuzzification* (Bothe 1998; Aliev et al. 2000)

Defuzzification was used to combine the results of each rule into one unique quantitative result. The researcher used the defuzzification technique called center of gravity (Eierdanz et al. 2008).The fuzzy set membership function had the graph of a triangle. As done by Eierdanz et al. (2008) this formed a trapezoid. These trapezoids were then superimposed one upon another, forming a single geometric shape. Then, the centroid of that shape, called the fuzzy centroid, was calculated. The x coordinate of the centroid was the defuzzified value.

Measuring Sensitivity

In measuring sensitivity a metric of sensitivity based on the level of dependence on farming was developed according to (Allison et al. 2009; Marshall et al. 2010). That was done using surveys of 390 households living in 18 villages of Kinakomba Ward. Sampling of these households was done using a proportionate sampling design taking 10% from each village based on the population of the village. In developing the sensitivity metric, the respondents were asked to list all livelihood activities that brought in food or income to their household and ranked them in order of importance. Occupations was grouped as follows: farming, crop sales, vegetable sales, casual agricultural labour, casual non-agricultural labour, livestock sales(cattle, goats chicken etc.), fishing, skilled trader/artisan, Medium/large business, petty trade(firewood sales etc.), formal salary/pension, remittance, other and ‘None’ (Cinner and Bodin 2010). To narrow down sensitivity to extreme events like drought and floods the researcher categorized farm and non-farm sectors (Barrett et al. 2001). This metric of sensitivity incorporated the proportion of households engaged in farming. When these households also engaged in non-farm occupations the researcher treated that as linkages between sectors and when the respondents ranked farming higher than any activity that was treated as the directionality of these linkages the equation below was used:

$$S = \frac{F}{F + NF} \times \frac{N}{F + NF} \times \frac{(r_{fn/2}) + 1}{r_{fn} + r_{nf} + 1}$$

Where S = sensitivity, F = number of households relying on farming related activities, NF = number of households relying on non-farming activities, N = number of households, r_{fn} = the number of times farming related activities were ranked higher than non-farming activities (normalized by the number of households), r_{nf} = the number of times non-farming related activities were ranked higher than farming activities (normalized by

the number of households). The first part in this equation captured the ratio of farming to non-farming related activities.

The second part of the equation captured the extent to which households dependent on farming also engage in non-farming livelihood activities. That was linkage between sectors. This term decreased the level of sensitivity when many households were engaged in both occupational categories

The third part of the equation captured the directionally of linkages between farming and non-farming activities such that communities were more sensitive when households engage in farming and non-farming activities consistently ranking the farming sector as more important than other livelihood activities. Using that composite metric, the researcher captured some new aspects of sensitivity.

The sensitivity score had three factors. Firstly the fraction of households being engaged in farming related activities, that factor ranged from 0 to 1.0 because each household was engaged in at least one sector and potentially in both. Secondly the ratio of the total number of households to the total number of occurrences of households being engaged in either the farm or non-farm sector. The ratio here ranged from 0.5 to 1.0 though the researcher found 0.45 and rounded it off to 0.5. Thirdly the ranking of occupational importance was taken into Account. That was designed to differentiate between cases when farming was being ranked higher than non-farming (and vice versa). If the farming sector was ranked higher, the sensitivity index increased. And, if there were no linkages whatsoever, the sensitivity score would peak (Cinner et al. 2012).

According to Cinner et al. (2012) to account for the effect of households being engaged in varying numbers of occupations within two sectors say farming and non-farming, two approaches of arriving at the sensitivity index can be used. The researcher used the second approach which increases the link strength by 1.0 each time an occupation is ranked higher than the occupation that follows next after on the ranking list i.e. assuming that the other occupation belongs to the other sector. If, however, the occupation number three on the ranking list is the farming the link is increased by 2.0. Also, the link going from non-farming to farming is increased by 1.0 since there is one occurrence of a non-farming related occupation being ranked higher than a farming related occupation (i.e. position two and three on the ranking list). Irrespective of the chosen approach, the value of the term will never exceed 1.0. However, the minimum value depends on the number of occupations, and how they are ranked internally, for each household. It will typically be in the range of 0.5–1.0.

Measuring Social adaptive capacity index

There were two sets of respondents for this study. One was a panel of fifteen key informants (drawn from the line ministries, involved in this area), purposively chosen, to provide ratings on the relative importance of the different indicators of adaptive capacity. The ratings was elicited using the pairwise comparison questionnaire, which comes with the method of Analytic Hierarchy Process. These key informants ratings was used to generate the weights of each indicator using analytic hierarchy process (AHP) (Saaty 2008). The second set of respondents consisted of 390 farming households selected through proportionate random sampling. To form the adaptive capacity index a survey, with the aid of an interview guide, was conducted on these respondents to gather data on farming and household characteristics for the adaptive capacity indicators.

i. Method of Analysis

The adaptive capacity to climate change and variability of farming households was measured using a composite index. The index consisted of various indicators of adaptive capacity following the sustainable livelihoods framework. Based on this approach, adaptive capacity was determined by ownership and access to resources, information and technology, and ability to diversify livelihoods to cope with Climate-related stresses. The adaptive capacity index in this study followed the variables included in the vulnerability index of Eakin and Bojorquez-Tapia (2009). Each farming household was analyzed using five indicators of adaptive capacity that was physical, financial, information, human and livelihood diversity.

ii. Index Construction

The composite index was constructed to come up with adaptive capacity scores for each household. The first step was the scoring of categorical data using Analytic Hierarchy Process (AHP) based on the ratings/judgements of key informant. The Analytic hierarchy process is a multiple criteria decision-making tool introduced by Thomas Saaty (1980) that uses an Eigenvalue Betteridge (1965) approach to the pair-wise comparisons. Following the AHP procedure, the components, indicators, and sub-indicators of adaptive capacity were turned into a multi-level hierarchical structure to facilitate pairwise comparisons using key informant judgment at each level. The instrument for the pairwise comparisons used AHP's 9-point scale format wherein the relative importance of indicators and sub-indicators were compared and assessed based on key informant's ratings. The weights were computed using the Analytical Network Process (ANP) software, Super Decisions version 3.0

