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*Research Article*

# Climate Change Adaptation Strategies for Hydropower Development in Sondu Miriu Basin

**Willis Owino Ochieng**,[1] **Christopher Oludhe**,[1] **Simeon Dulo**,[2] **and Lydia Olaka**[1]

[1]*Department of Earth and Climate Sciences, University of Nairobi, Nairobi, Kenya*
[2]*Department of Civil & Construction Engineering, University of Nairobi, Nairobi, Kenya*

Correspondence should be addressed to Willis Owino Ochieng; wowino@gmail.com

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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 is vulnerable to rainfall variability and requires strategies for building resilience for the local communities. The objective of this study was to identify appropriate and sustainable strategies for integrating climate change adaptation into hydropower development within the Sondu Miriu River Basin. The methodology involved review of existing climate change adaptation strategies to identify appropriate strategies for integrating climate change adaptation in hydropower developments within the Sondu Miriu River Basin. The results indicate that no clear climate change adaptation strategies are being implemented within the basin. A framework is needed to implement appropriate climate change adaptation strategies within the basin. Climate Change act of 2016 created linkage with other existing policies for effective support of integration of climate change adaptation into hydropower development in Sondu Miriu River Basin. Strengthening community resilience to climate change impacts is one of the benefits to be derived from the hydropower projects by supporting appropriate adaptation strategies.

## 1. Introduction

The concept of integration of climate change adaptation is gaining pace to pool all resources together for the maximization of the benefits. The experiences from the ongoing integration of climate change adaptation programmes can present useful lessons that can be learnt from adaptation efforts. Many barriers for climate change adaptation integration have been identified to include, among others, lacking political commitment and active meaningful participation including institutional persistent practices that continuously ignore climate change impacts [1]. Whereas some of the threats due to climate change might be new, like exceptional climatic situations, most of the climate change adaptation initiatives are built on long-term efforts, such as reducing the risk of disasters [2]. It is evident that adaptation can potentially be aligned closely with major development objectives nationally and locally [3–5]. There is an urgent need to put in place appropriate water resources management strategies for ensuring the sustainability of the community livelihoods and environment, especially in the context of changing climate [6].

Countries all over the world have made hydropower development a priority for implementing adaptation measures against climate change impacts since 2008 [7]. While there have been few plans for adaptation measures against climate change impacts with a regional focus particularly in Africa [8], there is more potential to plan for already recognized climate change adaptation measures so far [9–11]. The interest in the identification of opportunities that are essential for adaptation needs in Africa is increasing, including presenting key success factors for adaptation. Klein et al. [12] identified opportunities such as awareness raising, capacity building, analysis tools, policy, learning, and innovation that are suitable for the implementation of adaptation measures during the hydropower development process that are simple low regrets and relatively low cost in reducing communities' vulnerability to the prevailing

climate variability, with several associated benefits from hydropower projects that in the long term are able to reduce vulnerability to climate change [8, 9, 13].

Hydropower is considered environmentally friendly with negligible greenhouse gases emissions [14]. Nevertheless, the use of various structural and nonstructural actions is still needed for the management of the impacts of climate change on hydropower projects. Appropriate management and operational strategies for hydropower projects are essential for adapting to climate change impacts on the hydropower projects [15]. Nonstructural and structural measures are essential for environmental safety for the population relying on hydropower projects [16].

Even though adaptation has been considered as an essential element in terms of sustainable development [17], the existing hydropower implementation frameworks in Kenya do not compel the development agencies to integrate adaptation measures into the development plans for hydropower. The existing and future hydropower projects within Sondu Miriu River Basin are at risk of failing to meet their set medium- and long-term objectives while compromising the resilience of local communities to cope with the impacts of climate change due to poor integration of local adaptation needs and appropriate actions into hydropower development processes. The research question for this study was to find out what strategies exist within the Sondu Miriu River Basin for integrating climate change adaptation into hydropower development.

