

# Impacts of Climate Change and Hydropower Development on the Community Livelihoods in Sondu Miriu River Basin, Kenya

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## Abstract

Hydropower is sustainable and environmentally friendly source of energy worldwide. Driven by streamflow, it is vulnerable to climate change and land use change. The hydropower production from the two-existing run-of-river hydropower projects on the Sondu Miriu river are vulnerable to rainfall variability and requires proper understanding of the climate change trends and policies to support sustainable hydropower development and put in place strategies for building resilience for the local communities. The main objective of this paper was to examine the impacts of both the climate change and the hydropower development projects on the livelihoods of the community living within the Sondu Miriu River basin. Participatory methodologies involving administration of questionnaires at household level and focus group discussions with the local leaders and actors were applied to determine the impacts of climate change and the hydropower development on the community livelihoods within the basin. The socioeconomic status of the basin indicates that majority of the households (>59%) are poor and earn below 8 US dollars per day. The employment rate is extremely low with only 22% in formal employment. About 49% of the households still use wood fuel and charcoal as energy sources which is a threat to catchment conservation. Strengthening community resilience to climate change impacts is one of the benefits to be derived from the hydropower projects by supporting appropriate adaptation strategies within the existing policy framework.

**Keywords:** change, hydropower development, community livelihoods, Sondu Miriu River basin

## 1. Introduction

### 1.1 The Problem

Climate change could substantially affect hydropower development through the threat to critical resources, such as water, and increased frequency of occurrence and natural disasters severity. The slowing of global warming and reduction of greenhouse gas emissions are very essential given the urgency of the prevailing problem. It has been recognized more recently that some climate change impacts are now unavoidable leading to growing campaigns for adaptation actions for effective response to threats of climate change by minimizing the impacts on both the ecosystem and people as both the people and ecosystems are vitally important (AKP, 2010). Climate change adaptation actions entail adjustments of ecological systems or social systems as a response to minimizing possible climate change damages. Even though adaptation actions are unable to fully eliminate the adverse climate change impacts completely (Füssel, 2007), there is possibility of decreasing the impacts while taking the advantage of opportunities that have been created in achieving positive outcomes. It should also be noted that, not all are equally well prepared for adaptation to the impacts of climate change due to the significant variations in adaptive capacity that depend on several variables including resource availability, prevailing socio and economic conditions, and governance status.

### 1.2 Importance of the Problem

Hydropower constitutes about 38% of the installed electricity generation capacity in Kenya. With Sondu-Miriu and Sang'oro hydropower schemes being the most recent to be developed (Kenya Power, 2018). The schemes within the Sondu-Miriu River basin, therefore, offers an opportunity as a case study to learn lessons on integrating climate change adaptation into hydropower developments that results in socioeconomic, environmental, and technical 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. Opportunity exists in responding to climate change and awareness enhancement that maintains ecosystem functioning for supporting livelihood and development fundamentally (Shackleton and Shackleton, 2012), and able to motivate new development trajectories (Niang *et al.*, 2014).

Hydropower offers a unique opportunity as a renewable energy for supporting social and economic developments locally. This is in the form of actions and strategies for climate change adaptation. Therefore, identifying these opportunities and harnessing them is important in forming part of the climate change adaptation integration activities for into hydropower developments. This is expected to have a major contribution towards the enhancement of the climate change resilience locally among local communities where implementation of these projects is taking place (Kumar *et al.*, 2011). Some of the benefits local communities usually associate with hydropower development are infrastructure developed by the project as corporate social responsibility with no linkage to any climate change adaptation measures. Climate change adaptation measures are always reactive or anticipatory in climate change response. Renewable energy technologies are very capable of supporting anticipatory adaptation actions or programmes in a sustainable manner (Klein *et al.*, 2007). Dams for hydropower generation can be useful in the management of the impacts caused by the meteorological extreme events that manifest themselves in the form of floods and droughts. In future, according to the World Commission of Dams (WCD, 2000) the frequency of these extreme events is projected to increase based on projected scenarios for climate change.

The main objective of this paper was to determine the impacts of climate change and hydropower development on the livelihoods of the local communities living within the Sondu Miriu River basin. Located in the western Kenya, Sondu Miriu river basin is as one of the basins within the Lake Victoria drainage system. There are two run-of-river hydropower projects within the Sondu Miriu basin that draw water from Sondu Miriu river, namely Sang'oro and Sondu Miriu, for generation of hydroelectric power into the Kenya national electricity grid. Therefore, this study was to determine the impacts climate change and hydropower development has had on the community livelihoods within the basin.