The calculation of priorities adopted the procedure of Beritella et al. (2007) which converted the responses of key informants into a judgmental matrix:

$$A = \begin{bmatrix} a_{11} & a_{12} & \dots & a_{1n} \\ a_{21} & a_{22} & \dots & a_{2n} \\ \dots & \dots & \dots & \dots \\ a_{n1} & a_{n2} & \dots & a_{nn} \end{bmatrix}$$

Where:

a_{ij} = the key informant's comparison rating between element i and element j of a given level with respect to the upper level of the hierarchy with

$$a_{ij} > 0; a_{ij} = \frac{1}{a_{ji}}; a_{ii} = 1 \text{ for all } i.$$

The priorities or weights of the elements were estimated by finding the principal eigenvector w of the matrix A which is: $AW = \lambda_{max} W$, λ_{max} is the largest eigenvector of the matrix A . The vector W was normalized to get the vector of priorities of elements of one level with respect to the upper level. The priorities served as weights of the elements at each hierarchic level.

The next step in the construction of the index was aggregating or combining all indicator scores with their corresponding weights to come up with one single index Value/scores ranging from zero to one for adaptive capacity. The final step was classification of the scores into three levels – low, moderate and high adaptive capacity.

3. Results and Discussion

3.1 Data Analysis Method

To understand the interaction of these variables this study Analysed a quantitative Vulnerability score by using an equation which combined three contributing indices of exposure, sensitivity and adaptive capacity each normalized to 0–1 Scale (Adger and Vincent 2005;Allison et al. 2009):

$$\text{Vulnerability} = \text{exposure} + \text{sensitivity} - \text{adaptive capacity}$$

From the data collected and the groups formed from the area of study the following table was established as shown in Table 2:

3.2 Vulnerability Score for Kinakomba Ward

The vulnerability score was obtained by adding exposure to sensitivity and subtracting the adaptive capacity as shown in Table 2 below:

Table 29 The single vulnerability score for Kinakomba Ward

	The single Vulnerability Index for Kinakomba Ward			Cumulative vulnerability
	Exposure	Sensitivity	Adaptive Capacity	
Kinakomba Ward	0.35	0.25	0.3	0.3

The totals of sensitivity 0.2458 + exposure 0.35 + Adaptive capacity 0.2998= 0.8956

Divide each element with the total – sensitivity 0.2744, Exposure 0.3908, Adaptive capacity - 0.3347 =0.9999.

The relative average of this normalised vulnerability score is 0.3333

3.3 Testing the Hypothesis

The chi-square goodness of fit test is applied when there is one categorical variable from a single population. It is used to determine whether sample data are consistent with a hypothesized distribution.

It is appropriate to use the chi-square goodness of fit test when, the sampling method is simple random sampling, the variable under study is categorical and the expected value of the number of sample observations in each level of the variable is at least 5. There are 4 steps: State the hypotheses, Formulate an analysis plan, Analyze sample data, and then interpret results.

Step 1: State the Hypotheses

Every hypothesis test requires the researcher to state a null hypothesis (H_0) and an alternative hypothesis (H_a). The hypotheses are stated in such a way that they are mutually exclusive. That is, if one is true, the other must be false; and vice versa.

- i. H_0 The vulnerability of the smallholder farmers is not significantly related to their exposure, sensitivity and adaptive capacity to climate related shocks in Kinakomba Ward.
- ii. H_0 The vulnerability of the smallholder farmers is significantly related to their exposure, sensitivity and adaptive capacity to climate related shocks in Kinakomba Ward

Step 2: Formulate an Analysis Plan

This analysis plan describes how to use sample data to accept or reject the null hypothesis.

1. Significance Level here is equal to 0.05
2. The test Method. We use the Chi-square goodness of fit test to determine whether observed sample frequencies differ significantly from expected frequencies specified in the null hypothesis.

Step 3: Analyze Sample Data

Using sample data the researcher looked for the degrees of freedom, expected frequency counts, test statistic, and

the P-value associated with the test statistic.

Degrees of Freedom (DF) is equal to the number of levels (k) of the categorical variable minus 1 in our case it is the number of the Criterion which are five:

$DF = k - 1$. In our case it is $3-1=2$

The expected frequency counts at each level of the categorical variable are equal to the sample size times the hypothesized proportion from the null hypothesis.

$E_i = np_i$

where E_i is the expected frequency count for the i th level of the categorical variable, n is the total sample size, and p_i is the hypothesized proportion of observations in level i . In this Study:

$E_1 = 390 * 0.2744 (107.016)$ $E_2 = 390 * 0.3908 (152.412)$ $E_3 = 390 * 0.3347 (130.553)$

The test statistic is a chi-square random variable (X^2) defined by the following equation:

$$X^2 = \sum [(O_i - E_i)^2 / E_i]$$

Where O_i is the observed frequency count for the i th level of the categorical variable, and E_i is the expected frequency count for the i th level of the categorical variable.

$$X^2 = \sum [(O_i - E_i)^2 / E_i]$$

$$X^2 = [(107-107.016)^2/107.016] + [(152-152.412)^2/152.412] + [(130-130.553)^2/130.553]$$

$$X^2 = [(-0.016)^2/107.016] + [(-0.412)^2/152.412] + [(-0.553)^2/130.553]$$

$$= 2.3922 + 0.0011 + 0.0023 = 2.3956$$

where DF is the degrees of freedom, k is the number of levels of the categorical variable, n is the number of observations in the sample, E_i is the expected frequency count for level i, O_i is the observed frequency count for level i, and X^2 is the chi-square test statistic.

The P-value is the probability that a chi-square statistic having 2 degrees of freedom is more extreme than 0.9997. Using the Chi-square Distribution Calculator to find $P(X^2 > 0.9997) = 2.3956$.

Step 4: Interpret Results

Since the P-value (2.3956) is more than the significance level (0.05), the researcher accepts the null hypothesis. This approach is appropriate because the sampling method was simple random sampling, the variable under study was categorical, and each level of the categorical variable had an expected frequency count of at least 5

3.4 Visualization of different components of Vulnerability

To visualize differences in key components of vulnerability the researcher plotted the three dimensions on a bubble plot, where sensitivity is plotted against Adaptive Capacity and exposure is indicated as the size of the points showing larger points to mean higher exposure Figure 3 below.