The objective of this study was to identify appropriate and sustainable climate change adaptation strategies for hydropower development in Sondu Miriu basin. Kenya's most priority in climate change response remains adaptation and resilience. Kenya is among the countries in the forefront advocating for climate change. Kenya launched a National Climate Change Response Strategy (NCCRS) in 2010 and a National Climate Change Action Plan (NCCAP 2013–2017) in 2013 to advocate for climate change. In 2018, another National Climate Change Action Plan (2018–2022) was again launched. The launch of these action plans is a clear demonstration that adaptation has been made one of the country's main priorities due to the adverse social and economic impacts that are related to the changing climate being experienced across various sectors and the increasing vulnerabilities of the various sectors including energy sector. The NCCAP clearly communicates that it is important to address the negative environmental, social, and economic impacts caused by the changing climate to achieve sustainable development. Climate change adaptation is therefore recommended to be integrated into hydropower development planning, budgeting, and implementation at the local or river basin level.

Climate change adaptation involves vulnerability and risk reduction, looking for opportunities and building the capacity of individuals, communities, and natural systems to manage climate impacts. It further involves mobilization of that capacity by implementing appropriate actions and decisions [18]. For hydropower development, climate change adaptation aims to reduce risk and vulnerability of the hydropower projects and local communities by seeking opportunities and building the capacity of various related sectors to cope with climate impacts at the river basin level while mobilizing the capacity at the same time both internally and externally to implement decisions and recommended actions [19]. Sufficient information on vulnerabilities and risks is needed for the identification of adaptation needs and appropriate adaptation options for building capacity and reducing risks.

There are two broad classes at the local level for determining vulnerability. These include socioeconomic determinants and biophysical determinants [20]. However, climate change adaptation needs are context specific and very diverse. Various stakeholders, both individuals and groups, have different climate change adaptation vulnerabilities and needs. Climate change adaptation limitations and constraints may portray that all the adaptation needs will not be satisfied, justifying the need to put more emphasis on monitoring to prevent going beyond critical thresholds [19].

Socially, vulnerability varies because of the groups or individuals' capacity to reduce and manage the climate change impacts. Ethnicity, gender, health, age, class, and social status are among the key factors that determine vulnerability [21, 22]. Among all the conditions that influence vulnerability related to climate change, persistent inequality and poverty are the most significant [19]. Relatively greater climate change impacts are expected to be experienced by the poor because of several factors that include poor conditions of shelter, limited financial resources, exposure to the climatic elements, unreliable local ecosystem services, and unreliable basic services provision and their lack of resources in supporting recovery from an increased frequency of losses caused by extreme climate events [23–33]. Because of the usually compromised health status and limited financial resources, the vulnerable groups including the elderly, the sick, and the poor are usually at increased risk caused by climate change impacts [34–44].

Adaptation to climate change for hydropower development requires adequate information on risks and vulnerabilities on hydropower operations for identification of appropriate adaptation needs and options that can lead to risk reduction and building capacity. Outlining an approach to climate change adaptation requires engagement of people with varying experience, backgrounds, and knowledge in addressing and achieving a shared approach for managing the challenges [18, 45–47]. In the past, adaptation needs identification was often based on the assessments of the impacts, but the use of resilience assessments or social vulnerability is on the increase [20, 46]. The framework for social vulnerability focuses on how the individuals, groups, and communities within the Sondu Miriu River Basin are vulnerable to the impacts of climate change. It focuses on how different factors influence the economic and social conditions that may place communities at risk [20, 48, 49]. These frameworks allow for overlaps and complementarities. Therefore, acquisition of adequate information risks and vulnerabilities on hydropower within the Sondu Miriu River Basin is critical for the determination of the adaptation needs for hydropower development.

