Climate Change Risk and Vulnerability Mapping and Profiling at Local Level Using the Household Economy Approach (HEA)

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Abstract

The increasing frequency of extreme climate events such as droughts and floods, as well as increasing temperatures and declining rainfall, are the expected future weather patterns of climate change hot spots such as Sub-Saharan Africa. Climate change and variability hot spot areas will be most vulnerable to diminishing crop production and water resources as most people in these areas depend on rainfed agriculture for their livelihoods. While much of climate change studies have been done at global scale, the impacts of climate change and variability will be felt locally at community level. In most cases adaptation occurs at local level in ways that are usually unnoticed and unaided by national governments or international organisations. This study down-scales the vulnerability of and adaptive capacity to climate change and variability to local level applying the Household Economy Approach. The focus is on local dimensions of climate change impact on water and agriculture in Western Zambia. A climate change vulnerability zone map is delineated using GIS, and a detailed profile of the zones is presented. The focus is on how communities cope with comparable climate change risks that occur today, like droughts, floods and pests, and then gauge their capacity to mitigate future CC shocks. Some adaptive measures that can be adopted to mitigate climate change impacts are recommended. The results equip policy makers with information on the impacts of climate change at local level, and capacitate them with a tool to make informed intervention.

Keywords: Water scarcity; Agriculture water; Irrigation; Water harvest; Adaptation capacity; Crop productivity

Introduction

It is envisaged that climate change (CC) will cause shifts in areas suitable for cultivation of a wide range of crops in Sub-Saharan Africa, whereas Europe and North America will experience an increase in area suitable for cultivation as they have the greatest capacity and resources to manage CC impact [1,2]. In Southern Africa farmers lack these resources making the region the most vulnerable to risk. The situation is worsened by the fact that crop production in Sub-Saharan Africa is almost entirely rainfed, meaning that once there is drought there will be total crop failure. According to Cooper [3], 89% of cereals in Africa are rainfed. Water in Southern Africa is a transient resource in both space and time and drought is a recurrent feature in the region and of late flash floods are a common occurrence. Climate influences development and it is now integrated into the African development agenda [4].

The impacts of CC on water and agriculture on the African continent can be very dire as agriculture constitutes approximately 30% of Africa’s GDP and contributes about 50% of the total export value, with 70% of the continent’s population depending on the sector for their livelihood [5,6]. CC and its impacts on water and agriculture are very crucial to the very survival of the continent and its people. Temperatures in Southern Africa are expected to increase in the range of 10°C to 30°C by as early as the 21st century [7] thereby bringing about variation in the cropping season and affecting livestock types that adapt to the present temperatures. The International Panel on Climate Change (IPCC) recognises that developing countries, especially Sub-Saharan African countries, are particularly vulnerable to CC [8]. Since the start of the Southern Africa food crisis in 2001, households and whole communities across the region have been subject to a variety of natural disasters and socio-economic shocks, which have undermined their ability to obtain sufficient food and income on a regular basis [9,10]. These shocks are attributed to CC and variability.

This study analyses the envisaged impacts of CC and variability on water and agriculture and the adaptive capacity of local communities to cope with these impacts in Western Zambia through CC risk and vulnerability mapping and profiling. The analytical tool used is the Household Economy Approach (HEA), developed by Lawrence et al., [11] and Seaman et al., [12]. The aim is to facilitate the implementation of long-term adaptation measures to increase the resilience of households and communities to the adverse impacts of CC and variability. The focus is on local dimensions of CC impact on water availability and agriculture productivity, focusing on how households and communities cope with comparable risks that occur today like droughts, floods, pests, crop failure, etc. and then an assessment of the factors that determine the capacity of local communities to deal with current and future CC and variability is made.

