Impact of Climate Change and Hydropower Development on the Community Livelihoods in the Sondu Miriu River Basin

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***Abstract:*-Climate change is the expected outcome of increases in atmospheric concentrations of "greenhouse" gases resulting from human activities. Energy has been identified as one of those sectors that contribute more towards GHGs emissions while renewable energy technologies have the potential to mitigate GHGs emissions. Among all the renewable energy technologies being utilised, hydropower stands out to be the most stable and proven technology over time compared to the others. Despite hydropower having the potential to mitigate climate change impacts and support some adaptation strategies, it is also likely to be impacted on by climate change. Both climate change and hydropower development are also most likely to impact on the community livelihoods.**

This paper assesses the the impacts of climate change and hydropower development on the community livelihoods within the Sondu Miriu River basin. It involves interviews with the local community, their leadership and other development actors within the basin. Vulnerability assessment and statistical applications tools have been used.

The results have shown that climate change and hydropower development have impact on the community livelihoods in general. They both have a big influence on the socioeconomic and environmental activities within the basin. The benefits derived from hydropower development project can be used to reduce the vulnerability of the local communities to climate change impacts.

Key words: **climate change, hydropower, livelihoods, vulnerability, benefits**

I. INTRODUCTION

For many years human activities have resulted into continuous increase of greenhouse gases concentrations in the atmosphere. There are several greenhouse gases that occur naturally in the atmosphere such as carbon dioxide. The occurance of these gases always keep the earth warm as they trap heat within the atmosphere. The major contributer to the atmospheric concentrations since the period of industrial revolution has been anthropogenic sources of CO_2. Some of the major sources that have been cited include the burning of fossil fuels for the production of electricity and and also for transportation. The process is believed to have been intensified by other man made greenhouse gases such as Chlorofluorocarbons (CFCs). Increased concentration levels of these greenhouse gases are projected to cause substantial temperature rise in the next century. Due to the current rates of economic and population growth, the scientific concensus have projected a global mean temperature rise of approximately 3^{o}C indicated that the global mean temperature will rise by 3^{o}C by the close of the following century. Increase in global precipitation levels of approximately 15% is expected to accompany this temperature rise. [8].

Though hydropower has been identified as one of the projects that can contribute towards mitigation of Greenhouse gases (GHGs) emissions, less emphasis on climate change issues has been considered during the planning, development and operational phases. Hydropower constitutes about 38% of the installed electricity generation capacity with Sondu-Miriu and Sang'oro hydropower schemes being the most recent to be developed. These schemes within the Sondu-Miriu River basin, therefore, offers an opportunity as a case study to learn lessons on how climate change adaptation can be integrated into hydropower developments that results in socioeconomic and environmental sustainability. As there is still existing potential within Sondu Miriu river basin, this can give guidelines on how to develop future hydropower projects with climate change adaptation fully integrated.

Hydropower being a renewable energy offers unique opportunity to support socio-economic developments locally in form of climate change adaptation strategies and actions. Therefore, it is important for the identification of these opportunities and harness them to form part of the activities for the integration of climate change adaptation into hydropower developments. It is expected that this will contribute majorly towards enhancing the local climate change resilience within the local communities where such projects are being implemented.

For a long time, no considerations have been always put in place for integrating climate change adaptation into the implementation of hydropower development activities. This has made a major contribution in increasing local communities susceptibility to impacts of climate change while improving social, economic and enevironmental conditions of

the larger region. Currently there is a growing demand for renewable energy technologies all over the world. One of the key driving forces behind this growth is the climate change mitigation to address the root causes of greenhouse gas emissions. Apart from Greenhouse Gas (GHG) emissions reduction, renewable energy technologies also offer many other benefits including air quality as a result of low/no pollution and good health conditions compared to the use of fossils fuels [12].

The only benefit to the local community usually associated with hydropower development is corporate social responsibility (CSR) which does not guarantee climate change adaptation activities or programmes. This is also coupled with none existence of a clear implementation framework that can compel the hydropower development agencies to integrate climate change adaptation activities or programmes into the hydropower development plans.

Currently, climate change adaptation is being considered an essential element of sustainable development [12]. This adaptation can be in the form of anticipatory or reactive to the changing climate. Several renewable energy technologies are capable of supporting climate change adaptation efforts which is usually anticipatory in nature [7]. The hydroelectric power generation dams can also be utilized in the management of the impacts of extreme meteorological events such as droughts and floods. These events are projected to increase in the future based on the projected climate change scenarios [15].