There is need to adopt an integrated and transformative system approach in responding to the challenges presented by complex and cross-cutting climate change problems for sustainable hydropower development and resilient livelihoods [50] within the Sondu Miriu River Basin. The current approaches being applied by various sectors to the initiatives for adaptation usually have the tendency of creating imbalances and hindering sustainable development [50]. Climate change adaptation is a component of the climate-resilient pathways. Therefore, it has been proposed to integrate adaptation actions in the form of ambitious goal. The proposal was made within the broader sustainable development framework [51, 52] especially with the prevailing financial commitments and considering policy towards responding to the changing climate focusing on following up adaptation actions.

Development of strategies to minimize the negative socioeconomic impacts of hydropower projects is needed to enable them to be implemented in a fair and cautious manner that benefits all the stakeholders [53]. There are several strategies for climate change adaptation. These include decision-making time horizons strategies, no regret strategies, soft adaptation strategies, safety margins strategies, and reversible and flexible strategies [54, 55].

The decision-making time horizons' strategies reduce the lifetime of investments to reduce uncertainty and corresponding costs as the uncertainty associated with future climate change increases with time. No regret strategies are capable of coping with climate uncertainty and yielding benefits even in conditions when the climate is not changing. Reversible and flexible strategies aim at minimizing the costs in case the future climate change does not happen as projected. Safety margins' strategies aim at reducing vulnerability at no or low cost. Soft adaptation strategies such as institutional and financial tools can also be applied [54].

## 2. Data and Methods

*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.

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 the generation of hydroelectric power into the Kenya National Electricity Grid.

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 $km^2$ [56]. 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. A number of these issues included general river ecological status, the river system aquatic biodiversity, and the various water uses' quality. The sedimentation rates that have been observed to be on the increase within Sondu Miriu River have compromised, over the years, the river water quality in the basin [56].

*2.2. Methodology.* To guide the evaluation of strategies for climate change adaptation in Sondu Miriu River Basin, the IPCC technical guidelines were adopted for the assessment of climate change impacts and adaptations [57]. They provide guidelines on the procedures for assessing potential climate change impacts and evaluation of appropriate adaptation actions. A study framework is outlined that allows for comparison assessments on impacts of changing climate and adaptation actions suitable for various geographical regions, economic sectors, and countries [57].

*2.2.1. Evaluation of Existing Strategies.* The available strategy documents that address climate change and its impacts were obtained from the Kenyan Ministry of Environment and Forestry. Officially, the main guide for information on climate change strategy is the National Climate Change Response Strategy (NCCRS) enacted in the year 2010, which was the first Kenyan national policy document to fully acknowledge the reality of climate change. This strategy provided the evidence of impacts of climate change on several economic sectors together with the proposed strategies for mitigation and adaptation. This strategy aims to address the climate change impacts across all sectors.

The National Climate Change Action Plan (NCCAP) was another critical document with the main purpose of operationalization of the NCCRS. The NCCAP development was done through an extensive consultative process that made the document acceptable across all the sectors. The NCCAP has been receiving a lot of support from the development partners and various stakeholders from all sectors including energy. The provision of the guidance on the national policy decisions and development is expected to come from NCCAP for all the economic sectors. After every five years, the NCCAP is updated to conform with the national budgetary and planning processes. For this study, the National Climate Change Action (2018–2022) was evaluated.

*2.2.2. Data Analysis.* The factors that were evaluated in the existing strategy include (1) defining the objectives of the adaptation strategies, (2) specification of the climate change impacts which are important for the hydropower generation and community livelihood, (3) identification of the relevant

climate change adaptation options, (4) examination of the limitations, (5) quantification of the measures and formulation of the alternative strategies, (6) weighting the adaptation objectives and evaluating the trade-offs, and (7) adaptation measures recommendations as outlined in the IPCC technical guidelines for the assessment of the impacts of climate change and climate change adaptations [57].

*(1) Defining the Objectives of the Adaptation Strategies*. The overall objective is to integrate of climate change adaptation measures into the development of hydropower projects within Sondu Miriu Basin specifically determining the most appropriate and sustainable strategies for integrating adaptation measures into the development of hydropower.

