ASSESSMENT OF AGRICULTURAL VULNERABILITY DUE TO CLIMATE CHANGE THROUGH EXPOSURE, SENSITIVITY AND ADAPTIVE CAPACITY BASED ON COMPOSITE INDEX: A CASE STUDY OF KENYA’S AGRO ECOLOGICAL ZONES

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Introduction

- Kenya’s economy is anchored on the agricultural sector which generates 26% of the country’s GDP, 75% of the employment and two thirds of the export revenues.

- Anthropogenic activities have increased GHG emissions which are the main cause of successive warming of the earth’s surface during each of the last three consecutive decades resulting to increased climate and weather deviation.

- Food crop production will be impacted negatively by climate change due to overreliance on rain for agricultural production that increases vulnerability to climate change; poor infrastructure; low levels of human and physical capital and high poverty levels.

- Climate change is already causing a decline in agricultural production in Kenya despite the government intensifying food crop production against a background of increasing population, limited arable land and predicted adverse climate conditions.

- In 2014 the country’s economic growth declined to 5.3% as compared to 5.7% growth in 2013. Agriculture recorded an even lower growth of 3.5% in 2014 as compared to 5.7% growth recorded in 2013 due to erratic rains in 2014.
Introduction

- Despite the deep in growth, agriculture still emerged as the leading contributor to the economy contributing 27.3% of the country’s GDP underscoring its pivotal position in the country’s economy.

- Adverse impact of global warming on agriculture in the future puts the country in a detrimental situation.

- Elaborate measures must be adopted to reduce the degree to which agricultural systems will be unable to or susceptible to adverse impacts of climate change and adapt to the changes.

- The aim of this study is to assess the vulnerability of agriculture due to climate change by developing agricultural vulnerability indices for the humid agro ecological zones in Kenya.

- Agricultural vulnerability indices will be significant in understanding food production potential of humid agro ecological zones under climate change and formulation of adaptation strategies that will enhance adaptive capacity of the Kenyan agricultural sector.
Problem Statement

- Classification of the agro-ecological regions is based on climate, vegetation, soils and potential land use.

- Growth of crops is largely influenced by rainfall intensity and duration, the correlation between potential evapo-transpiration and yearly rainfall and the year-to-year variation in rainfall. Evapo-transpiration depends on the prevailing atmospheric temperatures.

- Climate change alters the optimal temperature and rainfall required for optimal agricultural production in humid agro-ecological zones causing erratic and unpredictable weather and climate that is bound to jeopardise production.

- Agricultural vulnerability largely depends on the extent and magnitude of climate change and the ability of the agricultural systems to cope with or adapt to the changes.
Main Objective

- Potential impacts of climate change are determined by the exposure and sensitivity of the system to variation in precipitation or temperature and its adaptive capacity.

- The main objective of the study is to assess the agricultural vulnerability in Kenyan humid agro ecological zones due to climate change through exposure, sensitivity and adaptive capacity based on composite index.

Specific Objectives

- To review current knowledge on vulnerability, trends in climate, and impacts of climate variability and change on agriculture sector.

- To assess the food production potential of humid agro-ecological regions on the basis of agricultural vulnerability index.

- To explore technical and policy alternatives in order to cope with and adapt to impacts of climate.
Justification.

- Kenyan economy depends significantly on agriculture which is currently facing challenges due to growing population, food security, environmental degradation and climate change. 98% of agriculture in Kenya is rain-fed making it highly vulnerable to climate variability and change.

- The extent, trend and available information concerning climate change and its impacts should be assessed to generate information required for decision making and formulation of policies that will reduce susceptibility of agricultural systems to climate change.

- Climate, soils, vegetation and land use potential determine the agricultural potential of a region. Climate change is altering the conditions of such areas skewing their agricultural and food production potentials.

- Agricultural vulnerability index will be used in identifying agricultural and food production potential of the humid agro-ecological zones, highly vulnerable regions to climate change that require robust agricultural production system.

- The study will determine impact of climate change on agriculture, recommend the policy response options that can be used to mitigate and adapt to the economic impact of climate variability and change on agriculture and food security in Kenya.
Area of study

- Kenya is divided into seven agro-climate zones basis of moisture index; annual rainfall expressed as a percentage of potential evaporation, farming systems, rainfall, and vegetation.

- High potential areas make up only 12% of Kenya’s land mass. They are designated zones I, II and III and have moisture index greater than 50%, mean annual temperature below 18°C and an altitude of 1200m.