This paper focuses on assessing the impacts of climate change and hydropower development on the community livelihoods in the Sondu Miriu River basin.

The current drive for electricity generation expansion in Kenya is largely based on renewable energy. Among the renewable energy technologies, only hydropower is capable of providing both base load and peak load electricity supply for the growing peak demand. A well designed hydroelectric power plant is a strong driver for socioeconomic development as long as benefit sharing is adequately addressed [8]. Integration of climate change adaptation into hydropower development will, therefore, contribute towards reducing vulnerability of the local community and environment to inpacts of climate change.

II. AREA OF STUDY

Sondu-Miriu River basin is situated in the weatern part of Kenya within the Lake Victoria drainage basin as illustrated in figure 1. The basin currently has got two hydropower schemes, namely Sondu Miriu and Sang'oro, which draw water from the Sondu-Miriu River for hydroelectric power generation into the national electricity grid.

The position of Sondu Miriu River basin is confined within latitude $0^o17'$ and $0^o53'$ South and longitude $34^o45'$ and $35^o45'$ East. This River basin is the fourth largest basin amomg the Kenyan River basins that drain their water into Lake Victoria and it covers an area of approximately 3,500 km^2 [11]. Kapsonoi and Yunith rivers are the main tribituries of Sondu Miriu river. Sondu Miriu river has got its origin in the expansive water catchment area in Kenya defined as the Mau Complex. The characteristics of Sondu Miriu River basin include diverse land use types and development activities. The land use and development activities include forestry, agriculture, settlements, industries and energy among others. Due to the existing various human activities within the basin at different scales and intensities that have been taking place over the years, they are capable of causing far reaching implications to various issues within the basin. Some of the major issues include water quality for various uses, acquatic biodiversity within the river system and the general ecological status of the river. It has been observed that the sedimentation rates within Sondu Miriu River have been on the increase over the years. This has compromised the water quality within the river [11].

Majority of the local communities living in this area are poor. They are relying majorly on either incomes from their farm produce or self-employment. The only existing formal employment in the area that may be a source of steady income is only for the privileged few. There is large monthly income disparities in the area which is a symptomatic sign of inequity among the local communities in the area [14]. Tables 1,2,3 and 4 summarises the household sizes, poverty status, poverty gaps and employment status respectively in the counties touching he study area.

The basin just like any other basin within the larger Lake Victoria drainage basin is vulnerable to climate sensitive diseases like malaria, cholera pneumonia among others. This is further complicated by the poverty levels in the area and lack of adequately equipped health facilities in the area to be able to control these diseases during the outbreaks.

