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Climate change impacts and adaptation strategies in Kilimanjaro transect in Tanzania

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Climate change and variability exerts multiple stresses at different spatial and temporal scales on the biophysical as well as the social-economic and institutional environments in Kilimanjaro transect in Tanzania. The primary stresses include climate risks such as drought and flood, which in turn trigger secondary stresses such as the spread of water borne diseases, increased competition for resources, disruption of ecosystem services, habitat and biodiversity losses. This paper presents the key findings of the study which investigated the impacts of climate change on socio-economic activities and existing local adaptation strategies. The study was undertaken across the Kilimanjaro transect located in Pangani river basin upstream of Nyumba ya Mungu dam in Tanzania. The study area was sub-divided into three agro ecological zones namely: lower, middle and upper zone. Three villages were sampled purposively one from each zone in order to capture various economic activities requiring water as an input for development. Both quantitative and qualitative methods were used for data analysis. The study shows that, traditional surface irrigation (flooding) methods is the most common adaptation strategy for crop production and account for more than 79% of the total irrigation schemes in the study area. However, traditional irrigation schemes are characterized by poorly constructed and temporary infrastructures that are usually associated with significant water losses and low crop productivity. Therefore, promotion of efficient irrigation water use through research and adoption of good farming practices is, critical to ensuring sustainable use and management of the water resources for sustaining water availability for other socio-economic sectors. This study recommends application of Ecosystem-based Adaptation (EBA) approach that integrates the use of biodiversity and ecosystem services into climate change adaptation strategies.

Key words: Climate variability, climate change impacts, Rainfall Anomaly Index, irrigation, Kilimanjaro transect.

INTRODUCTION

Climate change has been declared unequivocal by IPCC in its Fourth Assessment Report (IPCC, 2007), and its impacts are already being observed in all sectors of agriculture, food, water, health, and energy (Schipper et al., 2008). For example, precipitation, temperature, and water availability for agricultural purposes will continue to be affected in many parts of the world as a result of climate change. This will cause agricultural productivity to decline by a third by 2050 (Ehrhart, 2008).

Similarly, impacts on health are on the rise due to poverty and the limited capacity of certain populations to access health care (Schipper et al., 2008). It is predicted that a reduction in local water sources will lead to increased demand on regional water supplies.

Changes in precipitation patterns may lead to reductions in river flows and falling groundwater tables, and cause saline intrusion in rivers and groundwater in coastal areas.

The Kilimanjaro transect in Tanzania like other areas in the country is vulnerable to climate change through its impacts on food production, water resources and human health among others. The adverse effects of climate change may particularly be felt by poor communities because of their low adaptive capacity associated with limited financial resources, poor infrastructure, low level of education, dependence on natural resources and lesser access to technology.

According to Agrawal et al. (2003) the sectors potentially impacted by climate change in Tanzania include agriculture, forests, water resources, coastal resources, human health, energy, industry and transport. Given the low level of human development, poverty, and high dependence on agriculture and natural resources, the area is considered to be vulnerable to future climatic

changes. For instance, the 2006 floods were reported to destroy crops and properties along the lowlands of northern Kilimanjaro, where about, 19,000 people became homeless, 998 houses submerged and 1,459 hectares of cropland destroyed (Asaba, 2009). Since then, extensive studies have been conducted in Kilimanjaro region especially around the Mount Kilimanjaro on climate change and shrinking glaciers. Those studies have focused on changes in temperature, humidity and precipitation patterns (Mölg et al., 2008; Thompson, 2010; Thompson et al., 2011).

However, rarely have these studies investigated the impacts of climate change on socio-economic activities and evaluate the existing local adaptation strategies. Adaptation is an adjustment of a system to moderate the effects of climate change to take advantage of the new opportunities (Osbahr et al., 2010). Adaptation to climate change requires intervention and coordination of the formal and informal institutions (Agrawal, 2008).