### *1.3 Relevance of the Study*

In the global electricity generation mix, the currently largest renewable energy source is hydropower. Regardless of the goals for climate change mitigation in many countries, hydropower is still projected to remain important in the future renewable energy mix (IEA, 2010). The prevailing climate determines the resource base and therefore makes the generation of hydropower to be highly dependent on future changing climate and related extreme weather events occurrences (Ebinger and Vergara, 2011; Mukheibir, 2013). The hydrologic cycle, which is driven by topographical features and prevailing climate, therefore, forms the resource base of hydropower.

Assessment of climate change impacts on the hydroelectric power generation is very complicated globally. Variable temporal and spatial mean seasonal and annual rainfall and temperatures changes, and the resultant evapotranspiration losses, with regional water demand changes necessitated by economic activities and population growth changes are challenging to projects implementation particularly the competition for the available water resources created by agricultural water demand for irrigation (Arent *et al.*, 2014). The current increasing drive to combine generation of hydropower with flood control and environmental flow objectives caused by climate change regimes also further complicates the matter.

In responding to changes in water availability interannual variations, seasonality, and water quantity in addition to other existing demands, a focus is needed on the possible impacts of climate change on hydropower development and adaptation options in the energy sector. Several studies have concluded that by 2050, it is projected that the overall impacts of climate change and extreme weather events on hydropower generation will be slightly positive in most regions and negative in some regions, with differing patterns across various watersheds, catchments, river basins and regions (IPCC, 2011). Several infrastructural and non-infrastructural measures are readily available such as adding bypass channels, raising dam walls, adjusting water release for protecting related infrastructure like turbines, channels, dams, among others and scheduling generation during high electricity prices for optimizing incomes (Mukheibir, 2013). The climate change adaptation tools for long term responses and planning of hydropower generation need to be enhanced for coping with continuous change in water resources availability. There is need to enhance short term management models for dealing with the impacts of extreme weather events.

Livelihood identification is linked to sustainability. Apart from providing income and food, livelihoods also make a significant contribution to social capital, personal and social fulfilment, and identity (Young and Goldman, 2015). Livelihood sustainability is measured on its ability to recover from and cope with stresses and shocks and still maintaining or enhancing its assets and capabilities both at present and in the future, without undermining the

natural resource base at the same time (Chambers and Conway, 1992). Sometimes, livelihood is to do with assets, entitlements, and activities for people to make a living. These are referred to as natural, social, and physical aspect (Foo *et al.*, 2016). Those definition and thought conclude livelihood as a process of perception (thinking), believes and action that frame human interaction among themselves and their physical environment (Foo *et al.*, 2016). Livelihood assessment basically defines individual, household, or a community behaviour under specific framework environments, as well as understanding livelihood system.

The past climate changes are responsible for the recently impacts on natural and human systems globally. There is strong evidence of climate change impacts. The evidence is very comprehensive within the natural systems. Various impacts are linked to the climate change and their minor or major contributions are distinguishable from other influences with the human systems (Niang *et al.*, 2014). Climate change will severely impact on hydroelectric power generation in future because the nature of rainfall-runoff process is not linear. Observations have shown that any reduction in rainfall be 10% can easily reduce the generation from hydropower by between 25% and 50%. Increase in year-to-year climate variability may also cause generally lower security in energy supply (Droogers *et al.*, 2009). Similarly, a rise in temperature by few degrees is capable of increasing evapotranspiration rates substantially and result in severe impact on hydroelectric power generation in addition.

The observed historical rainfall trends have indicated that there is a general decrease in the rainfall amount received during the March to May major rainfall season also referred to as “Long Rains” and a general increase in the short rainfall season from October to December within the region (Government of Kenya, 2010; Liebmann *et al.*, 2014). Based on the results of the recent studies, the “Short Rains” usually experienced from October to December period now seem to be extending into the January to February period which is normally known to be hot and dry. This has led to the increased frequency of prolonged droughts in the long rainfall Season. Hydropower is being promoted in Africa as one of the sustainable development technologies. The importance of affordable energy has also been emphasized in the developing world as being a critical input to realize the sustainable development goals (Kiteresi *et al.*, 2015). Electricity and water have also been identified as some of the essential resources for supporting socioeconomic growth and community livelihood enhancement.