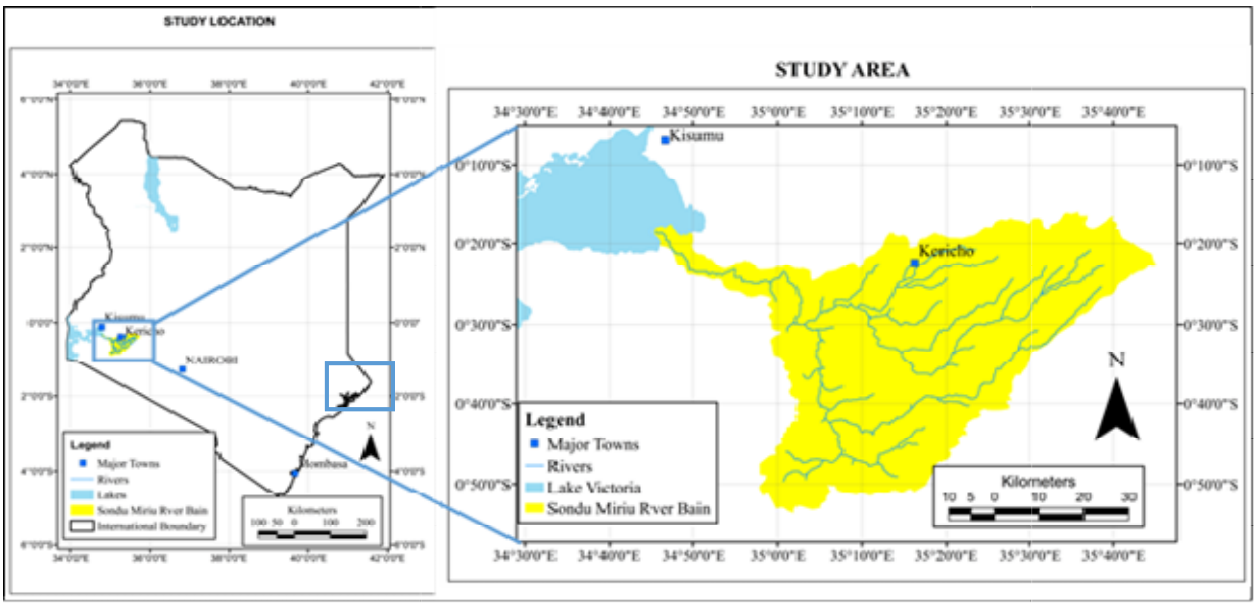

Figure 1:Map showing the position of the Study Area

III. LITERATURE REVIEW

Globally, climate change has got a lot of influence on precipitation and temperature. The two parameters determine availability of water resources for various competing uses including hydropower. Rainfall is considered the main river flow source for hydropower generation and other competing uses. In Kenya temperatures have been on increasing trends based on the long term observations. The minimum and maximum temperatures have risen generally by 0.7°C to 2.0°C and 0.2°C to 1.3°C respectively across the country [3].

The past changes in climate has recently caused a lot of impacts on human and natural systems globally. The evidence of impacts as a result of climate change is very strong. This evidence is most comprehensive within the natural systems. On the human systems, some of the impacts have been associated with climate change whose major or minor contribution can be distinguished from othe influences [13].

Changing precipitation alters hydrological charactaristics and this affects water resources in terms of the quantity and quantity. Hydropower will definitely be severely impacted on in future by these changes in climate due to the non-linearity nature of rainfall-runoff process. It has been observed that a reduction in rainfall by 10% can easily lead to a loss of hydropower generation by between 25% to 50%. At the same time a temperature rise by few degrees is also capable of substantially increasing evapotranspiration rates leading to severe impact on hydropower as well. Increases in year to year climate variability may well result in lower energy security in general [2].

Observation of rainfall trends in the past has given indications of a general decline of rainfall received in the main rainfall season of March to May also refered to as “Long Rains” and a general increase during October to December in the region [3], [10]. The recent studies have shown that the “Short Rains” which normally occur during October to December season is now extending into what has been normally known to be hot and dry period of January to February season. As a result of these changes, drought is becoming more frequent and prolonged in the Long Rains Season.

Climate variability and climate change have the potential to affect the resource potential for hydropower [8]. With the changing climate hydropower resource potential could change as a result of;

a) River flow regime changes caused by climate changes locally in particular precipitation and temperature changes within the river basin resulting in flow charectaristics changes such as volume, variability and seasonality that can directly affect the hydropower resource potential.
b) Changes in the frequencies of extreme meteorological events that may lead to increased cost and associated risks for the future planned hydroelectric power projects.
c) Changes in the characteristics of the sediment load resulting from changing hydrology and extreme meteorological events. Most sediments are likely to result in an increased turbine abrasion leading to decreased efficiency. Increased sediments loads may also results in filling up the reservoir at a faster rate leading to decreased live storage, reduced regulation capability and decreased storage services.

There exist various publications for the studies on the impact of climate change on the river flows. These studies mostly used catchment hydrological models that are driven by climate change scenarios. These scenarios are based on the

climate model simulations. Downscaling climate data that involves converting global climate model output into the corresponding climate data set in the catchments is always necessary before using any data in the catchment hydrological models. Finding the best methods for downscaling has currently been given high priority in research area whereby downscaling can be both temporal and spatial. [8].

Even though the climate change impact on the hydropower resource potential might sometimes be approximated as comparatively smaller on average at the global or continental scale, regional and local effects are more significantly possible. The factors that determine the hydropower resource potential include topography and hydrological characteristics such as the volume, variability of the flow and runoff seasonal distribution. In addition to depending on both the regional and local scales, an increase in the variability of climate without necessarily any variation in the mean runoff, is still capable of reducing the production of hydropower. This can only be avoided by increasing the reservoir capacity and modification of the operations to make them capable of accounting for the new hydrological conditions resulting from climate change.