METHODOLOGY

This study was undertaken across the Kilimanjaro transect located in Pangani river basin upstream of Nyumba ya Mungu dam (Figure 1). The Pangani River basin has two main tributaries, the Kikuletwa that rises on the slopes of Mount Meru and the southern slopes of Mount Kilimanjaro and the Ruvu that rises on the eastern slopes of Mt. Kilimanjaro and Lake Jipe. These rivers join at Nyumba ya Mungu, a reservoir of about 140 km^2 (Røhr and Killingtveit, 2002). The Pangani river provides 60% of the inflow to the Nyumba ya Mungu reservoir which is used for hydropower generation and fishing activities.

The Kilimanjaro transect upstream of Nyumba ya Mungu dam was sub-divided into three agro ecological zones namely: lower, middle and upper zone. Three villages were sampled purposively one from each zone (Table 1). The justification for dividing the area into three zones was based on the fact that water demands in this area have intensified with the increase of economic activities requiring water as an input such as hydropower generation, irrigated agriculture, industries, tourism, mining, livestock keeping, domestic, fisheries, wildlife and forestry activities.

The concentration of these activities is variable between the different zones. The economic activities in lower zone (Lowland in areas around Nyumba ya Mungu dam) are mainly fisheries, hydropower generation and irrigated agriculture; the economic activities in middle zone (Central zone in plain areas) are irrigated agriculture, industries and Livestock keeping and those in the upper zone (Highland in areas around Mt. Kilimanjaro) are mainly rain fed agriculture, tourism and forestry activities. The sample size was determined based on the formula for determining sample size from a finite population as described by Kothari (2004: 179).

Climate data were sampled from Tanzania Meteorological Authority (TMA). The most used statistical methods for assessing rainfall variability include Standard Precipitation Index (SPI), Rainfall Anomaly Index (RAI) and Decile methods (Hulme 1992).

This study utilized Rainfall Anomaly Index (RAI) method because it allows more than one station to represent rainfall at the sub-basin catchment. In view of the amount and the details of information required in a limited period of time the methodology were based on Participatory Rural Appraisal (PRA) (Theis and Grady, 1991). Both quantitative and qualitative methods were used for data analysis as described by Kothari (2004).

RESULTS AND DISCUSSION

Climate variability and impacts

Annual time series of rainfall at the spatial scale of the sub- catchment indicate that rainfall is decreasing except in times of extreme events such as El Nino in 1997/1998 (Figure 2). There is significant change in seasonal rainfall variability across all seasons during the period 1970 to 2010. The March, April and May (MAM) season exhibit ±25% variation in rainfall variability while during October, November and December (OND) season ±40% variability was observed. Dry season in July, August and September (JAS) indicate ±65% variability in rainfall. RAI analysis indicated that MAM seasonal rainfall is less variable compared to JAS and OND (Figure 3).

Following local peoples' perception, the major climate change impact in Lang'ata Bora village is drought with high frequency of occurrence. Other impacts includes changes in rainfall patterns and dry seasons leading to changes in planting seasons, drying of water sources, fishing etc,(Table 2). The results shows that, drought (78.1%) is the most common climate impact experienced in Lang'ata village. Others include drying of water sources (decreasing volume of Nyumba ya Mungu dam) and Changes in rainfall patterns and dry seasons, leading to changes in planting seasons, time to collect water. Drought again, appeared to be the climate hazard with high frequency of occurrence degree of negative impact, severe impacts and effects on household wager access in Lang'ata Bora.

In Oria village many of the respondents considers changes and variation in temperature (33.33%), and outbreak of diseases(33.33%) as major symptoms of climate change followed by changes in rainfall patterns and amounts(25%) and shortage of water (only 8.3%) (Table3).