The figure shows the plot of the vulnerability of Kinakomba Ward smallholder farmers to the impacts of Climate Related Shocks on their farming activities. Adaptive Capacity (x-axis; note values reversed so that high adaptive capacity is on the left) is plotted against Sensitivity (y-axis) such that more vulnerable smallholder farmers are on the right of the graph and less vulnerable smallholder farmers in the bottom left of the figure. These two dimensions of vulnerability can be modified by policy and development. The third dimension of vulnerability, exposure is represented as the size of the bubble (larger=more exposure). To aid in visualization, exposure values were represented as the lowest, middle and highest rather than scaled to actual site values. Colours represent villages.

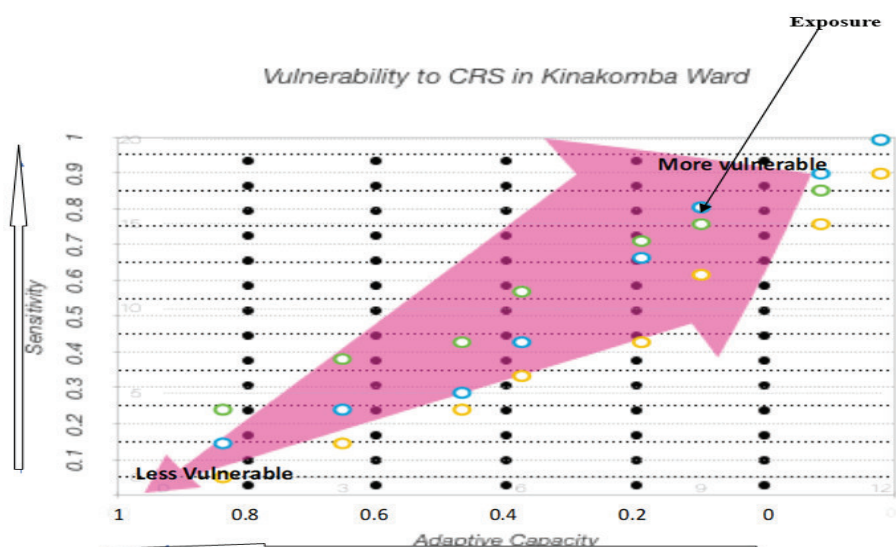


Figure 4 Visualization of different components of Vulnerability

4. Conclusion

Exposure at 0.39 contributed more than adaptive capacity at 0.3 to the cumulative vulnerability. At the same time Adaptive capacity at 0.3 contributed more than sensitivity at 0.25. Sensitivity contributed least to the cumulative vulnerability. Adaptive capacity at 0.3 was equal to cumulative vulnerability at 0.3. Exposure contributed the most meaning that the smallholder farmers in Kinakomba Ward were exposed more to climatic related shocks like drought and floods at about 40% out of the other factors like sensitivity and adaptive capacity all of which each contributed about 30% to cumulative vulnerability. The study concluded that if exposure is mitigated and adaptive capacity increased through policy then vulnerability of the smallholder farmers will greatly reduce. Consequently this will have empowered the smallholder farmers contributing to their sustainable food production and ultimately to their food security.

The study also concluded that as sensitivity increases vulnerability also increases while it was the opposite for adaptive capacity which when it increases vulnerability reduces. These two dimensions of vulnerability namely sensitivity and adaptive capacity can be modified by policy and development. Smallholder farmers are more sensitive to climatic shocks when they depend only on farming activities especially of a single crop or two. Diversification of farming activities including rearing of livestock, planting a variety of different crops would reduce sensitivity of the smallholder farmers. The study also concluded that the adaptive capacity of smallholder farmers would be greatly enhanced if they get trainings. Trainings in sustainable agriculture, agroecological approaches and even agroforestry. This will greatly reduce vulnerability of the smallholder farmers in Kinakomba Ward because their adaptive capacity would have increased.

Recommendations;

- i. The study recommended that the County and National governments and stakeholders to employ measures to adapt to climate change and variability.
- ii. This study also recommended that the Government in partnership with other stakeholders develop a comprehensive disaster risk management framework to address the drought hazards and undertake mitigation and adaptation measures by equipping the smallholder farmers with knowledge on how to cope with the cyclic and vicious droughts' impacts that have led to serious irreversible harm to humans and livestock in the area.
- iii. Also that the Government in partnership with stakeholders develop interventions of adaptation options and empowerment of farmers with skills in diversification of livelihoods options.
- iv. The Government to develop policy on irrigation where the Government and Stakeholders would support irrigation outside the floods plains because the farmers still use floods receded irrigation along the river.
- v. Another area would be supporting solar powered irrigation which is doing very well and it is cheaper for the farmers, environmentally friendly and produces clean energy without noise. Another area would be supporting irrigation by gravity which would be extremely cheap.
- vi. Further policy measure would be promoting and enforcing water storage in the village irrigation schemes that can last at least three months just in case the solar pump has mechanical problems. This would mean the stored water will take the planted crop to maturity.
- vii. Another would be enhancing the adaptive capacity of the farmers through availing and having the early warning system working and having smallholder farmer's access information on the correct seeds and at the right time.
- viii. Also the smallholder farmers to access credit easily and the land in the area to be demarcated and titled so that they can use the title deeds as collateral for accessing financial support from financial institutions.