Economic activities in any given area such as agriculture, forestry, fishing, mining, manufacturing among others are usually very sensitive to the climate change consequences. This can normally be attributed to their immediate dependence on the natural environment [6]. These economic activities dominate the Sondu Miriu River basin.

The impact of climate change on most of the economic sectors are projected to be relatively smaller compared to the impacts contributed by the other drivers. The changes in other factors will have major impacts especially on the demand and supply of economic services and goods that are most likely to be larger compared to impacts arising from climate change. These factors include age, population, household income, applied technology, relative prices both locally and globally, lifestyles, existing regulations, governance and other aspects of socioeconomic developments among others [6].

In responding to climate change mitigation and adaptation are the two main approaches. The Intergovernmental Panel on Climate Change (IPCC) defines mitigation as “an anthropogenic intervention to reduce the anthropogenic forcing of the climate system, which includes strategies to reduce greenhouse gas sources and emissions and enhancing greenhouse gas sinks” [4].

Adaptation is also defined by the IPCC as “adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities” [4].

The mitigation actions are mostly known for tackling the issues that are most likely to cause climate change. These actions normally target the reduction of CO_2 emissions. The mitigation actions may be implemented at any scale. This may range from local to global scale. On the other hand, adaptation actions aim at tackling the consequences resulting from climate change mainly targeting at local and regional scales. This is due to the fact that the benefits associated with adaptation actions are felt either locally or regionally [9].

Because adaptation is part of climate-resilient pathways, integrating adaptation actions has been proposed as an aspirational goal. This has been proposed within the broader framework of sustainable development [16, [1] particularly when the existing policy consideration and financial commitments towards response to climate change have to focus on persuing adaptation actions. In practice, however, adaptation actions normally have a tendency of involving various community interests, schedules and responsibilities for decision making [5], [16].

IV. DATA AND METHODS

The socioeconomic data were collected from the communitywithin the basin through administration of questionnaires at household levels, interviews, key informants and observation. Simple random sampling method was adopted. In this method every member of the population had an equal chance of being selected to respond to the questionnaire. Sampling frame was based on the Sondu Miriu basin map. This ensured that each and every subbasin was covered in the sampling. The sampling was done in all the seven subbsins and a total of 105 samples were considered with the number of samples varying based on the subbasin size. Focused group discussions involving the local leadership were conducted in every subbasin while the focused group discussions involving the local actors were targeted at the respective offices.

The data was collected from the seven subbasins as indicated in the TABLE 1. The subbasins are based on the Water Resources Authority classification of river basins in Kenya.

TABLE 1: SAMPLING SUBBASINS

S/N	Subbasin	2010 population	No. of households	Sample size
1	1JA	11,641	42	11
2	1JB	5,493	20	8
3	1JC	23,969	85	22
4	1JD	14,933	53	14
5	1JE	11,940	43	11
6	1JF	31,941	113	29
7	1JG	8,616	31	10
		108,533	387	105

The climate change adaptation and mitigation (CAM) vulnerability assessment framework and statistical methods (Ms-Excel) were applied to determine and quantify the impact

of climate change and variability as well as hydropower generation development in the area on the local community living in the Sondu Miriu River basin. This was carried out through the application of IPCC technical guidelines as follows:

- Determination of the scope through identification of the geographic and sectoral focus of the assessment and system which will be impacted such as natural, social, economic, institutional and built.
- Assessing the baseline for the description of the past and existing situation, trends and drivers across each of the systems identified. Projection of the changes to the systems will occur irrespective of climate change.
- Determination of climate change threat by analysing the past extremeevents and trends as well as climate modelling and downscaling future climate and hydrology against various scenarios.
- Assesment of the impact and vulnerability. This includes analysing the target systems within the defined time slices for any projected climate threats. Assessment of the impact should combine the degree of exposure of the key system components ans assets together with their relative sensitivity to the threats. The vulnerability considerations are the impact and the capacity of the component or asset to adapt to it.

Through the vulnerability assessment and statistical applications the impact of climate change and hydropower development on the community within the Sondu Miriu River basin were identified and quantified to be able to focus on the critical areas.