In Nduoni village it shows drought accounted for 47% as the major climate related event ever experienced in Nduoni, followed by hunger or famine (33%), Eruption of diseases (10%) and floods/heavy rains (10%) (Table4). Dry (drought) spells in Nduoni were confirmed to affect

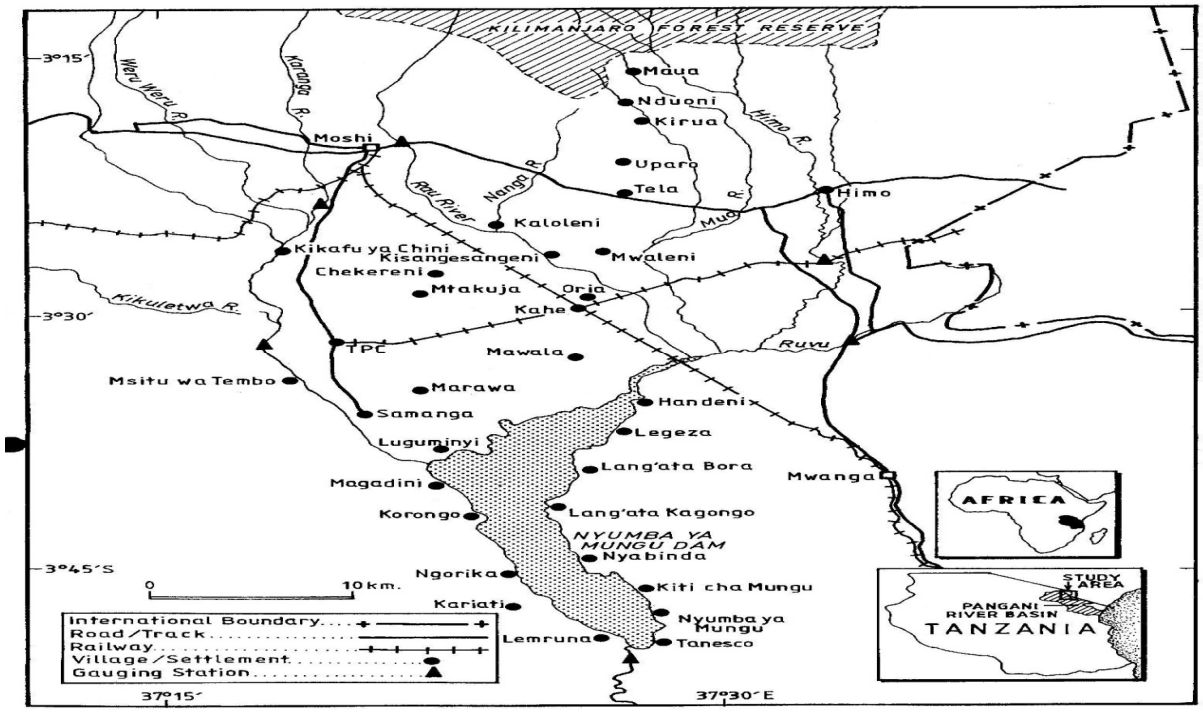


Figure 1. The location of study area in Tanzania.
(Source: Department of Geography, Cartographic unit-UDSM, 2012)

Table 1. Summary of sampled villages in three Agro ecological zones.

Agro ecological zones	Altitude (meters)	Rainfall (mm)	Major crops grown	Sampled Villages
Lower Zone (Lowland)	700 - 900	400 - 800	Paddy, maize, sugar cane by irrigation	Lang'ata bora
Middle Zone (Plain/Central)	901 – 1500	900 – 1400	Maize, bananas, beans and vegetables	Oria
Upper Zone (Highland)	1501 – 5895	1401 – 2000	Coffee, Bananas, maize, Avocados, beans, Natural forest.	Nduoni