References

- Acheson, J.M., Wilson, J.A. (1996) Order out of Chaos: The Case for Parametric Fisheries Management. *American Anthropologist* 98, 579-594.
- Acosta-Michlik L, Kavi-Kumar, K, Klein R, Campe S (2008). Application of fuzzy models to assess susceptibility to drought from a socio-economic perspective. *Reg Environ Change* (2008) 8:197–205 DOI 10.1007/s10113-008-0069-1
- Adejuwon, J. O.(2008). Vulnerability in Nigeria, a national level assessment. In Leary, N. Conde, C., Kulkarni, J., Nyong, A. and Pulhin, J. (eds). *Climate Change and Vulnerability*. Earthscan, London, UK, pp. 198-217.
- Adger, W. N. and Brooks, N. (2003) Does Global Environmental Change Cause Vulnerability to Disaster? in Pelling, M. (ed.) *Natural Disasters and Development in a Globalizing World*, London: Routledge.
- Adger, W. N., Arnell, N. W. and Tompkins, E. L. (2005a) Successful Adaptation to Climate Change Across Scales, *Global Environmental Change*, 15, 77–86.
- Adger, W Neil, Shardul Agrawala, M Monirul Qader Mirza, Cecilia Conde, Karen O'Brien, Juan Pulhin, Roger Pulwarty, Barry Smit, and Kiyoshi Takahashi. 2007. Assessment of Adaptation practices, options, constraints and capacity. *Climate change*: 717-743.
- Adger, W. N., Dessai, S., Goulden, M., Hulme, M., Lorenzoni, I. Nelson, D. R., Naess, L-O., Wolf, J. and Wreford,

- A. (2009a) Are There Social Limits to Adaptation to Climate Change? *Climatic Change*, 93,335–54.
- Adger, W. N., Eakin, H. and Winkels, A. (2009b) Nested and Teleconnected Vulnerabilities to Environmental Change, *Frontiers in Ecology and the Environment*, 7 (3), 150–58.
- African Development Bank; (2003) *Poverty and Climate Change: Reducing the Vulnerability of The Poor Through Adaptation*, www.undp.org/energy/povcc.htm (accessed 8 July 2008)
- Alcamo J, Acosta-Michlik L, Carius A, Eierdanz F, Klein R, Kro"mker D, Ta"nzler D (2008) A new approach to quantifying and comparing vulnerability to drought. *Reg Environ Change*. XX
- Aliev R, Bondif KW, Aliew F (2000) *Soft Computing: eine grundlegende Einfu"hrung*. Berlin
- Allison, E.H., Perry, A.L., Badjeck, M.C., Adger, W.N., Brown, K., Conway, D., Halls, A.S. Pilling, G.M., Reynolds, J.D., Andrew, N.L., Dulvy, N.K., (2009). Vulnerability of national economies to the impacts of climate change on fisheries. *Fish and Fisheries* 10, 173–196.
- Armitage, D., (2007) Building resilient livelihoods through adaptive co-management: the role of adaptive capacity, in: Armitage, D., Berkes, F., Doubleday, N.C. (Eds.), *Adaptive Co management: Collaboration, Learning and Multi-level Governance*. UBC Press, Vancouver, pp. 62-82.
- Asare-Kyei AK, Kloos J, Renaud FG (2015) Multi-scale participatory indicator development approaches for climate change risk assessment in West Africa. *Int J Disaster Risk Reduct* 11:13–34. doi:10.1016/j.ijdrr.2014.11.001
- Barrett, C.B., Reardon, T., Webb, P., (2001). Nonfarm income diversification and household livelihood strategies in rural Africa: concepts, dynamics, and policy implications. *Food Policy* 26, 315–331.
- Basurto, X., Gelcich, S, Ostrom, E., (2013). The social–ecological system framework as a knowledge classificatory system for benthic small-scale fisheries. *Global Environ. Change* (2013), <http://dx.doi.org/10.1016/j.gloenvcha.2013.08.001>
- Berritella, M., A Certa, M. Enea, P. Zito., (2007). An Analytic Hierarchy Process for the Evaluation of Transport Policies to Reduce Climate Change Impacts. *Fondazione ENI Enrico Mattei (FEEM) working paper 12.2007*.
- Bhattacharjee, A. (2012). *Social Science Research: Principles, Methods and Practices*. Published by Creative Commons Attribution, Florida, U.S.A. 159, pp
- Bliss, C. I. (1934). "The Method of Probits". *Science*. **79** (2037): 38–39.
- Birkmann J, Garschagen M, Mucke P, Schauder A, Seibert T, Welle T, Rhyner J, Kohler S, Loster T, Reinhard D, Matuschke I (2014) *World Risk Report 2014*. Bu"ndnis Entwicklung Hilft and UNUEHS doi:10.1126/science.79.2037.38. PMID 17813446.
- Bollin C, Hidajat R (2006) Community-based disaster risk index: pilot implementation in Indonesia, towards disaster resilient societies. In: Birkmann J (ed) *Measuring vulnerability to natural hazards*. UNU-Press, Tokyo, New York, Paris
- Bothe H-H (1998) *Neuro-Fuzzy-Methoden. Einfu"hrung in Theorie und Anwendungen*, Berlin
- Brundtland Commission, (1987), "Our Common Future", Oxford University Press.
- Bryk, Stephen W. Raudenbush, Anthony S. (2002). *Hierarchical linear models: applications and data analysis methods* (2. ed., [3. Dr.] ed.). Thousand Oaks, CA [u.a.]: Sage Publications. ISBN 0-7619-1904-X.
- Burton, I., 1997, "Vulnerability and adaptive response in the context of climate and climate Change", *Climatic Change*, Vol. 36, pages: 185–196.
- Carter, T.P., Parry, M.L., Harasawa, H., and Nishioka, N., (1994), *IPCC Technical Guidelines for Assessing climate change impacts and adaptations*, London: University College London.
- Cinner, J.E., Bodin, O" ., (2010). Livelihood diversification in tropical coastal communities: a network-based approach to analyzing 'livelihood landscapes'. *PLoS One* 5, e11999.
- Cox, M., 2011. Advancing the diagnostic analysis of environmental problems. *International Journal of the Commons* 5, 346–363.
- Cronbach LJ (1951). "Coefficient alpha and the internal structure of tests". *Psychometrika* 16 (3): 297–334.
- Downing, T.E., Ringius, L., Hulme, M., and Waughray, D., (1997), "Adapting to climate change in Africa", *Mitigation and Adaptation Strategies for Global Change*, Vol 2, pages: 19- 44.
- Eakin, H., and L. A. Bojorquez-Tapia., (2008). Insights into the Composition of Household Vulnerability from Multicriteria Decision Analysis. *Global Environmental Change* 18: 112–127.
- Eakin, H. C. and Wehbe, M. B. (2009) Linking Local Vulnerability to System Sustainability in a Resilience Framework: Two Cases from Latin America, *Climatic Change*, 93: 355–77.
- Eierdanz et al.,(2008).Using fuzzy set theory to address the uncertainty of susceptibility to drought, *Reg Environ Change* (2008) 8:197–205 DOI 10.1007/s10113-008-0069-1
- Engineering, and Public Policy (U.S.) Panel on Policy Implications of Greenhouse Warming committee on Science (1992). *Policy Implications of Greenhouse Warming: Mitigation, Adaptation, and the Science Base*. National Academies Press. p. 944. ISBN 0-309-04386-7. Archived from the original on 2 March 2007. Retrieved 2007-04-14.
- Epstein G, Sandberg A, Bay-Larsen I,Hovelsrud G.,(2014), *Institutions and adaptation processes: A social-*