*(2) Specifying the Climate Change Impacts of Importance*. This involved assessing all the possible impacts of changing climate on the hydropower projects and the livelihoods of the local communities within Sondu Miriu Basin. It includes specific details of climatic events expected to affect hydropower generation and local community livelihoods to be able to identify adaptation options that are most appropriate.

*(3) Identifying the Adaptation Options*. A list detailing all the possible adaptation actions for coping with climate change impacts was compiled through field surveys and literature review. It considered all practices that were previously used or are currently being used as well as other feasible alternative strategies that may be suitable for the basin.

The identification of the strategies for adaptation was guided by the IPCC technical guidelines for adapting to the climate change impacts which include (1) loss prevention that involves anticipatory actions for reducing the susceptibility of an exposure unit to the climate change impacts, (2) loss toleration that involves in the short term accepting adverse impacts that the exposure unit can absorb without causing long-term damage, (3) loss sharing or spreading that involves actions intended at distributing burden of climate change impact for covering a larger population or region beyond those affected directly by the climatic event, (4) change of activity or use that involves switching of resource use or an activity to make it possible to adjust to the positive impacts and the negative impacts of climate change, and (5) change of location that involves a situation where an activity preservation is considered to be more important compared to the place where it is located, and migrating to the areas that are considered suitable under the changed climate, and after the modification or damage due to climate change, carry out restoration with an aim of restoring the system to its original condition.

*(4) Examining the Constraints*. The existing constraints that may affect the implementation of available climate change adaptation actions choices were examined on how they might affect the possible choices available. These constraints include prevailing social norms and existing legislations, which may prohibit, restrict, or encourage their application.

*(5) Quantifying the Measures and Formulating Alternative Strategies*. Each adaptation measure performance was assessed in line with the adaptation objectives for the respective adaptation strategies. Under the different climatic scenarios, expert judgement was used to evaluate the success of different measures. At this stage, risk assessment and uncertainty analysis were also considered. This was a critical step for the development of strategies to maximize the achievements of the adaptation objective while at the same time maintaining the baseline levels of progress towards the other objectives of the adaptation strategies.

*(6) Weighting the Objectives and Evaluating the Trade-Offs*. The objective of the strategies was subjective in this step, depending on the preferences and then comparative analysis among the success of various strategies in meeting their objective. Standard impact accounting system was applied in the evaluation process. Selection of preferred strategies was determined based on the trade-offs between the available strategies.

*(7) Recommending Adaptation Measures*. The outcome of the evaluation process was put in the format to provide the policy decision makers and advisers with information on the best strategies available for adaptation. This included the rationale used such as key evaluation principles, decision rules, institutional capability, national and international support, technical capability to narrow down the choices and some indication of the uncertainties and assumptions involved in the evaluation procedure.

## 3. Results and Discussions

### 3.1. Results

*3.1.1. Defining the Objectives of the Adaptation Strategies.* The objective was to identify adaptation strategies within Sondu Miriu River Basin that can be applied in hydropower development projects. It looked at the national and local strategies and how these strategies can be improved locally. The main objective of the strategies was to identify adaptation actions that can be implemented within the Sondu Miriu River Basin to support sustainable hydropower development and building resilience to the communities locally in coping with the climate change impacts within the basin. It was found out that there are no strategies being implemented at the local level. Therefore, there is need to establish strategies for integrating climate change adaptation into hydropower development with clear objectives for integration.

*3.1.2. Climatic Change Impacts of Significance in Sondu Miriu River Basin.* There were several climate change impacts within Sondu Miriu Basin highlighted by the local leaders and development actors during the interviews. These impacts include displacement of populations, water scarcity, drought, land and ecosystem degradation, negative impacts on humans and livestock health, food and nutrition insecurity, declining agricultural and livestock productivity, and flooding. Within Sondu Miriu Basin, there are impacts of climate change on existing hydropower projects and local

community livelihoods. With the projected increased rainfall amounts and temperature, the frequency of the meteorological extremes is expected to increase and may make the current impacts worse. Droughts will lower hydropower, agricultural and livestock production, flooding will destroy property and cause displacement of the people in low land areas, food and nutrition insecurity will lead to malnutrition, negative health impacts will strain the existing health facilities, and land and ecosystem degradation will compromise the hydropower and livelihood sustainability while water scarcity and displacement will weaken the communities' resilience. These identified impacts of significance need to be considered during formulation of strategies for climate change adaptation at the Sondu Miriu Basin level.