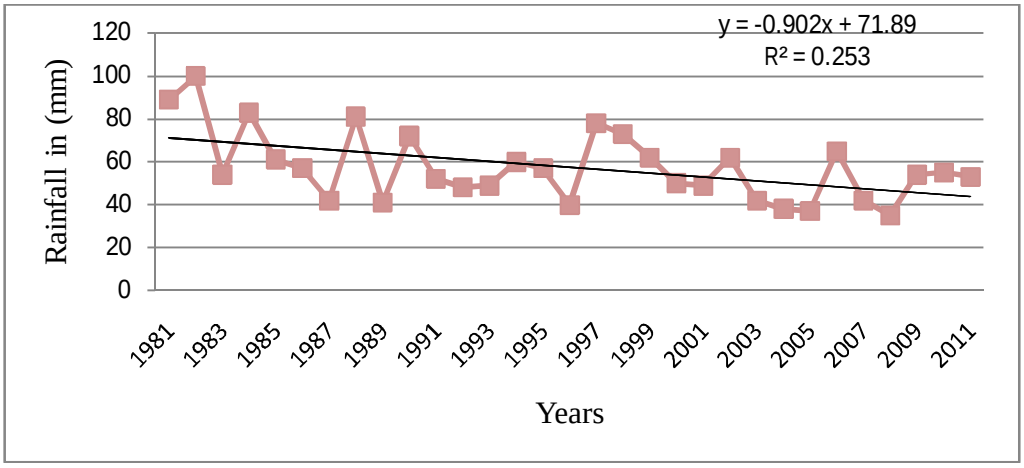


Figure 2. Annual Mean Rainfall trend from 1981 to 2011 (Source: TMA, (2012).

Table 2. Climate change impact and frequency of occurrence in Lang'ata bora village.

	Frequency	Percent	Valid Percent	Cumulative Percent
Drought	25	78.1	78.1	78.1
Drying of water sources	4	12.5	12.5	90.6
Changes in rainfall patterns and dry seasons, leading to changes in planting seasons, time to collect water etc.	3	9.4	9.4	100.0
Total	32	100.0	100.0	

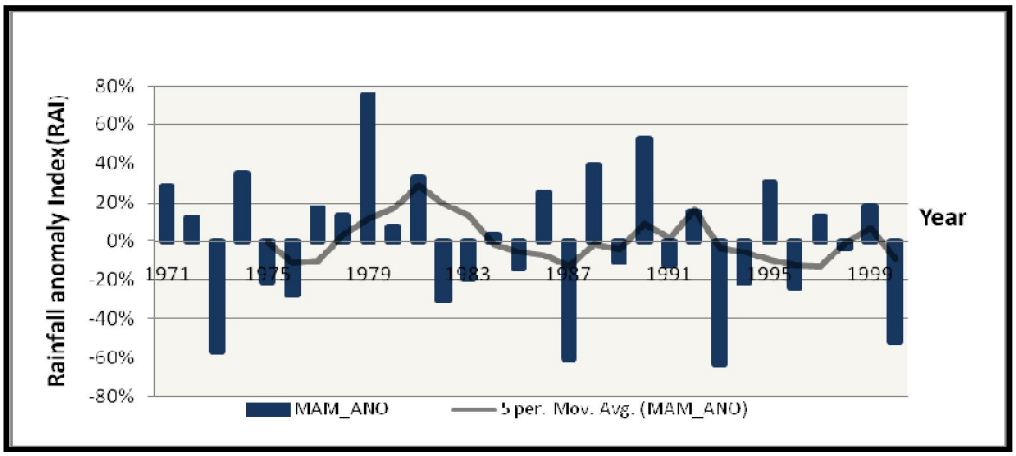


Figure 3a. RAI showing MAM seasonal rainfall variability and a 5-year moving average.