Rural economies are being transformed to more service oriented and industrial economies from traditional agriculture. These changes are always associated with economic and social impacts on nearby communities and sometimes lead to rural depopulation and fragmentation. It is recommended to support new types of economic activities that are land-based to be implemented on agricultural lands that are abandoned, reclamation of degraded lands, and introduction of new production methods and products (Chandy *et al.*, 2012). Even though benefits like employment from the local economic development projects have always accrued to the nearby rural communities, some adverse impacts may be experienced on the communities’ future livelihoods due to changes in peoples’ occupations and in land use.

#### 1.4 Hypotheses and Their Correspondence to Research Design

The main research question in this study was, what impacts do climate change and development of hydropower projects have on the livelihoods of local community in Sondu Miriu basin? The changes in the basin will always influence the local communities’ decisions made and resultant land use practices. The Lake Victoria Basin within which Sondu Miriu river basin is located has been experiencing land use changes caused by both critical natural and anthropogenic drivers concerning the livelihoods and resources sustainability of the local communities within the Sondu Miriu river basin (Makalle *et al.* 2008). The communities living nearer to river are more vulnerable to the impacts of climate change due to greater exposure to the risks associated with riverbank erosion and flooding, very low adaptive capacity because of low socioeconomic status and poor livelihood conditions and high sensitivity to inadequate access to basic amenities. The spatial characteristics within the area or river basin can be valuable in making decisions for addressing the communities’ livelihood vulnerability within the river basin (Huong *et al.*, 2019; Das *et al.*, 2020). The social and biophysical parameters are the main contributors for the varying vulnerabilities within an area. The variation in vulnerability of the communities depend on their location in respect to river and the approaches applied based on the social status of the communities.

Sustainability livelihoods framework involves looking at the theoretical understandings derived from analysis of sustainable livelihoods and combining with additional relevant analytical frameworks in assessing the climate change vulnerability of rural livelihoods. The integrated analytical framework aides in analysing climate change vulnerability, while at the same time helps in the identification and comparison of climate change adaptation options vulnerability reduction. The climate change adaptation options effectiveness can be measured by evaluating the sensitivity of natural capital and other capital assets to the level of exposure of the climate change a system (Reed *et al.*, 2013). Despite its weaknesses, the sustainable livelihoods framework can offer a structured

way in which complementary theories and concepts on community livelihood vulnerability to climate change can be organized and integrated.

## 2. Method

### 2.1 Area of Study

Sondu Miriu River basin has got two ROR hydropower projects running. The basin supports various socioeconomic activities within the basin and in the neighbouring basins. It is, therefore, of interest to study the interaction between hydropower development and socioeconomic and environmental activities in this area.

### 2.2 Location and Description of the Study Area

The location of Sondu Miriu River basin is geographically confined within latitude 0°17' S and 0°53' S and longitude 34°45' E and 35°45' E. Among the Kenya's river basins draining into Lake Victoria, Sondu Miriu river basin is the fourth largest covering an approximate area of 3,500 km<sup>2</sup> (Masese *et al.*, 2012). The main tributaries of the Sondu Miriu river are Yunith and Kapsonoi rivers. Sondu Miriu River originates from the Mau Complex which is an expansive water catchment within Kenya. Diverse development activities and land use types characterize the Sondu Miriu River basin. The development activities and land use include industries, energy, settlements, agriculture, and forestry, among others. The various current existing human activities that have been occurring at different intensities and scales over the years within Sondu Miriu basin have capability to cause a wide range of reaching consequences to several matters in the basin. The sedimentation rates that have been observed to be on the increase within Sondu Miriu River has compromised, over the years, the river water quality in the basin (Masese *et al.*, 2012). A number of these issues included general river ecological status, the river system aquatic biodiversity and the various water uses quality.