The study was done in Western Zambia which is within the Zambezi River Basin, one of the CC hot spot areas, highly vulnerable to the impacts of CC [13]. Some of the already evident impacts of CC in Western Zambia are:

(a) decrease in crop production due to low rainfall and shifts in agricultural patterns [13,14],
(b) High temperatures and the resulting high evaporation causing water unavailability [13,15],

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(c) Higher temperatures that are causing the spread of pests [8,16]
(d) Increased occurrences of floods as the incidence of sudden heavy rainfall events are increasing [17,18]
(e) There is an increase of water pollution and a decrease in water quality linked to erosion and high rainfall events [17,19].

Materials and Methods
Description of the study area

Western Zambia is within the Zambezi River Basin and most of its area is within the Western Province with a small northern part in the North Western Province. Western Zambia, like any other area within the Zambezi River Basin, is characterised by extreme climatic variability that adversely affects the riparian countries. The Zambezi River and its tributaries are subject to a cycle of floods and droughts that have devastating effects on the people and economies of the basin riparian countries. Rainfall patterns in Western Zambia are largely governed by the position of three systems; the Inter-tropical Convergence Zone near the equator, high-pressure cells south of the 20° parallel, and cold fronts at the southern tip of the African continent. Annual rainfall ranges from 700 mm to 1500 mm. Potential evapotranspiration exceeds average annual rainfall in most of the study area [20].

Western Zambia is over-reliant on rainfed agriculture for food production [21]. The livelihoods of the area are largely based on natural resources which are strongly affected by CC [22] and have a poor rural population [23]. The economy of Western Zambia is undiversified and comprised of poorly developed infrastructure. The area lacks public and private resources to deal with poverty and natural shocks like drought and floods. It lies in the western plateau of Zambia with an altitude of between 650 to 1300 m above sea level. The Ferralic Arenosols soils are infertile except in floodplains where soils are rich. The main crops grown are cassava, millet, nuts, rice maize, sorghum and vegetables. Cattle production, dairy and poultry farming are also practised. Figure 1 is a map showing the elevation and location of Western Zambia in Southern Africa.

According to Midgley et al [13], the Zambezi River Basin (where Western Zambia falls) is highly vulnerable to CC and variability because of multiple stresses and low adaptive capacity. The livelihoods of the people of the Zambezi River Basin riparian countries are often linked to the climate of the area.

The household economy approach (HEA)

The technique used to map and profile CC vulnerability zones is the Household Economy Approach (HEA), also called the food Economy Approach (FEA). The HEA is based on Amartya Sen’s theory of exchange entitlements and economic theories of risk [12,24]. It was first developed and used by major international agencies during the 1990s to assess the impact of shocks, such as natural disasters, on food security and livelihoods; it is now accepted as a standard methodology and is widely used by WFP, USAID, FAO, national governments and other donors [12]. More recently, it has been linked to macro and micro level policy analysis, particularly in relation to Poverty Reduction Strategy Papers (PRSPs) [11].

The HEA first describes and quantifies household economy or the way in which typical households, with defined wealth characteristics, survive in normal times. This understanding and quantification is then combined within an analytical framework to assess the current situation with respect to food and livelihood security and to predict the effects of changes in the external environment, for example, crop failure, increases in production costs or market prices, loss of markets, etc. [12].

There are four steps in a household economy analysis. The first two are concerned with dividing the population into groups of households that share similar characteristics in terms of their access to food and income. The assumption underlying these two steps is that access to food and income is determined by two main factors: geography and economic status (that is, relative wealth). While geography (where a household lives) determines the options for obtaining food and income, wealth generally determines a household’s ability to exploit those options. The third step involves developing a baseline picture of food access, income and expenditure for each wealth group. The fourth and final step is to combine information on baseline access with that on hazard and response in order to generate projections of future food and income access [11,13].

Applying the HEA in CC impact zoning

The principle underlying the understanding of CC impact on communities is based on that an analysis of local livelihoods is essential for proper understanding of the impact of hazards such as drought or crop failure [25]. A livelihood is the sum of ways in which people make their living [11,26]. Therefore, an understanding of livelihoods enables understanding the level and kind of impact likely to be faced by a community in case of CC hazard like flood, drought and diminished water resources. The first step in assessing the impact of CC is grouping a region into CC vulnerability zones based on climate and geography, and the livelihoods of the communities.