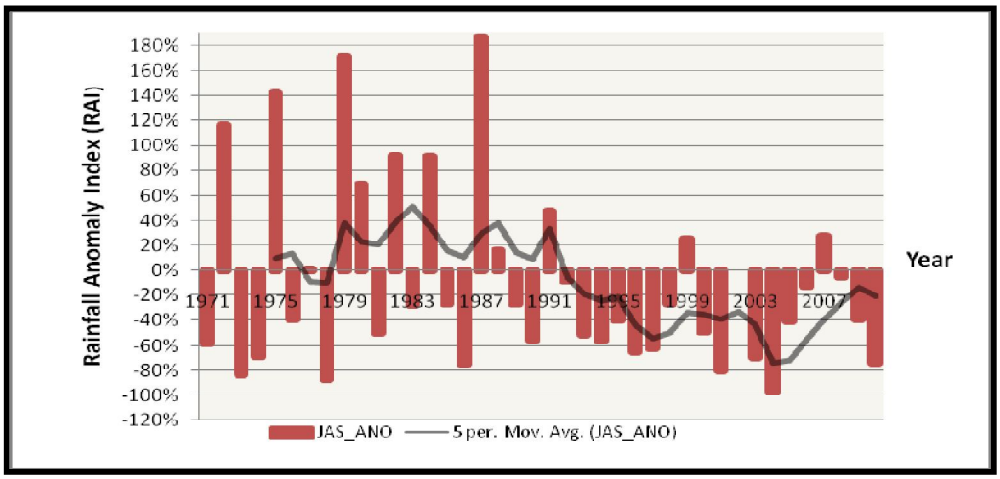


Figure 3b. RAI showing JAS seasonal rainfall variability and a 5-year moving average.

water availability to various socio-economic activities which require water as an input. It was reported that, in some years it takes more than 8 months per year. This presents the risk of accelerating rural poverty.

Local adaptation strategies in the water sector

Water scarcity is perceived at study areas due to unreliable rainfall, multiplicity of competing uses,

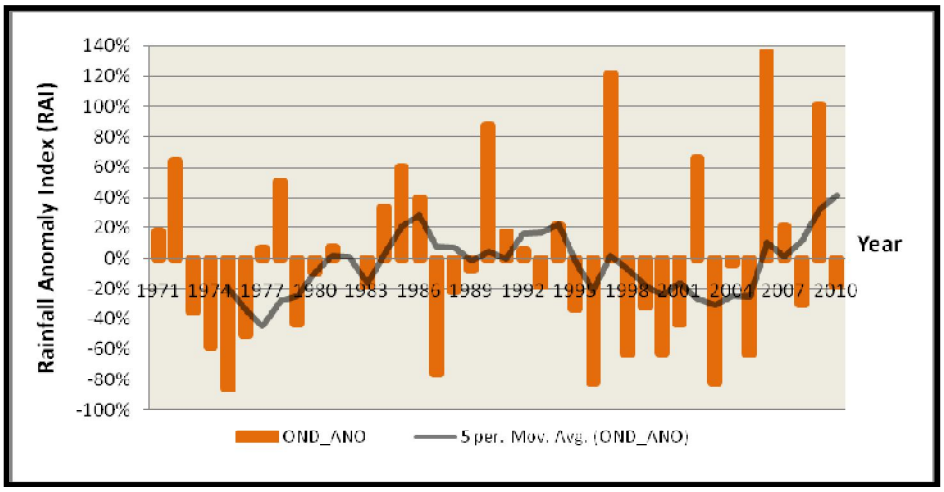


Figure 3c. RAI showing OND seasonal rainfall variability and a 5-year moving average.

Table 3. Climate change impact and frequency of occurrence in Oria village.

	Frequency	Percent	Valid percent	Cumulative percent
Changes in Rainfall patterns and amounts	3	25.0	25.0	25.0
Shortage of water	1	8.3	8.3	33.3
Outbreak of Diseases	4	33.3	33.3	66.7
Changes and variation in temperature	4	33.3	33.3	100.0
Total	12	100.0	100.0	

Table 4. Climate change impact in Nduoni village.

	Frequency	Percent
Drought	14	47.0
Flood	3	33.0
Eruption of diseases	3	10.0
Hunger/famine	10	10.0
Total	30	100.0

degradation of sources and catchments. Water scarcity threatens food security, energy production and environmental integrity and consequently there are water use conflicts between sectors of the economy. The climate change impact on water resources is the major challenge across the Kilimanjaro transect. In some areas, too little water leads to droughts and desertification, whereas in others too much water leads to increased flooding. The results presented in Table 5 show that, various adaptation strategies are used to cope with shortage of water for crop production in study villages. These includes boreholes for irrigation (32.8%), In shortage buying water from vendors for domestic use (16.0%), Rain water harvesting for domestic use (2.4%), Government based initiatives on Ground water supply projects (52%).