- ecological system approach for the study of adaptation to climate change*, The Vincent and Elinor Ostrom Workshop in Political Theory and Policy; Prepared for delivery at the Workshop on the Ostrom Workshop (WOW5) conference, Indiana University Bloomington, June 18–21, 2014.
- Farber, Daniel A., (2007) *Adapting to Climate Change: Who Should Pay*", 23 FLA. ST. U. J. LAND USE & ENVTL. L. 1, 8 2007.
- FAO (2014). *Adapting to climate change through land and water management in Eastern Africa: Results of pilot projects in Ethiopia, Kenya and Tanzania*. Rome, Italy: Food and Agriculture Organization of the United Nations. <http://bit.ly/1sbPHr5>.
- Fidell, Barbara G. Tabachnick, Linda S. (2007). *Using multivariate statistics* (5th ed.). Boston ; Montreal: Pearson/A & B. ISBN 0-205-45938-2.
- Folke, C., (2006). Resilience: The emergence of a perspective for social–ecological systems analyses. *Global Environmental Change*, **16**(3):253-267.
- Foxton, T. J. (2007) *Technological Lock-in and the Role of Innovation*, in Atkinson, G., Dietz, S. and Neumayer, E. (eds.) *Handbook of Sustainable Development*, Cheltenham: Edward Elgar.
- Freire, P. (1969, 2000) *Education for Critical Consciousness*, New York: Continuum.
- Füssel, H. M.,(2009). Review and Quantitative Analysis of Indices of Climate Change Exposure, Adaptive Capacity, Sensitivity, and Impacts. World Development Report 2010. Development and Climate Change Background Note. 34 p. Internet file retrieved on 26th, July, 2011, from, http://siteresources.worldbank.org/INTWDR2010/Resources/5287678-1255547194560/WDR2010_BG_Note_Fussel.pdf.
- Gálya B., Blaskó L., Jóvér J., Kovács Gy., - Tamás J., (2017) (CEST2017_00525). *Modelling vulnerability of drought in the Great Plain of Hungary*. 15th International Conference on Environmental Science and Technology Rhodes, Greece, 31 August to 2 September 2017
- Garschagen M., (2014) *Risky change? Vulnerability and adaptation between climate change and transformation dynamics in Can Tho City, Vietnam*. Steiner 15, Stuttgart
- Gbetibouo, G.A., C. Ringler and R. Hassan., (2010). *Vulnerability of the South African Farming Sector to Climate Change and Variability: An Indicator Approach*. *Natural Resources Forum* 34: 175–187.
- Harvey, D., (2010) *The Enigma of Capital*, London: Profile Books.
- Hedström, Peter, and Petri Ylikoski., (2010). Causal Mechanisms in the Social Sciences. *Annual Review of Sociology* 36 (1): 49-67.
- Hinkel, J., Bots, P. W., & Schlüter, M.,(2014). Enhancing the Ostrom social-ecological system Framework through formalization. *Ecology and Society*, 19(3), 51.
- Holling, C.S., (1986), "The resilience of terrestrial ecosystems: local surprise and global change", in Clarkland, W.C., and Munn, R.E., (eds), *Sustainable Development of the Biosphere*, pages: 292–317, Cambridge: Cambridge University Press.
- Holling, C.S., Meffe, G.K. (1996) *Command and Control and the Pathology of Natural Resource Management*. *Conservation Biology* 10, 328-337.
- Hovelsrud, G.K., White, J.L., Andrachuk, M., Smit, B., (2010) *Community Adaptation and Vulnerability Integrated*, in: Hovelsrud, G.K., Smit, B. (Eds.), *Community adaptation and vulnerability in Arctic regions*. Springer Netherlands, pp. 335-348.
- Hulme, M., (2009) *Why We Disagree About Climate Change*, Cambridge: Cambridge University Press.
- IPCC, (1996), "Climate Change 1995. Impacts, Adaptation, and Mitigation of Climate Change: Scientific-Technical Analyses", Watson, R.T., Zinyowera, M.C., and Moss, R.H., (eds), *Contribution of Working Group II to the Second Assessment of the Intergovernmental Panel on Climate Change*, Cambridge: Cambridge University Press.
- IPCC, (2001), *Climate Change 2001: Impacts, Adaptation and Vulnerability*, McCarthy, J.J., Canziani, O.F., Leary, N.A., Dokken, D.J., and White, K.S., (eds.), Cambridge: Cambridge University Press.
- IPCC, (2001), "Climate Change 2001: Impacts, Adaptation and Vulnerability". Grida.no. Retrieved 2010-08-29.
- IPCC, (2001), "Adaptation is a Necessary Strategy at All Scales to Complement Climate Change Mitigation Efforts". *Climate Change 2001: Working Group II: Impacts, Adaptation and Vulnerability*. grida.no.
- IPCC, (2004), "Successful adaptation to climate change across scales" (PDF). doi:10.1016/j.gloenvcha.2004.12.005. Retrieved 2010-08-29.
- IPCC Climate Change, (2007): *Impacts, Adaptation and Vulnerability* (eds Parry M. L., Canziani, O. F., Palutikof, J. P., van der Linden, P. J. & Hanson, C. E) (Cambridge Univ. Press, 2007).
- IPCC, (2010), "Assessment of adaptation practices, options, constraints and capacity" (PDF). Archived (PDF) from the original on 27 August 2010. Retrieved 2010-08-29.
- ISDR, (2004) *Living with Risk: A Global Review of Disaster Reduction Initiatives*, Volume II, Geneva: ISDR.
- ISDR (2005) *Hyogo Framework for Action 2005–2015: Building the Resilience of Nations and Communities to Disasters*, Geneva: ISDR.

