Sustainable and appropriate climate change adaptation strategies for hydropower developments in the Sondu Miriu River Basin

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Abstract

As climate change continues impacting on various economic sectors all over the world, a lot of efforts are being put on adaptation actions. Energy is one of those sectors contributing more towards GHG emissions while renewable energy technologies have the potential of mitigating GHG emissions. Among all the renewable energy technologies being utilised, hydropower stands out to be the most stable and proven technology over time compared to geothermal, wind, solar, biogas and ocean waves among others. Despite hydropower being capable of mitigating the impacts of climate change while supporting some appropriate adaptation strategies, less emphasis has been put on how to integrate climate change adaptation into the hydropower development activities.

The research questions that was formulated for the study is what are the existing strategies for integrating sustainable climate change adaptation into hydropower developments in the Sondu Miriu River basin. The main objective of the study was to determine the most sustainable and appropriate strategies for integrating climate change adaptation into hydropower development activities.

The methodology used in this study included the evaluation of existing strategies for integrating climate change adaptation into developments in order to determine the most appropriate strategies.

The results indicate that the development of hydropower in the area presents opportunities for supporting adaptation actions that are capable of addressing some of the impacts of climate change on the local community. Several adaptation strategies exist that can be applied to integrate climate change adaptation into hydropower development activities.

Key words: Climate change, Adaptation strategies, Hydropower development, Sondu Miriu River basin.

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 occurrence of these gases always keep the earth warm as they trap heat within the atmosphere. The major contributor 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 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 consensus have projected a global mean temperature rise of approximately 3^{o}C indicating 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. (Kumar *et al.,* 2011).

It is also projected that changes in the river flow characteristics specifically quantity and timing accompanied by increased water evaporation from the reservoirs have got higher likelihood of impacting on the hydropower production. This is inclusive of impacts on system operation, financial and other energy sectors (Harrison *et al.,* 1998).

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 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.

A hydropower development scheme has the potential of providing major supporting role for the climate change adaptation actions locally. 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 environmental 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 (Moomaw *et al*., 2011).

Currently, climate change adaptation is being considered an essential element of sustainable development (Moomaw et al., 2011). 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 (Klein *et al*., 2007). 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 (WCD, 2000).

The objective of this study is to determine the most sustainable and appropriate climate change adaptation strategies for hydropower developments. The current drive for electricity generation expansion 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 (Kumar *et al*., 2011). Integration of climate change adaptation into hydropower development will, therefore, contribute towards reducing vulnerability of the local community and environment to impacts of climate change.

The area of study which is Sondu-Miriu River basin is situated in the western 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 0º17' and 0º53' South and longitude 34º45' and 35º45' East. This River basin is the fourth largest basin among the Kenyan River basins that drain their water into Lake Victoria and it covers an area of approximately 3,500 km^2 (Masese *et al*., 2012). Kapsonoi and Yunith rivers are the main tributaries 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, aquatic 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 (Masese *et al*., 2012). The biophysical status in this area has got much influence on the human activities in this area. It defines the scope of human behaviour to be able to fit within the prevailing condition.