A CC vulnerability zone is an area within which people share broadly the same means of production and living, and these are influenced by climatic and geographic conditions. Levels of CC vulnerability vary from one area to another, and they are influenced by local factors such as climate and soil type [12]. The first step was to

![Figure 1: Elevation, location and shape of Western Zambia.](image-url)
prepare a CC vulnerability zone map, delineating geographical areas within which people share basically the same patterns of access to food (i.e. they grow the same crops, keep the same type of livestock, collect the same type of wild fruits, etc.), share the same type of climate and have the same access to markets. Figure 2 is a map of CC vulnerability zones of Western Zambia delineated on the basis of agro-ecological zones [27-30]. Agro-ecological regions are determined by soil types, temperature, rainfall, mountain ranges or rivers. A CC vulnerability zone map divides a country into homogenous zones defined according to soil types, climate, geography and means of production. Besides being a CC vulnerability map, the map on Figure 2 also represent the agro-ecological zones of Western Zambia.

Field work was carried out in each defined CC vulnerability zone, collecting information on wealth, sources of food and income, patterns of expenditure, bad year coping strategies, and seasonal calendar. Data was collected from district and community level key informants and community level focus groups. A wealth classification of the zones is made according to how communities are able to exploit the available options within a given zone. The ranking of a zone was based on wealth aspects such as land holdings, livestock holdings, capital, education, skills, and labour availability. The zones are classified as poor, middle or better off. A community whose zone is classified as poor will not be able to cope when a hazard strikes. The community in a middle class zone are able to cope to some extent, but the better off community will be able to cope to a larger extent.

CC vulnerability profiling

The zone profiles are divided into zone description, CC vulnerability, and adaptive strategies. The profiles are compiled through a combination of field work and reference to secondary data sources especially from Central Statistical Office of Zambia (Zamstats). The methodology to profile the zones is demonstrated through an analysis of the Zambezi West Bank Zone. Profiles for the rest of the zones are indicated in Table 3.

Profiling the Zambezi west bank CC vulnerability Zone

Zone description and general characteristics: The Zambezi West Bank Zone is generally a floodplain ecosystem. It is a poor zone bordering with Angola to the west, south and north, whilst to the east the Zambezi River forms the natural boundary. It has population of approximately 262,000 people. Livelihoods are based on small-scale subsistence agriculture, livestock rearing and fishing. The main food crops cultivated are cassava, maize, rice and millet. A small quantity of the cultivated crops like rice and cassava are traded locally. Other crops that are cultivated in small quantities are sweet potatoes, groundnuts and beans. The soils are deep Kalahari sands with sparse vegetation consisting mainly of grasslands that support cattle, goats and rich wildlife. Chicken rearing is practised at a small scale. Cattle are essential as income sources as well as for ploughing, pulling carts and providing manure.

The Zambezi West Bank Zone is prone to chronic and periodic hazards such as floods and cattle disease. Cattle production is threatened by disease, which has claimed the lives of 30-40% of animals in the last few years [29,31]. The effects of livestock death have already started showing in the form of loss of draught power, manure, and loss of cattle sales income or potential exchange for other goods.

The Zambezi West Bank is mostly rural and inaccessible due to poor infrastructure arising from the nature of the terrain and remoteness. The zone has no passable road network making it one of the most inaccessible parts of Zambia, limiting imports and exports. The am bezi River is crossed by pontoons (small boats), which farmers use to transport their produce to town markets. The community exports cattle, fish, and rice and forest products. The zone is a cereal (maize) deficit zone. Maize is the staple food yet it is imported from other regions as the zone does not produce enough to feed itself. The seasonal calendar of major agricultural and economic activities and natural hazards of the zone is shown in Figure 3.