### 2.3 Methodology

The objective was to determine the impacts of hydropower development and climate change on livelihoods of the local community living in the Sondu Miriu basin. Quantitative and qualitative social research methods were adopted to explore the community views on the impacts of the hydropower projects. These methods include questionnaires administration at household levels and in-depth interviews due its ability to offer flexibility to understand and explore fully most of the issues from the affected people's perspective. The study selected a sample size of 378 households distributed among the Sondu Miriu river subbasins based on the 2009 population census. The questionnaires were distributed based on population sizes of the sub-basins. The in-depth interviews were conducted at the various existing development actors and local administration offices such as chiefs and assistant chiefs within the Sondu Miriu river basin. The questionnaires were to collect response on the range of socio-economic status of the livelihoods of the local communities within the Sondu-Miriu river basin such as income sources, energy sources, economic activities, sources of water and health.

### 2.4 Data Collection

The socioeconomic data were collected from the community within the seven subbasins in the Sondu Miriu river basin through administration of questionnaires at household levels, interviews, key informants, and observation. The sub-basins are based on the Water Resources Authority classification of river basins in Kenya. Simple random sampling method was adopted for household data collection. In this method, there is an equal chance of every member of the population being selected to respond to the questionnaire. The population total within the basin is approximated at 86,826,533. Based on an average household size of 4 members per household as per the Kenya 2009 population census, the total households in the basin are estimated to be 21,707 (Table 1).

The sample size was determined using sample size formula as described in the Kotrlik and Higgins in 2001.

$$n = N \times \frac{\frac{Z^2 \times p \times (1 - p)}{e^2}}{\left[ N - 1 + \frac{Z^2 \times p \times (1 - p)}{e^2} \right]}$$

Equation 1: Sample size formula

Where,

n = Sample size

N = Population size,

Z = Critical value of the normal distribution at the required confidence level,

$p$  = Sample proportion,

$e$  = Margin of error

Sampling frame was based on the Sondu Miriu basin map. This ensured that all the seven (7) sub-basins were covered in the sampling with questionnaires administered in 378 households (Table 3-1). The questionnaires were administered at household levels (Appendix I). In-depth interviews with the local leadership comprising 14 chiefs/assistant chiefs were conducted in every sub-basin (Appendix II) while the in-depth interviews with the local development actors comprising Kenya Electricity Generating Company (KenGen), Water Resources Authority (Lake Victoria South (WRA-LVS) catchment area), Lake Basin Development Authority (LBDA), Kenya Agricultural and Livestock Research Organization (KALRO), and National Environment Management Authority (NEMA) were conducted at their respective offices within the vicinity of the existing hydropower projects.

This provided for continuous field data analysis, using constant comparison and coding methods through the grounded theory guided guidance (Strauss and Corbin 1990; Charmaz 2008). As a means of validating interpretations of the results of the analysis, discussions were held with the interviewees. Views from the local leaders and development actors were collected and documented as suggestions that need to be considered during stakeholders' consultations.

Table 1. Administration of questionnaires per sub-basins

S/N	Sub-basin	2009 population	Estimated No. of households	Sample size
1	1JA	9,313	2,328	41
2	1JB	4,394	1,099	19
3	1JC	19,175	4,794	83
4	1JD	11,946	2,987	52
5	1JE	9,552	2,388	42
6	1JF	25,553	6,388	111
7	1JG	6,893	1,723	30
	Total	86,826	21,707	378

### 2.5 Data Analysis

Statistical means of the responses were computed in Ms excel to determine and quantify the impact of climate variability and climate change together with hydropower generation development in the area on the local community living in the Sondu Miriu river basin. This was used to determine response of the community on various socioeconomic issues such as main source of income, average monthly income, source of energy, primary economic activities, secondary economic activities, domestic water sources, expenditure on health and distance from health facilities.

## 3. Results

There are four main sources of income within the basin. These are from formal employment, private enterprises, skilled casual labour, and unskilled casual labour. The main source of income within the Sondu Miriu River basin is private enterprises which accounts for 31% followed by casual unskilled labour at 25% and then casual skilled labour and formal employment at 22% each. The results indicate that the households' incomes are fairly distributed among the four main sources of income. The high income dominated by private enterprises is an indicator of economic opportunities in the area.

### 3.1 Socioeconomic Status

During the period of data collection, between January and March 2017, The Central Bank of Kenya mean exchange rate for the period was one United States Dollar was equivalent to Kenya shillings 103 (1 USD = Ksh. 103).