- Jerneck A. and Olsson, L., (2008) Adaptation and the Poor: Development, Resilience and Transition, *Climate Policy*, 8(2): 170–82.
- J.E. Cinner et al., (2012): Vulnerability of coastal communities to key impacts of climate change on Coral reef fisheries / *Global Environmental Change* 22 (2012) 12–20
- J.W. Kalungu, W.L. Filho and D. Harris., (2013) Smallholder farmers' perception of the Impacts of climate change and variability on rain-fed agricultural practices in semi- Arid and sub-humid regions of Kenya. *Journal of Environment and Earth Science*, 3 (7), pp. 129-141. <http://bit.ly/1zhteM7>.
- Kates, R.W., (2000), "Cautionary Tales: adaptation and the global poor", *Climatic Change*, Vol 45 (1), page: 5–17.
- Klein, R.J.T., (2007). Print version: Cambridge University Press, Cambridge, UK, and New York, N.Y., U.S.A. This version: IPCC website. ISBN 978-0-521-88010-7. Archived from the original on 21 April 2010. Retrieved 2010-04-06.
- Klein, R.J.T., Huq, S., Denton, F., Downing, T.E., Richels, R.G., Robinson, J.B., & Toth, F.L., (2007). Inter-relationships between adaptation and mitigation. In M.L. Parry, O.F. Canziani, J.P. Palutikof, P.J. van der Linden & C.E. Hanson (Eds.), *Climate change 2007: Impacts, adaptation and vulnerability. contribution of working group II to the fourth assessment report of the intergovernmental panel on climate Change (Intergovernmental Panel on Climate Change. Working Group II Trans.)*. (pp. 745-777). Cambridge: Cambridge University Press.
- Klein, R. J. T. et al., (2014): *Climate Change Impacts, Adaptation, and Vulnerability* (eds Field, C. B., Barros, V. R. & Dokken D. J.) Ch. 16, 902–927 (Cambridge Univ. Press, 2014).
- Kloos J, Asare-Kyei D, Pardoe J, Renaud FG., (2015): Towards the development of an adapted multi-hazard risk assessment framework for the West Sudanian Savanna Zone. *UNU- EHS Publication* 11:4–26
- Kroonker D, Eierdanz F, Stolberg A., (2008): Who is susceptible and why? An agent-based approach to assessing vulnerability to drought. *Regional Environmental Change*.(2008) 8:197–205 DOI 10.1007/s10113-008-0069-1 Volume XX
- Leary, N and Beresford, S., (2007). Vulnerability of people, places and systems to environmental change. In Knight, G. and Jaeger, J. (eds). *Integrated Regional Assessment*. Cambridge University Press, Cambridge, UK.
- Leary, N., Conde, C., Kulkarni, J., Nyong, A. and Pulhin, J. (eds), (2008). *Climate Change and Vulnerability*. Earthscan, London, UK.
- Lee, E. K. O., Shen, C. and Tran, T. V., (2009) Coping with Hurricane Katrina: Psychological Distress and Resilience among African American Evacuees, *Journal of Black Psychology*, 35: 5–23.
- Levin, S., Xepapadeas, T., Crépin, A., Norberg, J., De Zeeuw, A., Folke, C., Hughes, T., Arrow, K., Barrett, S., Daily, G., Ehrlich, P., Kautsky, N., Mäler, K., Polasky, S., Troell, M., Vincent, J.R. and Walker, B., (2013). Social-ecological systems as complex adaptive systems: modeling and policy implications. *Environment and Development Economics*, 18(02): 111.
- Kangas AS, Kangas J., (2004) Probability, possibility and evidence: approaches to consider risk and uncertainty in forestry decision analysis. *For Policy Econ* 6(2):169–188. doi:10.1016/S1389-9341(02)00083-7
- Kininmonth W.R., Voice M.E., Beard G.S., de Hoedt G.C., Mullen, C.E., (2000), Australian climate services for drought management. In D.A. Wilhite (ed.) *Drought, a global assessment.*, Routledge, pp. 210–222.
- Kothari C. R., (2004), *Research Methodology, Methods and Techniques*, Second Revised Edition 2004, New Age International (P) Ltd., Publishers, India at Dharmesh Printers, Delhi.
- Mackay DS, Robinson VB., (2000) A multiple criteria decision support system for testing integrated environmental models. *Fuzzy Sets Syst* 113:53–67. doi:10.1016/S0165- 0114(99)00012-3
- Mansur AV, Brondizio ES, Roy S, Hetrick S, Vogt N, Newton A.,(2016) An assessment of urban vulnerability in the Amazon Delta and Estuary: a multi-criterion index of flood exposure, socio-economic conditions and infrastructure. *Sust Sci*. doi:10. 1007/s11625-016-0355-7
- Mark Pelling,(2011), *Adaptation to Climate change: from Resilience to Transformation* by Routledge 2 Park Square, Milton Park, Abingdon, Oxon, OX14 4RN Simultaneously published in the USA and Canada by Routledge, 270 Madison Avenue, New York, NY 10016 *Routledge is an imprint of the Taylor & Francis Group, an informa business*
- Marshall, N.A., (2010). Understanding social resilience to climate variability in primary enterprises and industries. *Global Environmental Change* 20, 36–43.
- Marshall, N.A., Marshall, P.A., (2007). Conceptualizing and operationalizing social resilience within commercial fisheries in northern Australia. *Ecology and Society* 12, 1.
- McClanahan, T.R., Cinner, J.E., Maina, J., Graham, N.A.J., Daw, T.M., Stead, S.M., Wamukota, A., Brown, K., Ateweberhan, M., Venus, V., Polunin, N.V.C., (2008). Conservation action in a changing climate. *Conservation Letters* 1, 53–59. 697–709
- McGinnis, M. D., (2011). Networks of adjacent action situations in polycentric governance. *Policy Studies Journal* 39(1):51-78.