*3.1.3. Policy and Adaptation Options.* Since the launch of NCCRS in 2010, it has been the guide for policy decisions in Kenya. The first national policy document was National Climate Change Response Strategy (NCCRS) enacted in 2010 that fully acknowledged the reality of climate change. The evidence of climate change impacts was provided by the NCCRS on various economic sectors together with the proposed strategies for climate change adaptation and mitigation [58].

The NCCRS implementation has been taken forward by the National Climate Change Action Plan (NCCAP). An extensively consultative process was adopted for the development of the NCCAP. There was a lot of assistance received from many development partners and stakeholders for the NCCAP. The NCCAP brief results included the following.

(i) Recommendations for capacity development and knowledge management

(ii) A development pathway for low carbon and climate resilience

(iii) A national performance and benefit measurement (NPBM) system

(iv) Recommendations for a regulatory framework and an enabling policy

(v) Consolidations for technology requirements

(vi) Priority actions and adaptation analysis

(vii) A financing mechanism for climate change

(viii) Mitigation options

The national policy and development decisions are expected to be guided by the NCCAP in all the sectors of economy. Various actors including civil society organizations, private sector, and government institutions are required to participate in implementing the NCCAP. Planning of climate change is considered as a process that is dynamic and cross-cutting. Therefore, it is expected to continuously track the recommended actions while a revision and update of the NCCAP will require to be conducted every 5 years to conform with budgetary and planning processes at the national level.

Kenya as a country has very minimal current or historical responsibility for the global climate change if any. This is due to the country's very minor emissions in relation to the entire global emissions. The vulnerability of country to climate change impacts, in spite of all these, is still very highly. One of the Kenya's main priorities is adaptation to climate change and particularly in the hydropower development.

During the period for preparing National Climate Change Action Plan (NCCAP), the climate risk-based adaptation analysis that was performed relied majorly on the findings of the National Climate Change Response Strategy [58]. The aims of the adaptation analysis were as follows:

(1) Climate change impacts assessment in all the sectors

(2) Provision of the evidence to Kenya as a country of key climate risks

(3) Documentation of all the recommended, planned, or ongoing activities on climate adaptation

(4) Giving support to the integration of climate change adaptation into appropriate strategies in the existing and new sector, budgetary and planning processes, development, and policies across different levels

(5) Development of potential adaptation actions and a set of priority for addressing the projected climate change impacts in each sector for feeding into the Kenya's National Adaptation Plan (NAP)

In Kenya, National Climate Change Secretariat (NCCS) is currently tasked with coordination of all the activities related to climate change. Administratively, the NCCS falls within the Ministry of Environment and Natural Resources. The NCCS is also the UNFCCC's National Focal Point. In various agencies, departments, and ministries, climate change coordination units work with NCCS for ensuring mainstreaming of climate change into the several sectors of economy [59].

Kenya National Climate Change Action Plan covering the period from 2018 to 2022 has highlighted several adaptation actions for implementation to address the climate change impacts at county and national levels [60]. Based on the county integrated development plans of 2018, the study identified several actions that are most appropriate for the Sondu Miriu Basin to address some impacts of climate change that were identified to be of significance in the basin (Table 1). These actions need to be part of the strategies to enhance resilience for both the hydropower projects and community livelihoods within the basin.

These adaptation actions are in line with the six types of strategy identified by IPCC technical guidelines for adapting to the impact of climate change that include restoration of the ecosystem, changing location, changing use or activity, spreading, or sharing loss, tolerating loss, and prevention of loss [57, 60].