V. RESULTS AND DISCUSSIONS

A. Socio-economic status within the Sondu Miriu Basin

The main source of income within the Sondu Miriu River basin as shown in figure 2 is private enterprises which accounts for approximately 31%. This followed closely by casual unskilled labour at 25% and then casual skilled labour and formal employment coming at 22% each.

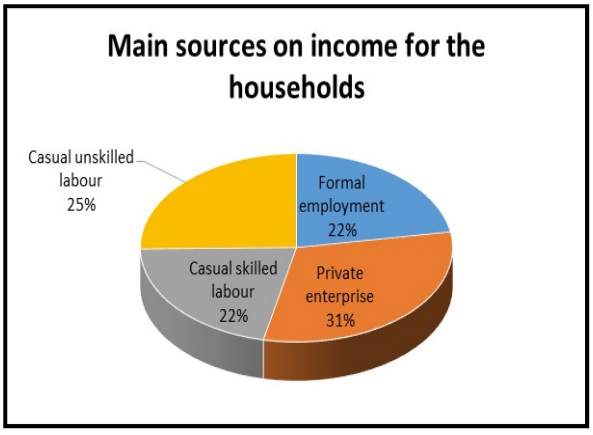

Figure 2: Main Source of Income

Majority of the households in Sondu Miriu basin have got monthly income less than Kshs 25,000.00. Those who earn below Kshs 10,000.00 are approximately 32% while in total 59% earn below Kshs 25,000.00 in a month. This means that only about 41% of the householde within Sondu Miriu basin earn above Kshs 25,000.00 in a month as shown in figure 3.

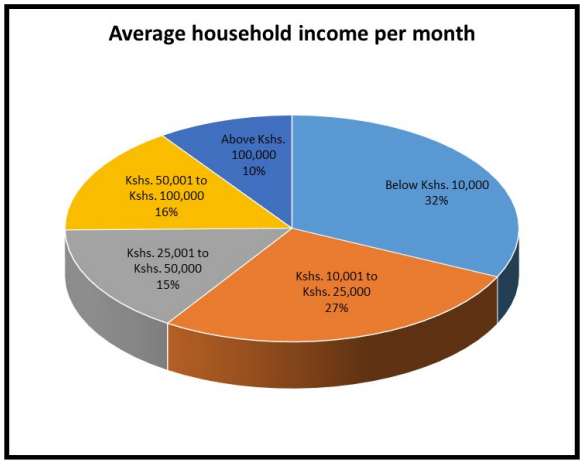

Figure 3: Monthly Household Income

The most commonly used source of energy in this basin are charcoal and wood fuel accounting for 25% and 24% respectively as illustrated in figure 4. The two sources account for approximately a half of the energy sources within the basin. The intensive use of the two sources of energy may affect the the environmental conservation effort and end up impacting on the hydropower production negatively.

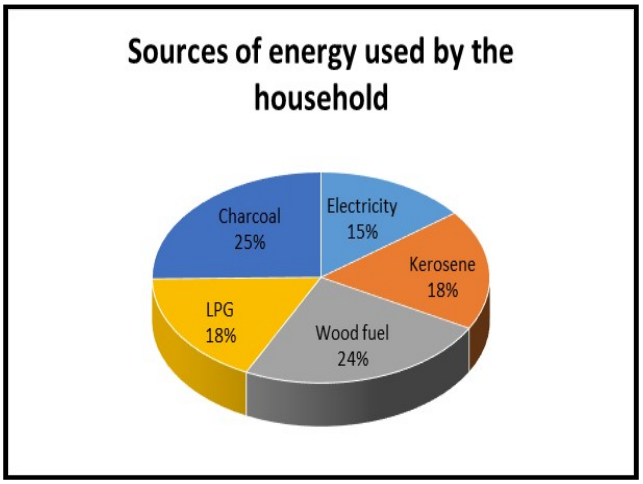

Figure 4: Energy Sources

The primary economic activities are well distributed with an execption of fisheries tha has scored very high with 26%. This is an indication that the primary economic activities are balanced with the basin as indicated in figure 5. The least activity is quarrying.