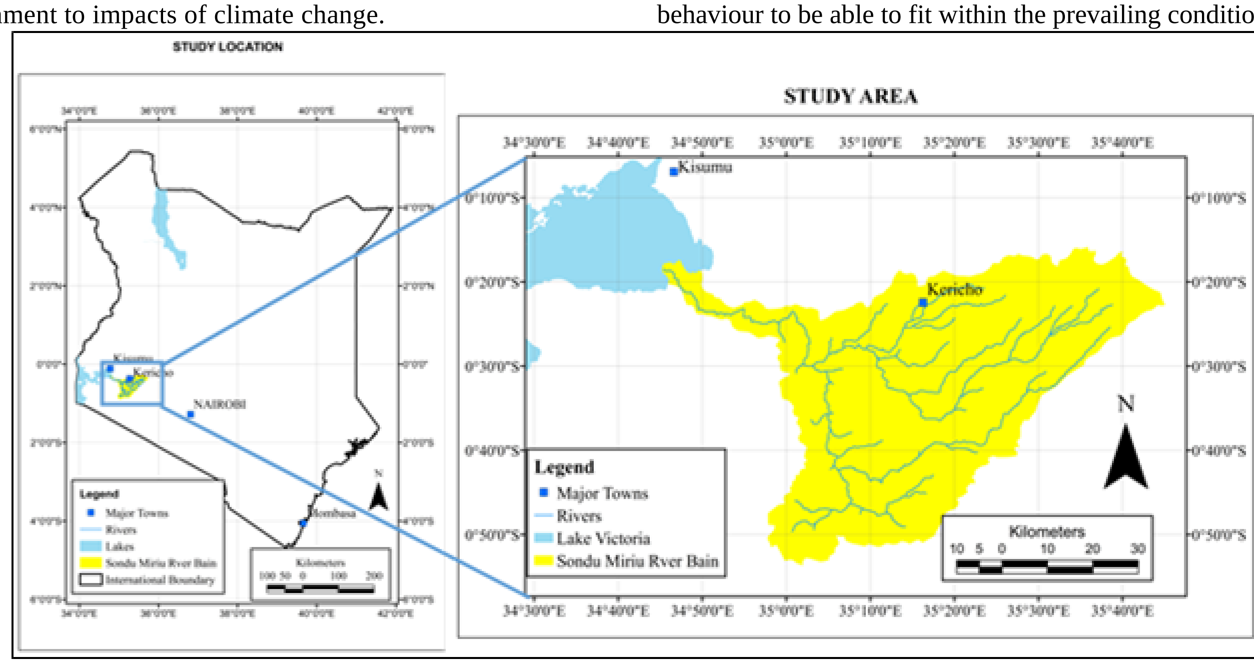

FIGURE 1: MAP SHOWING THE POSITION OF THE STUDY AREA

The climate in Kenya is controlled by several factors such as latitude, altitude, prevailing winds characteristics, distance from relatively large water bodies and topography. Topography plays a more significant role especially in areas with diversity of relief which in some cases can form barriers to the prevailing winds. The greatest insolation is always experienced during the periods when the sun is directly overhead. This creates a low pressure area which is also known as the Inter-Tropical Convergence Zone (ITCZ). This is an area of convergence of air masses. During the movement of air mass there is transportation and inducement of particular climatic characteristics associated with that air mass throughout the entire areas or region over which it passes across. The convergence of the air masses usually causes cooling, condensation and precipitation as a result of upward movement of the air mass over the low pressure belt (GoK, 2010).

Sondu-Miriu River catchment experiences two distinct rainfall seasons also referred to as bimodal rainfall pattern. The season of long rains usually start from the month of March and ends in the month of May while the seasons for short rains are usually experienced from September to November. However this seasonality is much clearer in the lower region compared to the highland regions. The highland region receives a total amount of annual rainfall of approximately 1,800 mm annually, and decreases to about 1,500mm towards the lowlands. The features that influence the amount of rainfall received in this area are altitude and relief. The amount of rainfall received in the upper regions if the basin is usually higher compared with the amounts received in the both the middle and lower regions. Rainfall that is normally received in the highland areas is as a result of south-easterly winds. These winds transport air masses from the Indian Ocean, which are warmer, towards the highlands resulting into orographic rainfall. Most of the rains that occur in the lowlands near Lake Victoria are caused by the convective currents present in the lake. The lowlands have an average annual temperature of 26ºC. The mean annual maximum temperature is about 30ºC and the mean annual minimum temperature is 18º C. The relative humidity is approximately 62% for most of the year (Masese *et al*., 2012).

The Sondu Miriu river basin is densely populated. The population density in the area is approximated to be nearly 500 persons per kilometre square. In the upper reaches which is dominated by the forest has got lower population density compared with other areas within the basin. The community livelihoods in the catchment depends on agriculture, fishing and trade. Tea growing is majorly practiced in the upper part of the catchment while on the lower part subsistence agriculture is common. There is also fishing along Sondu-Miriu River especially in the lower reaches. In addition to agriculture and fishing, there are also small scale business enterprises within the area.