*3.1.4. The Constraints.* The current policies and laws do not compel any development action within the Sondu Miriu River Basin to provide for integration of adaptation actions

Table 1: Adaptation actions appropriate for Sondu Miriu River Basin.

| Impacts | Adaptation action |
|---|---|
| Drought | (i) Harvesting of flood water<br>(ii) Early warning systems establishment for droughts<br>(iii) Nutritional and food supplements like school feeding programs<br>(iv) Diversification of livelihoods |
| Flooding | (i) Strategic placement of dykes and dams<br>(ii) Early warning systems establishment for floods<br>(iii) Storm water harvesting and storm waters drainage systems<br>(iv) Riparian areas protection along rivers<br>(v) Insurance cover for losses caused by flooding |
| Food security crops | (i) Climate-smart agriculture<br>(ii) Crop diversification<br>(iii) Farm forestry/agroforestry<br>(iv) Establishing irrigation systems, such as drip irrigation upscaling, and constructing dams for irrigation<br>(v) Drought-tolerant crops<br>(vi) Conservation agriculture and soil and water conservation<br>(vii) Promoting nonrainfed agricultural practices, such as greenhouse farming<br>(viii) Improvement of agricultural extension services<br>(ix) Efficient water-use technologies<br>(x) Climate information services for the local community |
| Livestock | (i) Adopting new techniques for animal husbandry<br>(ii) Proper management of fodder banks, controlled grazing, and pasture lands |
| Fisheries | (i) Fish harvesting<br>(ii) Fish farming |
| Water scarcity | (i) Protection of water catchment areas and springs<br>(ii) Water harvesting<br>(iii) Water storage<br>(iv) Water pans, boreholes, and dams<br>(v) Groundwater management<br>(vi) Water treatment |
| Ecosystem degradation | (i) Protection of wetlands<br>(ii) Water catchment areas restoration<br>(iii) Rehabilitation of degraded rivers<br>(iv) Control of erosion (gabions, terracing) and soil conservation<br>(v) Promotion of the natural resources' conservation |
| Infrastructure | (i) Infrastructure that are climate proof through use of concrete for roads, bridges, and dykes |
| Health | (i) Promote family planning<br>(ii) Vaccination/immunization campaigns<br>(iii) Mosquito nets<br>(iv) Disease surveillance and reporting |

into the development planning for approvals. This makes integration of adaptation actions into any planned development difficult to enforce within the basin including hydropower development despite good adaptation actions contained in the Kenya National Climate Change Action plans.

*3.1.5. Quantifying the Measures and Formulating Alternative Strategies.* For the adaptation strategy to be effective, both devolved and national governments should pull together for targeted development. The centralized national government oversighting gives an overarching, strong leadership, and national framework while local and regional involvement integrates specific issues locally and increases buy-in by stakeholders which facilitates implementation. This is critical for the Sondu Miriu River Basin for the local solutions that can be owned and well understood by the local communities within the project area and basin.

Assessing the risks or vulnerability and strategy implementation using sector-by-sector approach is pragmatic due to its mapping into the already existing stakeholder groups and government structure. Assessing risks or vulnerability at the national level is resource intensive and more complex than sector by sector assessment. Having an effective stakeholder engagement process and a robust regional and sectoral risk assessments to build upon is critical for the success. At this stage, it will be effective to group all the identified appropriate actions into relevant sectors for robust evaluation and implementation strategy within the basin.

Adaptation strategies within the Sondu Miriu River Basin may gain from providing more comprehensive attention to relationships between adaptation and mitigation

policies, social justice, and treatment of the international impacts in making them acceptable, both locally and internationally.

*3.1.6. Weighting the Objectives and Evaluating the Trade-Offs in Sondu Miriu River Basin.* At present, there is no well-defined strategy for the integration of adaptation measures into the development of hydroelectric power projects. No specific objectives have been put in place that can be weighted and evaluated for trade-offs. This can be cited as a major gap for developing and implementing adaptation actions within Sondu Miriu Basin. At the inception of any hydropower development in Sondu Miriu Basin, the objectives need to be developed that can be weighed based on the local, national, regional, and global levels and then different strategies are evaluated based on their effectiveness in achieving the objectives. The process can be evaluated using standard impact accounting systems. This will lead to selection of preferred strategies based on the trade-offs among the available strategies.