- McGinnis, M. D., & Ostrom, E.(2014). Social-ecological system framework: initial changes and Continuing challenges. *Ecology and Society*, 19(2), 30.
- Mugenda, O.M. and Mugenda A.G., (2010).Research Method; Qualitative and Quantitative approaches. African Centre for technology studies (ACTS) press – Nairobi (Kenya)
- Nature, (2007) "Adaptation To Global Climate Change Is An Essential Response To A Warming Planet". 2007-02-08. Retrieved 2010-01-06.
- Ndegwa, Peter et.al.,(2015): Assessment of Factors Influencing Food Security in Wenje Division, Tana River County – Kenya, in: Food Science and Quality Management, Vol.44. <http://www.iiste.org/Journals/index.php/FSQM/issue/view/2112> [accessed 4 February, 2018]
- Nguyen TTH, De Bie CAJM, Ali A, Smaling EMA, Chu TH., (2012): Mapping the irrigated rice cropping patterns of the Mekong delta, Vietnam, through hyper-temporal SPOT NDVI image analysis. *Int J Remote Sens* 33:415–434. doi:10.1080/01431161. 2010.532826
- Nyong, A., Dabi, D., Adepetu, A., Berthe, A. & Ihemegbulem, V. C.,(2008). Vulnerability in the Sahelian zone of northern Nigeria, a household level assessment. In Leary, N., Conde, C., Kulkarni, J., Nyong, A. and Pulhin, J. (eds). *Climate Change and Vulnerability*. Earthscan, London, UK.
- O’Connell, D., Walker, B., Abel, N., Grigg, N., (2015) *The Resilience, Adaptation and Transformation Assessment Framework: from theory to application*. CSIRO, Australia.
- O’Brien, K., Eriksen, S., Schjolen, A. and Nygaard, L.,(2004). What’s in a word? Conflicting interpretations of vulnerability in climate change research. CICERO Working Paper 2004:04. 16 p. Internet file retrieved on 26th July 2011 from <http://dspace.cigilibrary.org/jspui/bitstream/123456789/7304/1/>
- O’Brien, K., Eriksen, S., Nygaard, L. P. and Schjolden, A.,(2007). Why different interpretations of vulnerability matter in climate change discourses. *Climate Policy* 7:73–88.
- Ohl, C., Krauze, K. and Grünbühel, C., (2007). Towards an understanding of long-term ecosystem dynamics by merging socio-economic and environmental research: Criteria for long-term socio-ecological research sites selection. *Ecological Economics*, 63(2–3): 383- 391.
- Ostrom, E. (2005). *Understanding institutional diversity*. Princeton University Press, Princeton, New Jersey, USA.
- Ostrom E.,(2007).A diagnostic approach for going beyond panaceas. *Proceedings of the National Academy of Sciences* 104 (39):15181-15187. <http://dx.doi.org/10.1073/pnas.0702288104>
- Ostrom, E.,(2009). A general framework for analyzing sustainability of social-ecological systems. *Science*, 325(5939), 419-422
- Ostrom, E. (2010). Beyond markets and states: polycentric governance of complex economic systems. *American Economic Review* 100(3):641-672. <http://dx.doi.org/10.1257/aer.100.3.641>
- Ostrom, E., and M. Cox.,(2010). Moving beyond panaceas: a multitiered diagnostic approach for social-ecological analysis. *Environmental Conservation* 37(4):451-463. <http://dx.doi.org/10.1017/S0376892910000834>
- Ostrom, E., (2013). Do institutions for collective action evolve? *Journal of Bioeconomics*: 1-28
- Pelling, M., High, C., Dearing, J. and Smith, D.,(2007) Shadow Spaces for Social Learning: A Relational Understanding of Adaptive Capacity to Climate Change within Organisations, *Environment and Planning A*, 40(4): 867–84.
- Perry, R.I., Ommer, R.E., Barange, M., Jentoft, S., Neis, B. and Sumaila, U.R.,(2011). Marine social-ecological responses to environmental change and the impacts of globalization. *Fish & Fisheries*, 12(4): 427-450.
- Pollnac, R., Crawford, B., (2000). Assessing Behavioural Aspects of Coastal Resource Use, Proyek Pesisir Publications Special Report. Coastal Resources Center, University of Rhode Island, Narragansett, Rhode Island, USA, p. 139.
- Pulhin, J. M., Peras, R., Cruz, R., Lasco, R., Pulhin, F. and Tapia, M.,(2008). Climate variability and extremes in the Pantabangan-Carranglan watershed of the Philippines, an assessment of vulnerability. In Leary, N., Conde, C., Kulkarni, J., Nyong, A. and Pulhin, J. (eds). *Climate Change and Vulnerability*. Earthscan, London, UK.
- Republic of Kenya., (2013) National Climate Change Action Plan 2013 – 2017. Nairobi, Kenya: Government of Kenya. <http://bit.ly/1AkMWsU>.
- Richard Heeks and Angelica Ospina., (2011),Disaster Management, Developing Country Communities & Climate Change: The Role of ICTs, <http://www.niccd.org>
- Roberts DW (1996) Modelling forest dynamics with vital attributes and fuzzy systems theory. *Ecol Modell* 90:161–173. doi: 10.1016/0304-3800(95)00163-8
- Rogers, E. M., (1995) *Diffusion of Innovations*, New York: The Free Press.
- Rubin, Donald B.(2005). Causal Inference Using Potential Outcomes. *Journal of the American Statistical Association* 100 (469): 322-331.
- Saaty T. L.,(1980). The analytic hierarchy process: planning, priority setting and resource allocation. McGraw-Hill, New York "Themes and Issues in Disaster Risk Reduction" (PDF). UNISDR. Retrieved 2012-08-02
- Schipper, E. L. and Pelling, M.,(2006) Disaster Risk, Climate Change and International Development: Scope and Challenges for Integration, *Disasters*, 30(1): 19–38.