Sondu-Miriu catchment is one of the areas with inhabitants and biodiversity that has been adversely affected due to the construction of various infrastructure developments including hydropower projects within the basin. The effects of these developments on the inhabitants and biodiversity are yet to be understood both upstream and downstream of the project locations. Even though these effects have not been understood, the reality is that biodiversity and ecological processes are threatened in this ecosystem (NEMA, 2009). Most of the land within Sondu Miriu River basin are arable land. The land is used mostly for agricultural production while a good percentage is also under forest cover especially in the upper regions of the basin. Agricultural land use include pasture and crop production. Non-agricultural land uses include forest reserves, roads and settlements. Sondu Miriu River and its tributaries form the main sources of water for various uses in the basin. Ground water abstraction is still minimal in the area. All the rivers within the basin are permanent rivers with reasonably adequate flows throughout the year.

There are several factors that influence economic activities in this area and go along in shaping the social behaviour. These factors have got a lot of influence especially on how a particular group or socio economic class behave within the society including their actions. 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 (Olago *et al*, 2007). 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 luck of adequately equipped health facilities in the area to be able to control these diseases during the outbreaks.

II. 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 0.7ºC to 2.0ºC and 0.2ºC to 1.3ºC respectively across the country (GoK, 2010).

The only known available primary tools for investigations on how the climate system responds to various forcings are climate models. These climate models also provide the possibility of producing climate predictions not only on seasonal and dekadal time scale but also predictions for the next century and beyond (Flato *et al*., 2013). Both the simple energy balance models and the complex earth system models require state-of-the-art computing capabilities with high performance. Scientific question being addressed will directly determine the choice of model to be applied in the research (Held, 2005; Collins *et al*., 2006). These applications include simulations of palaeoclimate, process studies and sensitivity analysis for characterization and physical understanding, short term prediction of climate change and variability based on both seasonal and dekadal time scales. This facilitates the future climate change projections in the next century and downscaling these projections for the purpose of providing more details at both the regional and local time scales. When larger ensembles or longer integration are required, it is possible to use simplified models which have reduced complexities or spatial resolution due to computational costs that may be involved (Flato *et al*., 2013).

A. Impacts of Climate Change

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 other influences (Niang *et al*, 2014).

Changing precipitation alters hydrological characteristics 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% and 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 (Droogers *et al*, 2009).

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 referred to as "Long Rains" and a general increase during October to December in the region (GoK, 2010; Liebmann *et al*, 2014). 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 (Kumar *et al*., 2011). 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 characteristics 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. (Kumar *et al*, 2011).

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.

B. Impacts on Economic activities

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 (IPCC, 2013). 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 (IPCC, 2013).

C. Climate change adaptation strategies for hydropower development

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" (IPCC, 2007).

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" (IPCC, 2007).

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 (Lebel *et al*., 2012).

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 (Wilbanks *et al*., 2007; Bizikova *et al*., 2010) particularly when the existing policy consideration and financial commitments towards response to climate change have to focus on pursuing adaptation actions. In practice, however, adaptation actions normally have a tendency of involving various community interests, schedules and responsibilities for decision making (IPCC, 2007a; Wilbanks *et al*., 2007).

The framing of adaptation as it is currently has been moved to focus more on the wider socioeconomic drivers of vulnerability and people's ability that can help them in responding to the climate change impacts. This has changed from initial focus which was mainly on biophysical vulnerability. The socioeconomic drivers include issues to do with gender, health, age, social ethnicity and institutions put in place either locally, nationally, regionally or even internationally. The expression of adaptation goals is normally done in terms of the ability to increase resilience. This usually encourages the incorporation of broader development goals with multi-sectoral objectives and various scales of operation that are capable of capturing complex interactions involving human societies and environment within which they exist (Noble *et al*., 2014).

So long as there is existence of anticipated risks and experienced impacts due to climate change that need actions for ensuring safety and security of the population including their own assets as well as ecosystem and their services, adaptation needs will always arise. Adaptation needs can be described as the difference between what is most likely to happen due to climate change impact and what would be preferred to happen. For the National Adaptation Programmes of Action (NAPAs) "needs" have been looked at in the form of major vulnerabilities and adaptation activities which are of high priority. This may be referred to as a hazard based approach. This approach pays more attention to the drivers of climate change impacts and actions with a target of moderating them. It is still most commonly used approach in many urban and regional programmes. The focus has recently changed to find ways of how the underlying causes of vulnerability can be addressed. These include various needs including information, capacity, financial, institutional and technology.