*3.1.7. Recommended Adaptation Measures within the Sondu Miriu River Basin.* Currently, there is no evidence of a properly organized and coordinated adaptation actions being implemented within the basin with the main objective of integrating adaptation to climate change into the development of hydropower within the basin.

The current adaptation actions are mostly at the national level as proposed in the national adaptation action plans. These adaptation actions need to be translated to the local level for the to be active and effective. Based on the International Federation of Red Cross and Red Crescent Societies (IFRC), Red Crescent Climate Centre and Prevention Consortium guidelines, some of the most appropriate strategies in Sondu Miriu Basin for integration of adaptation measures locally are outlined as follows:

(1) Incorporation of the projected changing climate trends into the present risk and vulnerability assessments depending on the present climate variability.

(2) Prioritize adaptation measures in zones where vulnerabilities are highest and there is greatest need for resilience and safety.

(3) Fully integrate climate change adaptation actions into the poverty reduction strategies and long-term local and national sustainable development.

(4) Prioritize and strengthen existing local capacities such as private sector, civil society organizations, and local authorities. Opportunities will be created by this strategy for effective local governance and community-based risk reduction to achieve rapid up-scaling of adaptation actions, and a comprehensive climate risk management.

(5) Leverage on the available opportunities in the disaster response and prevention. This can be done through improvement of contingency planning, early warning systems, and integrated response for the promotion of effective community-based risk reduction and adaptation.

(6) Development of a robust mechanisms for mobilization of resources for adaptation to ensure continuous flow of support to local actors in the form of financial and technical.

There is need to motivate local communities to participate in adaptive actions. The communities can be motivated for actions through some shared community values, such as:

(i) Social equity and community cohesion,

(ii) Community identification with the surrounding ecosystems or natural resources,

(iii) Need to enhance, sustain, or revitalize social and economic situations.

The community actions for an efficient strategy for adaptation can incorporate some initiatives, as follows.

(i) Actions related to grey and green infrastructure

(ii) Adaptive capacity enhancement

(iii) Management of natural resources or ecosystems

(iv) Bolster and develop human and social capital

Two critical factors need to be put in place for the effective adaptation actions implementation. They include building community support and effective leadership. The description of the prerequisites for these factors are as follows.

(a) Building Community Support

(i) Guide community climate change debates to be in line with public and local political attitudes.

(ii) Support enhancement through community organizations or grassroots.

(iii) A focus on co-benefits to broaden the support.

(iv) Engage more vulnerable populations.

(b) Effective Leadership Requirements

(i) Ability to work together as a coalition.

(ii) Ability to enact change through sustenance of effectiveness for a long duration.

(iii) Ability to supply a vision for change and identify needs.

## 4. Discussions

With the expected rise in temperature and increase in rainfall, Sondu Miriu River Basin is expected to get warmer and wetter. But due to climate variability, some episodes of meteorological extremes are expected. This might increase vulnerability of the hydropower development and local community livelihood. The meteorological extremes are more likely to affect the run-of-river (RoR) development projects than storage-type hydropower development projects due to flow variability. The climate change also varies from season to season.

There are climate change adaptation actions proposed in the Kenya National Adaptation Action Plan and CIDPs without any strategy for reaching river basin or local level. The existing climate change adaptation actions in the national adaptation action plan and CIDPs forms a good starting point for developing appropriate strategies for integrating climate change adaptation actions into hydropower development within the Sondu Miriu River Basin. The basin wide strategy needs to be cascaded to the ward and village levels for effectiveness and more impacts.