According to Figure 3, all food and income acquisition strategies in this zone revolve around the rainy and flood seasons. The rainy season usually begins at the end of November and continues through March. The communities are better off during the harvesting period between March and May, while the months leading up to the harvest (September to February) are the most difficult months in terms of food security. Floods normally occur in January through to March, but in some instances of very high floods the problem prolongs until June. Fishing which is an important source of income and food lasts from March through November.

The Zambezi West Bank Zone is a poor zone where the major determinant of wealth is cattle ownership. The average livestock ownership per household is 10 heads of cattle and 4 goats. Food relief is a major characteristic of the zone as most families are not able to produce enough to take them throughout the year. Relief food accounts for 3-5% of the food needs of the community [32]. Wild foods (including seeds, fruits and tubers) contribute 5% of annual food needs in the zone [32].

CC vulnerability: CC has impacted the Zambezi West Bank Zone by the prevalence of cattle disease which is reducing livestock numbers and productivity every year. Floods damage crops, grazing areas and houses and block communications on an annual basis, but they also bring fish which are a major source of income and food. Dry spells are a common feature, as well as crop diseases. Early warning indicators for hazards include delayed start to the rainy season or long periods without rain at critical stages for crop development. These are followed by dry season indicators like staple food price rise and increased livestock sales, then negative consequences can be expected
in the communities. Table 1 shows the major indicators of imminent crisis caused by CC annually in the Zambezi West Bank Zone.

**Adaptive strategies:** When faced with reduced crop production or water deficiency, the community in the Zambezi West Bank Zone uses various response strategies like livestock sales, excessive exploitation of forest resources, and collection of wild foods. In bad seasons expenditure is more directed towards essential goods. Labour migration increases in bad seasons as well as migration to fishing camp sites. Table 2 lists the impact of CC already evident in the zone and the possible adaptive measures that can be implemented to reduce the impact.

**Benefits of CC the zones and profiles:** CC vulnerability zoning and profiling offer an analysis of CC impact and adaptation strategies on a geographical basis and at community level. The zoning and profiles help in making targeted interventions in case of CC impact and to mitigate CC impacts. The profiles are useful on three levels as follows [19]

- **A guide to the impacts of CC at local level:** The results unpack the impacts of CC on communities who share common resources for their livelihoods, assess food security situations in defined geographic zones, and determine intervention strategies depending on the conditions of each geographic zone. The results assist development planners in identifying the degree of vulnerability of communities to CC, and to find ways of reducing their vulnerability and increase their capacity to cope.

- **Early warning system:** The CC vulnerability profiles help to understand community capacity to adapt to CC and variability, especially failed crop or livestock production, or drought. The profiles are useful in answering questions like

  - (i) Which areas and what types of communities are likely to cope should a hazard strike?
  - (ii) Which geographical zones need assistance?

| Season | Month | Indicator |
|--------|-------|-----------|
| Rainy season | Nov | Late start and early cessation of rains |
| | Dec | Long periods without rain at critical stages of crop development |
| | Jan | Long periods without rain at critical stages of crop development |
| | Feb | |
| | Mar | Destruction of crops by floods before maturing |
| Dry season | Apr | |
| | May | |
| | Jun | Increased sales of livestock at low prices immediately after harvest |
| | Jul | High staple food prices after harvest season |
| | Aug | |
| | Sep | |
| | Oct | |

Table 1: Indicators of imminent crisis due to climate change in the Zambezi West Bank Zone.

| Climate Change impact | Adaptive Strategy |
|-----------------------|-------------------|
| Floods | Permanent solutions to flood damage through selection of safe settlement areas for the community and construction of small dykes to protect crop fields from floods |
| Lack of draught power and loss of income due to livestock death | Switch to more resilient livestock production systems. Restocking schemes and other agricultural loans that are carefully tailored to the area |
| Cattle diseases | Support to disease control programmes, timely vaccination, and restriction of movement of livestock |
| Damaged roads by floods, causing problems of marketing agricultural produce | Small-scale and locally appropriate road improvement schemes |

Table 2: Climate change impact and adaptive strategy in the Zambezi West Bank Zone.
(iii) What types of intervention will be most appropriate?