III. DATA AND METHODS

There are several strategies available in literature. Different strategies are suitable under different conditions. The available climate change adaptation strategies will be identified through literature review.

Comparative analysis of the available strategies are carried out and assign priorities to the most critical strategies that can yield the best impacts. Several tools are available for the comparative analysis. For this study a combination of action impact matrix (AIM) and sustainable development assessment (SDA) tools are applied to provide the most effective strategies.

In the action impact matrix, evaluation of available climate change adaptation strategies against their economic, environmental and social impacts is carried out. This facilitates the sustainability of development by analysing economic, environmental and social interactions. The approach helps in coming up with win-win strategies that will achieve conventional macroeconomic objectives as well as making local and national development efforts more sustainable. The tool identifies key linkages between development efforts and climate change adaptation. Development paths that embed local climate change adaptation in the overall hydropower development strategy are also identified.

The sustainable development assessment tool is also critical specifically at the local or project level. The tool incorporates environmental and social assessments into the conventional process of economic decision making whereby the economic valuation of environmental and social impact serving as the basis for cost benefit analysis.

Using the two tools will enable the identification of appropriate strategies that will be applicable within the Sondu Miriu River Basin both downstream and upstream of the proposed or existing hydropower development projects. It will also link the strategies with the possible actors operating within the basin. At the end of this exercise the outcome and recommended actions are to be shared with the opinion leaders through dissemination workshops.

IV. RESULTS AND DISCUSSIONS

In Kenya, the National Climate Change Response Strategy (NCCRS) of 2010 became the first national policy document that was able to fully acknowledge the reality of climate change. The policy decisions in Kenya has been guided by the NCCRS since its launch in 2010. This strategy was able to provide the evidence of climate change impacts on various economic sectors and proposed adaptation and mitigation strategies.

The National Climate Change Action Plan (NCCAP) has been able to take forward the NCCRS implantation. The development of the NCCAP was done through a process that was extensively consultative. The NCCAP received a lot of support from various stakeholders and development partners. The NCCAP summary findings included;

i. A low carbon, climate resilient development pathway,
ii. Recommendations for an enabling policy and regulatory framework,
iii. Adaptation analysis and priority actions,
iv. Mitigation options,
v. Consolidations for technology requirements,
vi. A national performance and benefit measurement (NPBM) system
vii. Recommendations for knowledge management and capacity development,
viii. A climate change financing mechanism

The NCCAP is expected to give guidance on the national development and policy decisions in all the economic sectors. Various actors such as Government institutions, private sector and civil society organizations are also expected to contribute towards the implementation of the NCCAP. Climate change planning is considered a cross-cutting and dynamic process. Therefore, the recommended actions are expected to be continuously tracked while the NCCAP will also need to be revised and updated every five (5) years in conformity with the national planning and budgetary processes.

Kenya as a country has got very minimal historical or current responsibility if any for the global climate change. The country's emissions are also very insignificant compared to total emissions globally. Despite all these the country is highly vulnerable to the climate change impacts. This makes climate change adaptation to be one of the main priorities for the country.

The adaptation analysis based on the climate risk that that was conducted during the National Climate Change Action Plan (NCCAP) preparation period majorly relied on The National Climate Change Response Strategy (NCCRS) findings. The aims of the adaptation analysis were:

(1) Providing the evidence of key climate risks to Kenya as a country,
(2) Assessing the impacts of climate change on all the sectors,
(3) Documenting all the activities that are on-going, planned or recommended on climate adaptation,
(4) Developing a set of actions for potential and priority adaptation that are capable of addressing the projected impacts of climate change in each and every sector to feed into the Kenya's National Adaptation Plan (NAP),
(5) Supporting the climate change adaptation integration into the relevant existing and new sector policies, development, budgetary and planning processes and strategies across different levels.