The main objective of the adaptation strategies for development of hydropower is to integrate adaptation actions into hydropower development for sustainable hydropower generation and building resilience for the local community. To be able to respond effectively to the climate change impacts, a multisectoral adaptation strategy needs to be put in place at the local level that translate the national proposed actions to the local level. A study in Southern Africa in 2018 proposed several climate change adaptation strategies for their region, among them being promoting renewable energies with low-carbon footprint [50].

Climate change impacts of significance within Sondu Miriu River Basin include displacement of populations, water scarcity, land and ecosystem degradation, negative impacts on humans and livestock health, food and nutrition insecurity, declining agricultural and livestock productivity, flooding, and drought. These impacts affect the existing hydropower projects and local community livelihoods. With the projected increased rainfall amounts and temperature, the frequency of the meteorological extremes is expected to increase and may make the current impacts worse.

The Kenya National Climate Change Action Plan for the period from 2018 to 2022 and the County Integrated Development Plans (CIDPs) has highlighted several adaptation actions that are most appropriate for Sondu Miriu Basin to address impacts of climate change identified as of significance in the basin. These actions are expected to enhance resilience for both the hydropower projects and community livelihoods within the basin. The proposed adaptation measures will be effective if the local community is fully involved.

The national and county governments should play complementary roles in implementing adaptation actions towards integration of adaptation into hydropower development based on governance structure. Planned adaptation responses have been significantly increasing in the developing countries particularly within the rural communities locally since the fourth assessment report [61]. Adaptation to climate change is uniquely linked to location as it is context dependent making it predominantly a community and local government level action [62–64]. The local knowledge can highlight impacts of climate change and vulnerabilities that may not be well known in addition to adaptive capacity [65].

For adaptation strategies to be effective, there is need to recognize cross-sectoral coordination internally as crucial and encouraged within the suitable institutional structures [66] within Sondu Miriu Basin. In a collaborative process, data sharing is also a crucial component. A data sharing platform among various stakeholders including government departments would be useful in fostering collaboration and promoting efficiency. These collaborative efforts require trade-offs and political blessing that can be addressed on a wider scale [66].

Based on the experience in Mekong River Basin, the negative impacts of climate change can be reduced potentially by the human interventions, while in contrast climate change can also lead to increased negative impacts on human interventions. A good understanding of the complex interrelations between water use, land use, technological interventions, climate change, and socioeconomic activities both upstream and downstream is required for better support of the strategies for climate change adaptation [67].

With a good knowledge on the past climate change trends and future projected scenarios together with community livelihood actions within the Sondu River Basin, it will be possible to evaluate these actions to determine how they may impact on the water resource availability and hydropower projects. This will help in identifying adaptation actions that may be appropriate for hydropower development and sustainability within the basin. Through stakeholders' participation including the local communities, local development actors, and local leadership, strategies for responding to the climate change impacts can be prepared, which incorporate the interests of all the groups for their acceptability and ownership. These strategies are expected to offer local solutions with or without some improvements to enhance catchment conservation and management for hydropower development sustainability.

## 5. Conclusions and Recommendations

There exist several proposed adaptation actions for the purpose of integrating climate change adaptation into hydropower development within Sondu Miriu River Basin. These actions can be implemented in the Sondu Miriu River Basin through multisectoral approach guided by the Kenya's national adaptation plan and county integrated development plans. These plans have well-elaborated programmes and actions that if implemented will enhance climate change adaptation integration not only in the hydropower development but also other sectors within the Sondu Miriu River Basin. These programmes and actions are yet to be implemented at the local level.

The programmes and actions should target the local communities living both in the upstream and downstream of the existing and proposed projects on hydropower and 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 them 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.

All the stakeholders participating in the hydropower project should be sensitized on the existing and proposed strategies for climate change adaptation integration into the

development of hydropower and be made aware through awareness creation on all the existing policies to be followed to avoid any conflicts during the project implementation.

## Data Availability

The available strategy documents that address climate change and its impacts were obtained from the Kenyan Ministry of Environment and Forestry.

## Conflicts of Interest

The authors declare that they have no conflicts of interest regarding the publication of this paper.

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