- They are mostly suitable for livestock rearing (mostly cattle and sheep), cultivation of cash crops (coffee, tea and pyrethrum) and key food crops (maize, beans and wheat).
Kenya’s agro climatological zones
Literature review

Socio-economic Approach

- Gender, health status, technology, information access, level of education, wealth, accessibility to credit and political power are socio economic and political factors that are used to determine socioeconomic vulnerability of people.
- Institutional and economic changes in a society are key as they shape vulnerability of people.
- Internal characteristics of individuals or communities are used to identify their adaptive capacity in the socio economic vulnerability assessment approach.
- Focus on variation between individuals or within the communities is the main setback of socioeconomic vulnerability assessment approach.
Bio-Physical Approach

- The biophysical vulnerability assessment approach focuses on examining the destruction level that is caused by a specific environmental disaster on biological and social systems.

- Climate prediction models play a vital role in generating estimates or forecasts that are used to estimate the damage caused by environmental stresses.

- Estimation of the damages can also be achieved by creating sensitivity indicators through identification of potential or real hazards including their frequencies.

- The biophysical approach has a limitation of only considering the physical damages like yield reduction and does not illustrate what the changes mean to different communities and people.
Integrated assessment approach

- Vulnerability is determined by integrating both socio-economic and biophysical approaches.

- IPCC’s definition in 2001 describing vulnerability as a function of adaptive capacity, sensitivity, and exposure accommodates the integrated approach to analysis of vulnerability.

- Absence of standard for integrating the biophysical and socio-economic data sets is the main limitation of this approach.

- Different variables of unknown weights are used in this approach but no common metric for assessing the relative significance of individual variable or the relevance of social and biophysical vulnerability is used.

- Inability for this method to account for dynamism in vulnerability is the other limitation.
Methods for measuring vulnerability to climate change

Econometric method

- Utilizes data from household socio-economic survey in the analysis of vulnerability level of various social groups and has its origins from literature on poverty and development.

Vulnerability as expected poverty

- Looks at a person’s vulnerability as the possibility of that person becoming poor in the future if he is not poor currently or prospects of that person continuing to be poor if poor currently

- It is based on estimating the probability that a specific shock or collection of shocks shifts the level of consumption by a family unit to remain under the required minimum or forces the consumption level to stay under the lower threshold that is required if it is already at that level

Vulnerability as low expected utility

- It is defined as the difference between the expected consumption utility and the utility derived from some level of certainty equivalent consumption at and above, which the household would not be considered vulnerable

Vulnerability as uninsured exposure to risk

- It is based on ex post assessment of the extent to which a negative shock causes welfare loss

- Shocks impose a welfare loss that is materialised through reduction in consumption in the event that risk-management tools are absent.

- This method may not be applicable in the absence of panel data sets that are used to assess the impacts of shocks to quantify the shift in induced consumption.
The indicator Approach

- Composite indices capture multi-dimensional nature of vulnerability in a form that is comprehensible by selecting a set of potential indicators and then merging them systematically.

- The first option in this method makes an assumption that all vulnerability indicators have equal significance hence generate weights that are equal.

- The second option, assigns different weights to the vulnerability variables considering that they are diverse.

- Although the indicator approach is appropriate for monitoring and exploring conceptual frameworks, application of the indices is constrained by a selection of variables and their weights being subjective, data availability at different scale, and difficulty in testing or validating different metrics.

- This study intends to assess the agricultural vulnerability due to Climate Change in Kenya’s humid zones based on composite Index and therefore the indicator approach will be most appropriate.
The analysis in this study will be done on the basis of the vulnerability definition given by Intergovernmental Panel on Climate Change. According to IPCC, vulnerability is the ease with which a system is affected or responsive to, or unable to cope with adverse effects brought about by climate change, climate variability and extremes. It is determined by; the character, magnitude and climate variation rate to which a system is exposed, its sensitivity and adaptive capacity.

The first aspect of vulnerability is represented by a system’s exposure to climate variations. The second one is an internal aspect that is more complex and is represented by a system’s sensitivity and adaptive capacity to the climate variations.

Normally, connection exists between exposure and sensitivity and they both contribute to the potential impact of climate related stressors. Vulnerability is therefore an aggregation of exposure, sensitivity and adaptive capacity.

The schematic illustration of the conceptual framework given below gives the conceptual model of how logical sense was arrived at as regards several variables that are considered significant in assessment of agricultural vulnerability and the relationships among them.
Climate (Rainfall, Temperature, extreme events)

Exposure

Ecological Sensitivity

Demographic Sensitivity

Socio economic Capacity

Adaptive Capacity

Sensitivity

Standardization

Principal Component Analysis (STATA)

Aggregation \( \frac{(E + S(1 - AD))}{3} \)

Agricultural Vulnerability Index

Potential for Food Crop Production
Data and Methodology

Choice of indicators

- Agricultural vulnerability indices for humid AEZs will be developed from variables of exposure, sensitivity, and adaptive capacity.