Early warning institutions will have knowledge on the vulnerability of communities in a country. The HEA helps to provide a framework for the full use of that knowledge, as well as adding a new level of information to it.

c) Policy development: Disaster management has been the main impetus to the spread of early warning systems. The rationale in early warning is to improve the efficiency in the scale and timing of intervention in an emergency. However, increasingly planners, scientists and institutions are looking at alternatives to reduce the envisaged impact of CC on communities by early intervention. The intervention often requires changes in policy and practice and the HEA is a useful tool to this effect.

Results and Discussions

The gathered information on each zone’s climatic, geographic and economic characteristics, as well as CC vulnerability and adaptive strategies is profiled as shown in table 3. With clearly defined and mapped CC vulnerability zones (shown on the map in Figure 2) and
the gathered information from fieldwork a profile for each zone is made. The profiles give information on economic activities, sources of livelihoods, possible CC impact and adaptive capacity of communities to withstand CC impacts. The profiles are structured primarily to aid early warning activities.

The profiles presented in Table 3 show that vulnerability to CC impacts in Western Zambia will be severe. Some of the CC impacts are already evident in the region. The severity of the region to CC impacts is mainly due to the high dependence of the communities to climate-sensitive sectors of agriculture and fisheries. Agriculture is generally rainfed, except in floodplain areas where there is irrigation at a small scale. The high dependence on rainfed agriculture has compromised food security as crops are produced once a year because rainfall is seasonal, falling between November and March. From April to September the land remains fallow. Reliance on rainfed agriculture has resulted in total crop failure in years of drought as irrigation is almost non-existent. Household food security improves in the post-harvest months, but in the months prior the planting season households are food insecure, to the extent of requiring food aid.

Livestock, which is a major source of income and food supplement in times of a shock, is affected by diseases because of the rising temperatures. Chronic CC shocks presently experienced in the region are drought, floods and cattle disease. Low lying areas are affected by perennial floods, but uplands are affected by prolonged dry spells, both of which affect crop production. The problem of vulnerability to CC impacts is worsened by poor crop marketing and accessibility.

The profiles show that Western Zambia is a generally poor rural region, where crop production is low, the level of poverty is high, and human, institutional, economic, technical, and financial capacities are limited. Strategies that can be adopted to mitigate CC impact include introducing water harvesting techniques, use of groundwater and encourage irrigation agriculture that crops may be grown throughout the year to ensure food security.

The described geophysical, climatic and economic characteristics of Western Zambia have made the region to be pronounced as a climate change hot spot zone.

Conclusion

CC vulnerability mapping and profiling offer an analysis of CC vulnerability on a geographical basis. A country or a region is divided into homogenous zones defined according to a CC vulnerability framework. The mapping and profiling of CC vulnerability zones facilitate the implementation of long-term adaptation and mitigation measures to increase the resilience of communities to the adverse impacts of CC and variability. The methodology used can be exported to other areas as it an important tool that ensures decision makers and farmers have access to relevant knowledge and information on the effects of CC and variability in order to enhance timely intervention and adaptive capacity respectively. The zones and profiles are essential in making targeted interventions in case of CC impact and mitigate those impacts.

The application of the HEA in mapping and profiling CC vulnerability at local level gives a baseline picture of how communities survive during a normal year and during a CC shock like drought. The approach is important in projecting future impacts of CC as it is an early warning tool and therefore, essential for decision makers to make early intervention. The approach provides an important and reliable CC baseline picture for each zone based on field work and interviews with key informants. In order to meet the food requirements of the rising population of CC hot spots areas there is need to stimulate CC adaptive capacity through CC risk and vulnerability mapping. Adaptive capacity is strengthened by potential access to water, which is only possible through the development of suitable and affordable technologies like rain water harvesting and storage and the use of groundwater for irrigation.

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