Table 2. Income status within the basin

S/N	Income Bracket	Size (%)
1	Below Ksh. 10,000 (97 USD)	32
2	Between Ksh. 10,000 (96 USD) and Kshs. 25,000 (242 USD)	27
3	Between Ksh. 25,000 (242 USD) and Kshs. 50,000 (484 USD)	15
4	Between Ksh. 50,000 (484 USD) and Ksh. 100,000 (967 USD)	16
5	Above Ksh. 100,000 (967 USD)	10

Most of the households in Sondu Miriu basin representing 59% earn monthly income of below Ksh. 25,000 (242 USD) while the households that earn above Ksh. 25,000 (242 USD) are 41%. The results indicate that households living below poverty line are more than 32% within Sondu Miriu river basin.

Five sources of energy were identified within the basin. These sources include electricity, charcoal, liquified petroleum gas, kerosene, and wood fuel. The most used sources of energy in this basin are charcoal and wood fuel accounting for 25% and 24% respectively as illustrated in Figure 5-3. 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 accelerate the land degradation that impacts on water catchment areas leading to siltation of rivers within the Sondu Miriu River basin. This if not checked may end up impacting on the hydropower production through changing river flow regimes. LPG and kerosene accounts for 18% each while electricity accounts for 15% of the energy use in the basin. The indication that only 15% use electricity is sign that there is need to enhance electricity connectivity in the area for the benefit of catchment conservation as a large percentage still use charcoal and wood fuel comprising 49% and an additional 18 percent use fossil fuel (kerosene) that has a high contribution of the greenhouse gases.

The main primary activities within the basin are crop production, animal production, forestry, quarrying, fisheries, and logging. The primary economic activities are well distributed within the basin. Fisheries accounts for the highest primary economic activity at 26%. Crop production accounts for 17%, animal production and logging accounts for 16% each, forestry accounts for 13% while quarrying activities account for 12% of the primary activities within the basin. The primary economic activities within the basin need to be managed well to promote catchment conservation. Forestry activities need to be enhanced to a larger percentage more than the current 13% while the other activities like fisheries, animal production, crop production, logging, and quarrying need to be practiced in a sustainable manner that promotes catchment conservation and management.

Secondary economic activities also seem to be relatively balanced with the construction accounting for 31%, trade accounting for 26%, housing accounting for 24% and manufacturing accounting for 19%. The higher percentage of the households engaging in construction is an indication of more infrastructural developments within the basin which need to be managed well so that such secondary activities do not impact on the hydropower operations negatively. Many households also take part in trading that can improve the economic status of the basin. Hydropower projects can also be used to support manufacturing that is being practised by 19% of the households within the Sondu Miriu river basin.

The four main water sources in the area include river, ponds, water wells and piped water supply. Majority of the community still fetch water from the rivers representing 39% of the households. Water supply from the wells represent 29%, while ponds and piped water represent 16% each. Accessibility to water supply is of great concern as only 16% of the households are connected to piped water within the basin while the majority still fetch water directly from the river, ponds, or water wells. This is an exposure of the local communities to water borne and water related illnesses which can have negative impacts on the socioeconomic activities at the local level especially during flooding and drought.

On health, many households within the basin spend less than Ksh. 10,000.00 (96.72 USD) annually on their health representing 38%. Only 4% of the households spend more than Ksh. 75,000 (725 USD) annually on their health. The households representing 33% spend between Ksh. 10,000 (96 USD) and Ksh. 25,000 (242 USD) annually, 18% spend between Ksh. 25,000 (242 USD) and Ksh. 50,000 (484 USD) while 7% spend between Ksh. 50,000 (484 USD) and Ksh. 75,000 (725 USD) annually. With most of the households at 38% spending less than one hundred US dollars (100 USD) annually on healthcare is an indication that the community health status within the Sondu Miriu river basin is good.

### *3.2 Feedback on the Interview with the Local Leaders*

The public consultation involved the local communities and other various stakeholders within and outside the Sondu Miriu River basin. This could be termed as all-inclusive as most of the stakeholders participated in the consultations. Land issues are always very delicate to deal with in Kenya and this includes the Sondu Miriu River basin. The community leadership acknowledged that the land compensation for the landowners was handled well.

During the discussions with the local leaders, which included the chiefs and assistant chiefs, their opinion was that major economic activities within the Sondu Miriu River basin include fishing, farming, livestock keeping, agroforestry, trade, and logging. This concurred with findings during the household surveys within the Sondu Miriu river basin where fishing accounted for higher percentage on the primary economic activities.