- **Exposure** indicates the nature, frequency, extent, and duration of weather conditions on the agricultural areas of a region.

- Three exposure indicators; mean annual temperature, mean annual rainfall and frequency of past climate extremes will be considered for assessment of exposure.

- The study will use historical rainfall and temperature data provided by the Kenya meteorological department spanning from 1980-2015

- **Sensitivity** is the responsiveness of a system to climatic stresses which is a function of socio-economic and environmental conditions.

- Sensitivity indicators will be grouped into ecological sensitivity (rate of irrigation, land degradation index and crop diversification index) and demographic sensitivity indicators (density of rural population and percentage of small scale farmers)
Adaptive Capacity

- The major determinant of adaptive capacity of individuals, households, or communities to reduce risk, to cope with and adapt to adverse impacts of climate change is their asset.

- Adaptive capacity indicators will be collectively grouped as social economic capacity indicators which include social capital (share of farmers in farm organisations), human capital (literacy rate), financial capital (farm income, farm assets, access to credit) and physical capital (infrastructure index).
Sampling Procedure and Sample Selection

- Multistage strategy will be used to carry out sampling.

- Cluster random sampling will be used to divide the geographical area covered by the humid agro ecological zones into districts.

- Systematic random sampling will be used to sample the individuals within the districts.

- Purposive sampling will be used to identify specific groups of people who depend on agriculture for their livelihoods and are adversely affected by climate change.
Vulnerability Index Calculation

- Normalization will be performed on the indicators to eliminate differences in scales and make sure that they are comparable using this formulae:

\[ Z_v = \frac{X_i - X}{SD} \]

- \( Z_v \) is the standardized value of variable \( v \), \( X_i \) is the observed value of \( v \), \( X \) is the mean value of the set of values \( i \), and \( SD \) is the standard deviation of the set of values \( i \).

- Assigning equal weights to the indicators is not appropriate because it is too subjective.

- Assigning of weights using the expert judgment method has a limitation in terms of expert knowledge availability especially in smaller communities and hitches in striking agreement on weights among expert panel members.

- Principal Component Analysis technique extracts those few orthogonal linear combinations of variables that most successfully capture the common information from a set of variables.
Vulnerability Index Calculation

- The first principal component of a set of variables is the linear index of all the variables that captures the largest amount of information common to all the variables.

- Generation of weights and construction of an overall vulnerability index is done using the first principal component:

\[ V_j = \sum_{i=1}^{k} \left\{ b_i (a_{ji} - x_i) \right\} / s_i \]

- \( V \) is the index of vulnerability, \( b \) is the weights from PCA 1, \( a \) is the indicator value, \( x \) is the mean indicator value, \( s \) is the standard deviation of the indicators, \( i \) is them indicators and \( j \) is the specific province.
Vulnerability Mapping

- In order to get final values using a scale ranging between 0 and 5, values of vulnerability will be normalized according to the equation:

\[ V_{\text{normalized}} = 5 * \frac{V - V_{\text{min}}}{V_{\text{max}} - V_{\text{min}}} \]

- In the equation, \( V_{\text{normalized}} \) is the vulnerability value for a specific humid AEZ, \( V \) is the vulnerability value for the humid AEZ, \( V_{\text{min}} \) is the minimum value of the set of values (v), and \( V_{\text{max}} \) is the maximum value of the same set of values (v).

- Five classes will be used to classify the normalized vulnerability values into the following scales: very high vulnerability, \( 4 \leq V_{\text{normalized}} < 5 \); high vulnerability, \( 3 \leq V_{\text{normalized}} < 4 \); medium vulnerability, \( 2 \leq V_{\text{normalized}} < 3 \); low vulnerability, \( 1 \leq V_{\text{normalized}} < 2 \); and very low vulnerability, \( 0 \leq V_{\text{normalized}} < 1 \).

- Spatial mapping of agricultural vulnerability to climate change in the humid AEZ's was done using these classifications.
EXPECTED RESULTS

- It is expected that this study will generate agricultural vulnerability indices of AEZs based on their exposure, sensitivity and adaptive capacity to climate change.

- The agricultural vulnerability indices will highlight those areas that are highly vulnerable to climate change and those that have low vulnerability.

- The study is expected to ascertain if climate change is occurring in the humid zones and to what extent.

- It is also expected that the indices will provide fundamental information that will be significant in formulation of policies and strategies for mitigation and adaption to climate change in the AEZs.
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