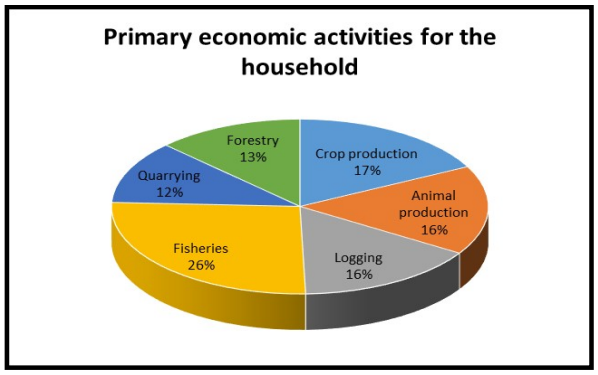

Figure 5: Primary Economic Activities

Secondary economic activities also seem to be balanced as shown in figure 6. The highest secondary economic activity within the basin is construction while the least is manufacturing.

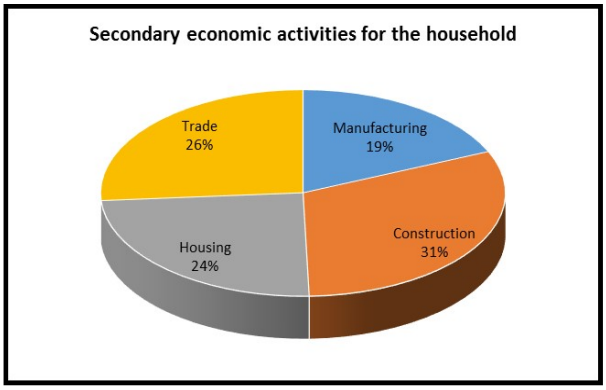

Figure 6: Secondary Economic Activities

Mojority of the community still fetch water from the rivers. This represent 39% of the population. This is closely followed by water supply from the wells. Only 16% of the population has access to piped water. Those who get water from the ponds also represent 16% and shown in figure 7.

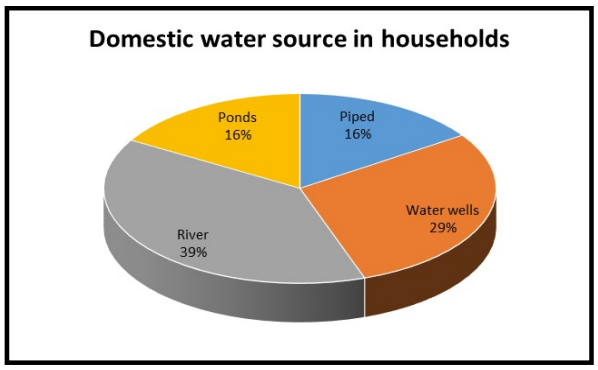

Figure 7: Domestic Water Sources

On health, the majority of the households in tha basin spend less than Kshs 10,000 per annum with only 4% spending more than Kshs 75,000 as shown in figure 8. Another majority of about 33% also spend between Kshs 10,000 and Kshs 25,000 per annum on health.

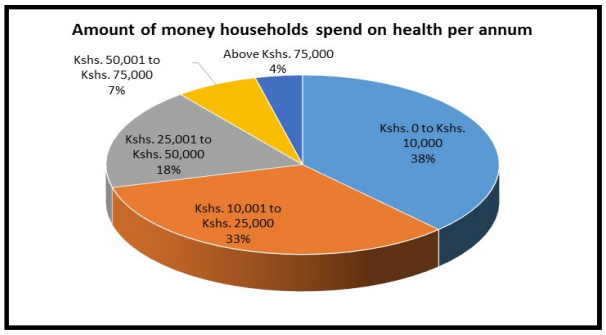

Figure 8: Expenditure on Health

22% of the population are able to access health facilities within a distance of 5 Km while another 28% are able to access the facilities within betwee 5Km and 10Km as shown in figure 9. Only 16% are more than 15Km from the health facilities.