Opinion from the local leaders indicated that some climate change impacts that were experienced by the local communities included reduction in agricultural production, reduction in rainfall amounts, disruption of food production and animal health because of changing climatic conditions, reduction in pasture for the animals, reduction in fish population and reduction in forest cover.

Highlighted impacts of the development of hydropower on the local communities within the basin include improved power supply and reliability, improved environmental conservation and management through environmental conservation projects supported by the hydropower development project, improved infrastructure 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 within the basin.

There exists positive attitude from some communities towards the hydropower development projects within the Sondu Miriu River basin. These communities feel that the existing hydropower projects have brought a lot of socioeconomic development activities within the basin. On the other hand, some communities especially those on the upstream have got negative attitude towards the existing hydropower projects where they feel that they did not receive enough benefits from the existing hydropower projects.

During the development of the existing hydropower projects within the Basin, some of the benefits cited by the community include road network, watering points for the livestock and the local community, provision of a primary school and a resource centre and provision of a health centre. All these were done within the proximity of the project area. Some of the major benefits the communities were expecting during the development of the existing hydropower projects included irrigation infrastructure and piped water supply scheme for the local communities.

Even though the consultations were handled well especially within the proximity of the hydropower project area, there was no consultation at the initial stages and the consultation did not cover the entire Sondu Miriu River basin. The community leadership recommended that it is critical to have wide consultation covering the entire basin to ensure harmonious coexistence of all the communities sharing the same resource without any suspicion.

For the sake of sustainability of the catchment area for the hydropower project, several initiatives need to be introduced to support livelihoods for the communities living within the Sondu Miriu River basin. These include but not limited to irrigation projects, fish processing plants, agricultural produce processing plants for tea, potatoes, pineapples, bananas among others, afforestation programmes within the basin and environmental conservation and monitoring programmes. These when implemented within the basin will enhance resilience to climate change impacts.

### *3.3 Feedback on the Interview with the Local Actors*

From the local actors' perspective, the real livelihood challenges associated with climate change within the basin included poverty, crop failure, water-borne and water related diseases, poor water quality and water availability. Other challenges in addition to those that are associated with the changing climate include those associated with construction of the existing hydropower plants such as resettlements, noise pollution, air pollution and water pollution.

To address these challenges, it is recommended that several interventions could have been put in place during the project development cycle. These include awareness creation and education for local communities within Sondu Miriu River basin, provision of social amenities in advance before the construction works for the project to improve the local communities' resilience and promotion of livelihood projects capable of supporting adaptation to actions within the basin.

Climate change adaptation is critical for the sustainability of the hydropower development projects and provision of alternative livelihood activities within the Sondu Miriu River basin. To achieve this, several actions need to be integrated into hydropower development such as human resources and trans-disciplinary systems perspectives for

dealing with climate change, integration of environmental conservation, appropriate agricultural practices, activities that are pro-poor community-based for adapting to climate change and use of sustainable technologies and strengthening research and development capacity.

During development of the two run-of-river systems, some of the benefits expected by the community such as irrigation scheme and water supply system were not implemented due to budget constraints and prioritization. With the hydropower development in the Sondu Miriu River basin, the community expected improved access to electricity within the basin to many community households if not all of them. This did not happen as this function was left to the national government through the power off-taker (Kenya Power) which undertakes electricity distribution and connectivity tasks.

To support the stated actions, legal instruments are needed. These include official policies for addressing the impacts of climate change and adaptation actions for Sondu Miriu River basin, laws to compel all development actors within the basin to set aside a budget for adaptation actions within project area and by-laws for ensuring everyone within the basin participates in climate change adaptation actions.

#### **4. Discussion**

##### *4.1 Socioeconomic Status of Sondu Miriu River Basin*

The socioeconomic parameters considered include source of income, household income, source of energy for the households, primary and secondary economic activities, water supply sources, household expenditure on health and accessibility of health services. The socioeconomic status of the Sondu Miriu river basin indicates that majority of the households constituting about 59% are poor and earning below 241 US dollars a month. This translates to below 8 US dollars per day per household. The high income dominated by private enterprises is an indicator of economic opportunities in the area. The employment rate also is exceptionally low within the basin with only 22% in formal employment while the remaining 78% are either in private enterprises or engaged as casual labourers.