- Sebesvari Z, Renaud FG, Haas S, Tessler Z, Hagenlocher M, Kloos J, Szabo S, Tejedor A, Kuenzer C., A review of vulnerability indicators for deltaic social–ecological systems, (2016), *Sustain Sci* DOI 10.1007/s11625-016-0366-4
- Shadish, William R, Thomas D Cook, and Donald Thomas Campbell.(2002). *Experimental and Quasiexperimental designs for generalized causal inference*. Wadsworth Cengage learning.
- Silvert W., (2000) Fuzzy indices of environmental conditions. *Ecol Modell* 130:111–119. doi:10.1016/S0304-3800(00)00204-0
- Smit, B., Burton, I., Klein, R. J. T. and Wandel, J.,(2000) AnAnatomy of Adaptation to Climate Change and Variability, *Climatic Change*, 45: 223–51.
- Stanton, E. A., Ackerman, F. and Kartha, S, (2008) *Inside the Integrated Assessment Models: Four Issues in Climate Economics*, Working Paper WP-US-0801, Stockholm Environment Institute. Accessed 10/05/2010 from <http://devweb2.sei.se/us/WorkingPapers/WorkingPaperUS08-01.pdf>
- Tãnzler D, Carius A.,(2008) Assessing the susceptibility of societies to droughts: a political science perspective. *Reg Environ Change*. XX
- TEEB.,(2010b). *The economics of ecosystems and biodiversity: mainstreaming the economics of nature: a synthesis of the approach, conclusions and recommendations of TEEB*. TEEB, October 2010.
- Tigkas D & Vangelis H & Tsakiris G.,(2015), DrinC: a software for drought analysis based on drought indices, *Earth Sci Inform* (2015) 8:697–709 DOI 10.1007/s12145-014-0178-y
- Tsakiris G, Pangalou D, Vangelis H (2007) Regional drought assessment based on the reconnaissance drought index (RDI). *Water Resour Manag* 21(5):821–833
- Turner II, B. L., Kasperson, R. E., Matson, P. A., McCarthy, J. J., Corell, R. W., Christensen, L., Eckley, N., Kasperson, J. X., Luers, A.,Martello, M. L., Polsky, C., Pulsipher, A. and Schiller, A.,(2003). A framework for vulnerability analysis in sustainability science. *Proceedings of the National Academy of Sciences* **100**:8074–8079.
- United Nations, 1992, United Nations Framework Convention on Climate Change, Rio de Janeiro, Brazil, www.unfccc.int/text/resource
- UN (United Nations), (2009): Global Assessment Report on Disaster Risk Reduction. Risk and poverty in a changing climate United Nations, Geneva
- UN (United Nations), (2011):Global Assessment Report on Disaster Risk Reduction. Revealing risk, redefining development United Nations, Geneva
- UN (United Nations), (2013):Global Assessment Report on Disaster Risk Reduction 2013. From Shared Risk to Shared Value: the Business Case for Disaster Risk Reduction. United Nations, Geneva
- United Nations Framework Convention on Climate Change.,(2013). Workshop on the Monitoring and evaluation of adaptation, Nadi, Fiji, 9–11 September 2013 [Background Note].Bonn,Germany:Author. http://unfccc.int/files/adaptation/cancun_adaptation_framework/adaptation_committee/application/pdf/ac_m&e_ws_background_note_16august2013.pdf
- Uphoff, N. (1993) Grassroots Organizations and NGOs in Rural Development: Opportunities with Diminishing States and Expanding Markets, *World Development*, 21(4): 607–22.
- Vaidya, O. and S. Kumar.,(2006). Analytic Hierarchy Process: An Overview Of Applications. *European Journal of Operational Research* Volume 169, Issue 1, 16:1–29
- Walker, B., Holling, C. S., Carpenter, S. R. and Kinzig, A.,(2004). Resilience, adaptability and transformability in social–ecological systems. *Ecology and Society*, 9(2): 5-9.
- Walker, G., Devine-Wright, P., Hunter, S., High, H., & Evans, B.,(2010). Trust and Community: Exploring the meanings, contexts and dynamics of community renewable energy. *Energy Policy*, 38(6), 2655–2663.
- Wambua RM, Mutua BM, Raude JM., (2014) Drought Forecasting Using Indices and Artificial Neural Networks for Upper Tana River Basin, Kenya-A Review Concept. *J Civil Environ Eng* 4: 152. doi:10.4172/2165-784X.1000152
- Westley, F., Tjornbo, O., Schultz, I., Olsson, P., Folke, C., Crona, B. and Bodin, Ö.,(2013). A Theory of Transformative Agency in Linked Social-Ecological Systems, in *Ecology and Society* 18 (3) : 27.
- Wisner, B., (2006) *Let Our Children Teach Us: A Review of the Role of Education and Knowledge in Disaster Risk Reduction*, Geneva: ISDR and Action Aid.
- Wisner, B., Blaikie, P., Cannon T. and Davis, I. (2004) *At Risk: Natural Hazards, People’s Vulnerability and Disaster*, London: Routledge.
- Wu H-I, Li B-L, Stoker R, Li Y., (1996) A semi-arid grazing ecosystem simulation model with probabilistic and fuzzy parameters. *Ecol Modell* 90:147–160. doi:10.1016/0304-3800(95)00162-X
- Young, O.R., Berkhout, F., Gallopin, G.C., Janssen, M.A., Ostrom, E. and Van Der Leeuw, S., (2006). The globalization of socio-ecological systems: An agenda for scientific research. *Global Environmental Change*, **16**(3): 304-316.
- Young, O.R., King, L.A., Schroeder, H., (2008). Building regimes for socioecological systems: institutional

diagnostics. In: Young, O.R., King, L.A., Schroeder, H. (Eds.), *Institutions and Environmental Change: Principal Findings, Applications, and Research Frontiers*. MIT Press, Cambridge, MA.

Ziervogel, G., Nyong, A., Osman, B., Conde, C., Cortés, S. and Downing, T.,(2008). *Climate Variability and Change: Implications for Household Food Security*. AIACC Working Paper No. 20, January 2006. 32 pp. Internet file retrieved on 17th August 2011 from http://www.aiaccproject.org/working_papers/Working%20Papers/AIACC_WP_20_Ziervogel.pdf.