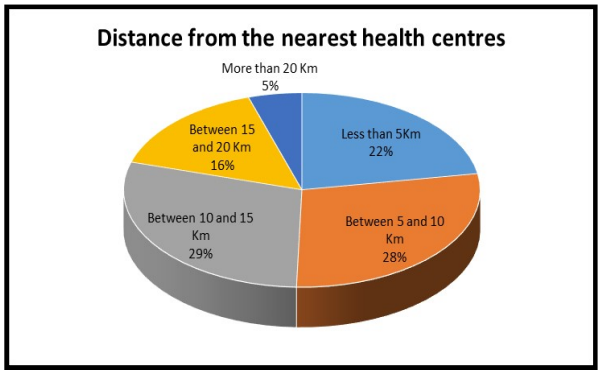

Figure 9: Distance from Health Centres

B. Local Leaders Opinion

Based on the interview held with the local leaders their opinion was as follows;

1) Major economic activities in the area according to the local leaders include fishing, farming, livestock keeping, agroforestry, trade and logging.
2) The local leaders interviewed felt that some of climate change affected the local community by reducing agricultural production, reducing rainfall ammounts, causing emergence of new crop and animal diseases, reducing pasture for the animals, reducing fish population and reducing forest cover.
3) The development of hydropower has impacted on the local community by improving power supply and reliability, improved environmental conservation and management through environmental conservation projects, improved inftrastructure in the area, change of land use from agricultural/forests to other uses such as roads, canals, tunnel among others, employment for the local people and other business enterprises.
4) According to the local leaders some community members have got positive attitude to the hydropower project. They feel that the project has

brought a lot of socioeconomic development activities in the area. On the other hand, some community members especially those on the upstream have got negative attitude to the existing hydropower projects feeling that they did not receive enough benefit from the projects.

5) Some of the benefits cited by the local leaders to the local community during the development of the existing hydropower projects include road network in the project area, watering points for the livestock and the local community, provision of a primary school and a resource centre and provision of a health centre.
6) The benefits that were left out during the development of the existing hydropower projects according to the local leaders include irrigation infrastructure for the local community and piped water supply scheme.
7) It was also the opinion of the local leaders that the hydropower projects should also be able to support connectivity of power supply to all the local community households.
8) During the development stages for the existing hydropower projects, the local community and other stakeholders were involved through public barazas and consultative meetings.
9) During the development of the exisiting hydropower projects the local leaders identified that consultations with the local community and compensation for the land owners were well done.
10) The only gaps that the local leaders stated were poorly done included exclusion of many stakeholders during the initial stages and that consultations were not covering the entire basin.
11) Other programmes that can be introduced within the community when implementing hydropower projects in this basin include irrigation projects, fish processing plants, agricultural produce processing plants for tea, potatos, pinapples, bananas among others, afforestation programmes within the basin, and environmental conservation and monitoring programmes.

C. Local Actors Opinion

The results of the interviews held with the local actors were as follows;

1) The real livelihood challenges associated with climate change in the area include, poverty, crop failure, water quality, water availability and deseases.
2) The challenges caused by the construction of the existing hydropower plants included resettlements, noise pollution, air pollution and water pollution.
3) To avoid the challenges what could have been put in place included awareness creation and education, provision of social amenities in advance before the construction works for the project and promotion of livelihood projects in the area.
4) The actions that should be supported by hydropower projects in the future to avoid negative impacts or provide alternative livelihood activities include integration of environmental conservation, integration of appropriate agricultural practices, pro-poor community-based activities that can adapt to climate change and use of sustainable technologies, trait-based breeding and conservation of the animal genetic resources with their inherent adaptation traits which provide a means to mitigate climate change, strengthening research and development capacity, trans-disciplinary systems perspectives and human resources to deal with climate changeand ensuring increased investments in agriculture to promote greater agricultural development.
5) Legal instruments needed to be put in place to support the proposed actions include official policy to address climate change effects and adaptation actions, laws to compel all development actors to set aside a budget for adaptation to climate change actions at local level and by-laws to ensure everyone in the basin participates in climate change adaptation actions.

V. CONCLUSIONS AND RECOMMENDATION

A. Conclusions

The climate change and hydropower development have impacts on the local communities. The impacts are on socioeconomic and environmental aspects of community livelihoods. These include levels of income, energy use, domestic water supply, primary and secondary economic activities, expenditure and health status among others.

The community has several options for socioeconomic activities in the basin which are all vulnerable to climate change. These activities are also influenced by the hydropower development in the area as the development changes the economic landscape in the area due to increased activities. Hydropower provides more benefits to the community both directly or indirectly which goes along in reducing the vulnerability of the community to impacts of climate change.

The hydropower development in the area also has got varying impacts during different stages of development upto operations.

B. Recommendation

Hydropower development benefits can be tailored to address community vulnerability to climate change impacts. This can be done through climate change adaptation programmes supported by the hydropower projects for its long term sustainability.

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