Currently, the National Climate Change Secretariat (NCCS) is responsible for coordinating all the climate change activities in Kenya. The NCCS is under the Ministry of Environment and Natural Resources. The NCCS also double up as the National Focal Point for the UNFCCC. The NCCS works with the climate change coordination units in various ministries, departments and agencies to ensure that climate change in mainstreamed in the various economic sectors.

Most of the current adaptation actions proposed in the adaptaion action plans are at the national level. There is need to translate these actions to the local level. According to the International Federation of Red Cross and Red Crescent Societies (IFRC), Red Crescent Climate Centre and ProVention Consortium, the following are required to be part of the strategies to be able to have impact at the local level;

1. Prioritization of adaptation efforts in areas with the highest vulnerabilities and the greatest need for safety and resilience,
2. Incorporating the projected trends related to climate change into the current vulnerability and risk assessment based on the current climate variability,
3. Full integration of climate change adaptation into the long term national and local sustainable development and poverty reduction strategies,
4. Prioritization and strengthening of existing local capacities including local authorities, civil society organizations and private sector and strengthening of the existing local capacities including various actors such as local authorities, civil society organizations and private sector. This strategy will create opportunities for a very robust climate risk management as well as rapid up-scaling of adaptation actions achievable through community based risk reduction and effective local governance,
5. Developing robust mechanisms to mobilize resources for adaptation that will ensure continuous flow of both financial and technical support to local actors,
6. Leveraging the opportunities available in the disaster prevention and response. This is done through improving early warning systems, contingency planning and integrated response in order to promote effective community based adaptation and risk reduction.

The communities need to be motivated to take adaptive actions. Some of the shared community values that motivates action include:

i. Community identification with nearby natural resources or ecosystems,
ii. Community cohesion and social equity,
iii. Desire to revitalize, maintain, or enhance socio-economic conditions

For an effective adaptation strategy, the community actions can include but not limited to;

i. Managing ecosystems or natural resources,
ii. Green and gray infrastructure related actions,
iii. Enhance adaptive capacity,
iv. Develop and bolster human and social capital,

For the implementation of effective adaptation actions, two critical elements are required. These include effective leadership and building community support. The requirements for these elements are described as follows;

(a) Effective Leadership Requirements

i. Ability to identify needs and supply a vision for change,
ii. Ability to work in a coalition,
iii. Ability to sustain effectiveness for a long period of time to enact change,

(b) Building community support

i. Broadening support through a focus on co-benefits,
ii. Tailoring community discussions of climate change to fit within the local politics and attitudes of the public,
iii. Enhancing support through grassroots or community organizations,
iv. Engagement of more vulnerable populations,

Adaptation strategy development should be targeted at pulling together both national and devolved governments for it to be effective. Centralized oversight by the national government provides an overarching, national framework and strong leadership while Regional/local involvement integrates locally specific issues and increases stakeholder buy-in which aids implementation.

A sector by sector approach to vulnerability/risk assessment and strategy implementation is pragmatic as it maps into the existing government structure and stakeholder groups. National level vulnerability/risk assessment in more complex and resource intensive than sector by sector assessment. This depend upon having a robust sectoral and possibly regional risk assessments to build upon and effective stakeholder engagement process.

Adaptation strategies may benefit from giving more detailed consideration to linkages between adaptation and mitigation policies, treatment of international impacts and social justice.

V. CONCLUSIONS AND RECOMMENDATION

A. *Conclusions*

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 and 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 up to operations stage. There exist several strategies that can be adopted for integration of climate change to reduce vulnerability to climate change impacts in the basin.

B. *Recommendations*

Both technological and management interventions will be required going forward to manage the anticipated changes in order to minimize any negative impact the climate change may have on the hydropower energy production in the existing hydropower plants and any future hydropower plants that may be planned in the basin.

Hydropower development benefits can be tailored to address community vulnerability to the impacts of climate change. This can be achieved through establishment of climate change programmes which are supported by the hydropower development projects for its long term sustainability. For this to be successful, climate change adaptation rules are needed to be put in place in order to realize adaptation objectives.

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