Even though majority of the households within the basin earn very low incomes, the results indicate that the households' incomes are fairly distributed among the four main sources of income. About 49% of the households use wood fuel and charcoal as energy sources which can be considered a threat to catchment conservation. Promotion of catchment conservation and management is critical within the basin as because the existing primary economic activities within the Sondu Miriu river basin if not handled well can lead to catchment destruction. Enhancement of the forest cover is key through support to programmes that promote afforestation activities so that more households can take part in forestry to a larger percentage more than the current 13%. There is need to ensure sustainable utilization of the existing basin resources as a source of livelihood. The communities' activities practiced within the basin that are dependent on the basin resources include crop production, logging, animal production, fisheries and quarrying that promotes catchment conservation and management. About 84% of the households in the basin still fetch water from the rivers, wells and ponds indicating access to portable water is still a challenge within the basin. This may expose the local communities to water borne and water related diseases. The expenditure on health services is generally exceptionally low that can be a sign of a healthy community or a community too poor to afford health services.

##### *4.2 Benefits and Impacts of the Existing Run-of-River Hydropower Projects*

Hydropower project can support several adaptation actions that contributes to its sustainability. The success of adaptation actions usually depends on the socioeconomic status of a community. From the discussions with the community leadership, the community view is that climate change has resulted in reduction in agricultural production, reduction in rainfall which is also evidence from the analysis carried out for the last decade, and disruption of food production and health. On the other hand, the existing hydropower projects have brought with them several benefits. Some of their benefits include improved power supply and reliability, improved environmental management through environmental conservation projects supported by the existing projects, improved infrastructure, land use change, employment, and education facilities. Besides the benefits associated with the existing projects, the community leadership believe that more can still be done especially irrigation system and piped water supply project.

This discussions with the other local actors in the areas also reveal that there exist some livelihood challenges that are associated with climate change in the basin. These include poverty, crop failure, poor water quality, water availability and water-borne and water related diseases. These challenges could have been addressed from initial stages of the existing projects through several interventions. These include awareness creation and education for the local communities within the Sondu Miriu River basin, provision of social amenities in advance before the construction works for the project to improve the local communities' resilience and promotion of livelihood



projects capable of supporting climate change adaptation within the basin. For sustainability hydropower development projects and provision of alternative livelihood activities within the Sondu Miriu River basin, climate change adaptation actions are necessary. There is need to integrate adaptation actions into development of hydropower such as integration of environmental conservation, appropriate agricultural practices, activities that are pro-poor community-based for adapting to the changing climate and sustainable technologies use, strengthening research and development capacity, human resources, and trans-disciplinary systems perspectives for dealing with impacts of climate change.

Research findings have indicated that developing hydropower technology can yield various social and economic co-benefits like better energy services access in rural areas, energy security, and employment, (Shrestha and Pradhan, 2010; IPCC, 2013). These can contribute to building resilience among the local communities and sustainability of the hydroelectric power development projects within the basin. Major impacts of the opportunities provided by hydropower projects in the basin is most likely to be felt in several sectors including agriculture, manufacturing, disaster risk management, environment, trade, and health among others (Bruckner, *et al.*, 2014).

Research carried out by Chandy *et al.*, 2012 in Sikkim, India recommended that Governments should provide investment advisory services the future hydropower project to the beneficiaries that receive compensatory payments for long-term livelihood security by investment in enterprises that are appropriate. Opportunity for employment in the villages is a socioeconomic benefit which is very important, but most of the employment opportunities available are during the construction phase which are short term. Depending on the technology type adopted in the design, the depletion related to hydropower project of water, forests land and agricultural land can be a natural capital loss while creation of opportunities for employment is an enhancement of human and financial investment for the local communities. Run-of-river systems have got the least impact on natural capital. The temporary nature of the direct employment during construction phase may constitute a livelihood vulnerability issue that may need to be addressed. The development of infrastructure, electricity, and markets resulting from hydropower projects also create potential for economic activity in new areas, like small-scale industries (Chandy *et al.*, 2012).