Local adaptation strategies in the agriculture sector

The Tanzania Agriculture Policy advocates the need for the country to use irrigation potential as an important aspect of agricultural development strategy, which can help the nation to achieve three major objectives: improvement of food security; increasing farmer's productivity and income; and production of higher value

Table 5. Adaptation strategies in the water sector.

S/N	Adaptation options	Responses	Percent
1	Construction of boreholes	41	32.8
2	Buying water from vendors	20	16.0
3	Rain water harvesting	3	2.4
4	Government groundwater projects	52	41.6
5	None	9	7.2
Total		**125**	**100**

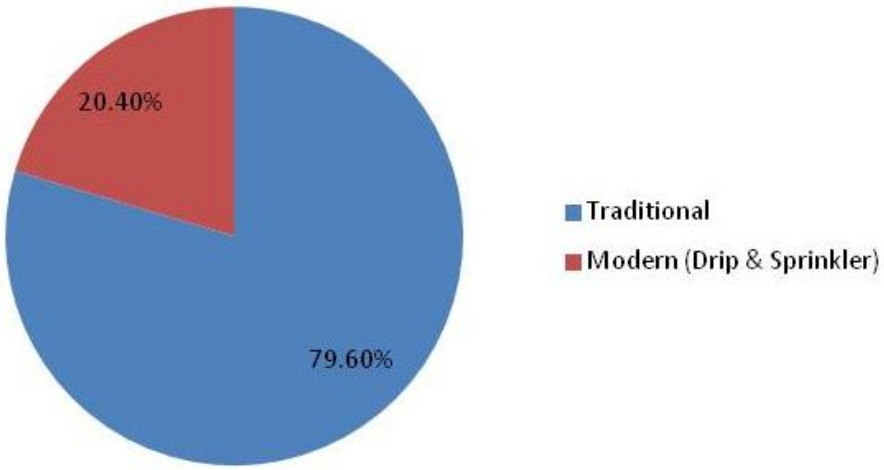


Figure 4. Irrigation Techniques used in the study area.

crops such as vegetables and flowers. Traditional irrigation schemes are the most common and account for more than 79% of the total irrigation schemes in the study area (Figure 4). Traditional schemes are usually initiated and operated by farmers themselves, with no external intervention or support. They include schemes based on traditional furrows for production of paddy, maize and vegetables.

Traditional schemes are usually characterized by locally improvised infrastructure which is poorly constructed and temporary in nature. They are often associated with low productivity due to poor farming and water management practices. Intake structures are made from locally available materials like stones, grass, earth, wooden poles and straw. Intake structures are usually built across the river, partially or wholly blocking the channel, and are thus prone to damage during high river flows. The majority of intakes do not have control gates to regulate the amount of water entering the furrow.

Conveyance canals are usually hand dug and not lined to minimize seepage. Because the canals are unlined, they quickly get clogged by vegetation growth which reduces their efficiency. The canals typically lack flow control devices for effective conveyance and distribution. This implies that, traditional irrigation has low efficiency due to wastage of water sources from the source to the field level.

This study shows that, about 11% of farmers are using modern short season seeds as adaptation strategy to cope with short season rains (Table 6). Some farmers (12%) are practising soil and water conservation measures to improve soil nutrients by mulching and fertilizers application while 11% adopting mixed farming to reduce food and income shortage in their families. Furthermore, livestock keepers adapt by exchanging or selling their livestock to obtain cereals for food.

Challenges on climate change adaptation strategies

Generally the study shows that, the Kilimanjaro transect like other areas in Tanzania is vulnerable to climate change through its impacts on food production, water resources and other socio-economic activities. The adverse effects of climate change may particularly be felt by poor communities because of their low adaptive capacity associated with limited financial resources, poor infrastructure, low level of education, dependence on natural resources and lesser access to technology. Given the low level of human development, poverty, and high

Table 6. Adaptation strategy to improve Food security and household Income.

S/N	Adaptation options	Responses	Percent (%)
1	Irrigation	30	24
2	Economic diversification	26	21
3	Not selling crops	8	6
4	Growing vegetables (cash and food)	10	8
5	Improving soil nutrients	15	12
6	Causal labour	5	4
7	Use of modern seeds	14	11
8	Mixed farming	11	9
9	Selling livestock to buy food	6	5
Total		**125**	**100**

dependence on agriculture and natural resources, the area is considered to be vulnerable to future climatic changes.