Within Sondu Miriu River basin, there exist various land use patterns that can be associated with the present community socioeconomic activities for their livelihoods. This is expected to have impacts on the catchment conservation efforts and management. Research done by Masese *et al.*, in 2012 discovered the existence of cumulative impacts in the catchment areas and on the riparian associated with human activities within Sondu Miriu basin. This was observed to have resulted from the intensified agricultural activities and clearing of forest by the local communities for their socioeconomic benefits (Masese *et al.*, 2012). The development of the existing run-of-river hydropower projects can act as a catalyst for further degradation of the catchment if not well managed or if alternatives livelihoods are not presented.

#### *4.3 Managing Community Livelihood Activities in the Sondu Miriu River Basin*

Good knowledge concerning expected future climate change patterns can inform the preparations for building communities' resilience to the anticipated climate change impacts. Knowing the trends for the past climate change can assist in explaining the reasons why the local communities take some actions for their survival. The results have demonstrated that the communities can engage in various activities with the basin that if managed well can assist in both building the community resilience and safeguarding the sustainability of other development activities in the area. For a successful climate change adaptation integration, more focus needs to be put on improving the socioeconomic status of the local communities in a sustainable manner.

Involvement of community social groups, which can be established within the Sondu Miriu river basin as consultative fora, water resource user associations, forest user associations and community lobby groups can be explored to create awareness in implementation of sustainable livelihood activities within the basin. Other community-based institution/organizations can be formed as development groups focusing on specific water subbasins or reservoirs. These community-based groups can add a lot of value to stakeholder participation in implementation of sustainable livelihood activities that contribute towards water resource and catchment conservation and management. Ong'or in 2005 considered the various community participation approaches that were being developed by the local communities to be included in the water resources management and to achieve higher levels of integration in the watershed resources management within the Lake Victoria Basin. It has been proposed that watershed management within the Sondu Miriu river basin should primarily involve several activities including protection, conservation, and development of water resources (Ong'or, 2005). The proposed integrated approach also involves management of the resources in a sustainable way for the benefit of livelihood activities especially general development, pottery and brick making, papyrus harvesting and utilization, irrigation,

and farming as well as conserving the river basin resources. Unfortunately, these have not been implemented due to lack of incentives and implementation strategy.

Some of the community livelihood activities and most likely to impact negatively on the catchment status. It has been demonstrated that some catchments within the area were experiencing a lot of pressure resulting from community livelihood activities within the subbasins or basin of the rivers and streams draining into the main river (Kairu, 2001; Osumba *et al.*, 2010; Morrison and Harper, 2009; Masese, Raburu and Kwena in 2012; Morrison *et al.*, 2012). The activities included agricultural practices, livestock keeping, forestry and settlement, solid waste disposal, water over-abstractions, wastewater disposal, and introduction of alien species (Masese, Raburu and Kwena, 2012). Makalle *et al* in 2008 concluded that there are conspicuous changes in community livelihoods resulting from intensive land use practices. These land use practices included cultivation expansion, overgrazing along the riverbanks, increased utilization of wetlands, and decreased forest cover. Makalle *et al* in 2008 also concluded that there is scarcity of original natural common resources which has forced the local farmers to explore intensification and diversification of the activities for their farm production but with limited success which can be associated with poor traditional farming practices.

The current local initiatives to be implemented within the basin will require integration of approaches that embrace policy studies and reforms, economic analysis, technical research, and indigenous knowledge (Makalle *et al* in 2008).

## 5. Conclusions

The hydropower development and climate change projects impact on the livelihood of the local communities. As the climate variability and change climate impact negatively on the local communities, hydropower projects can support adaptation actions that can assist the local communities to adapt to these impacts. The socioeconomic status of the communities around the run-of-river hydropower plants can be associated with the existence of opportunities created by the presence the two hydropower projects in the area. With the knowledge of future climate change trends, the communities within the Sondu Miriu river basin can be guided on the most appropriate and sustainable livelihood activities to implement within the basin.

## 6. Recommendations

The community vulnerability to the climate change impacts can be addressed through hydropower development benefits. Establishing climate change programmes supported by the projects on hydropower development could help in achieving this goal within the river basin for its long-term sustainability. The programmes should target the local communities living both in the upstream and downstream of the existing and proposed projects on hydropower. These programmes should be integral part of the larger hydropower project to make integration of adaptation sustainable. The strategies for integration of adaptation need to incorporate the local solutions to make the effective and acceptable to the local communities. This will bring about the sense of ownership and hence the community groups actively taking part in the development of these strategies to address the improvement of community livelihoods and build resilience in coping with the impacts of climate change.

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