Traditional irrigation schemes are characterized by poorly constructed and temporary infrastructures that are usually associated with significant water losses and low crop productivity. Traditional schemes have informal and inefficient management organizations with inadequate technical and financial knowledge and skills required for proper management of irrigation activities. Construction and maintenance of irrigation canals is labor intensive since they are excavated and cleaned by hand. Because most of the infrastructure is temporary and poorly constructed, the schemes have high labor requirements for maintenance of intake and conveyance structures over the growing season.

Another operational challenge is lack of control over the amount of water diverted with a traditional intake. As a result, excessive water is usually diverted leading to wastage and sometimes flooding and crop damage. There are incidences where river courses change, especially during high flows, and follow the course of an irrigation furrow. When this happens, new intakes and irrigation furrows have to be dug and new fields opened up accordingly. Traditional irrigation schemes are also faced with salinity and water logging problems resulting from poor on-farm water management practices and absence of proper drainage channels.

In order to stabilise agricultural production, water storage dams (small, medium and large) should be constructed. The design and construction of such dams should take into consideration of multiple uses where possible e.g. irrigation, livestock, power generation, and flood control. The irrigation water could also first be led through fish ponds and thereafter used for irrigation of vegetables and other crops. If agriculture and livelihoods are to be improved, the water available to agriculture will have to be used more efficiently. Since agriculture is a major water consumer, consequently, any savings in irrigation water use through efficient irrigation practices can go a long way in reducing pressure on the available water resources and in helping meet other sectors' water needs. Promotion of efficient irrigation water use through research and adoption of good farming practices is, therefore, critical to ensuring sustainable use and management of the water resources. Rainwater harvesting can greatly enhance the productivity of land and water in rain fed areas.

Since rural communities in study villages are adapting to spatial and temporal climate variability, with varying degrees of success, there is need for local government institutions, national policies and programmes to provide an enabling environment for climate change adaptation at local community level. This is mainly due to the fact that:

(a) Poor people settle in unsafe areas lacking water services and therefore demand additional public assistance;
(b) Migration patterns result in demand for services in new areas, sometimes on a temporary basis, resulting in a loss of local knowledge which would aid the selection of low risk areas for settlement;
(c) The need to employ better trained staff to deal with problems of water scarcity, which generally only have complex solutions;
(d) The need to enforce the law to better use and protect water sources in places.
(e) The management of water demand among users in order to satisfy the need for municipal water, including that required for food and energy production.

To become "climate proof", water utilities and the water sector in general will need to make additional efforts and incur considerable expense. Since the Kilimanjaro transect provides a number of ecosystem services for sustaining livelihoods of communities and national economy, it is recommended that, Ecosystem-based Adaptation (EBA) approach should be applied. EBA integrate the use of biodiversity and ecosystem services into climate change adaptation strategies. EBA provides opportunities where economies depend more directly on the provision of ecosystem services.

Furthermore, the study recommends intervention and coordination of the formal and informal institutions as

described by Agrawal (2008).

Conclusion

Kilimanjaro transect is vulnerable to climate change. The adverse effects of climate change is felt by poor communities because of their low adaptive capacity associated with limited financial resources, poor infrastructure, low level of education, dependence on natural resources and lesser access to technology. Traditional irrigated agriculture is the most common adaptation strategy for crop production and account for more than 79% of the total irrigation schemes in the study area.

However, traditional irrigation schemes are characterized by poorly constructed and temporary infrastructures that are usually associated with significant water losses and low crop productivity. Promotion of efficient irrigation water use through research and adoption of good farming practices is, therefore, critical to ensuring sustainable use and management of the water resources for sustaining various economic activities requiring water as an input.

This study therefore, recommends application Ecosystem-based Adaptation (EBA) approach that integrates the use of biodiversity and ecosystem services into climate change adaptation strategies.

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