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REPORT

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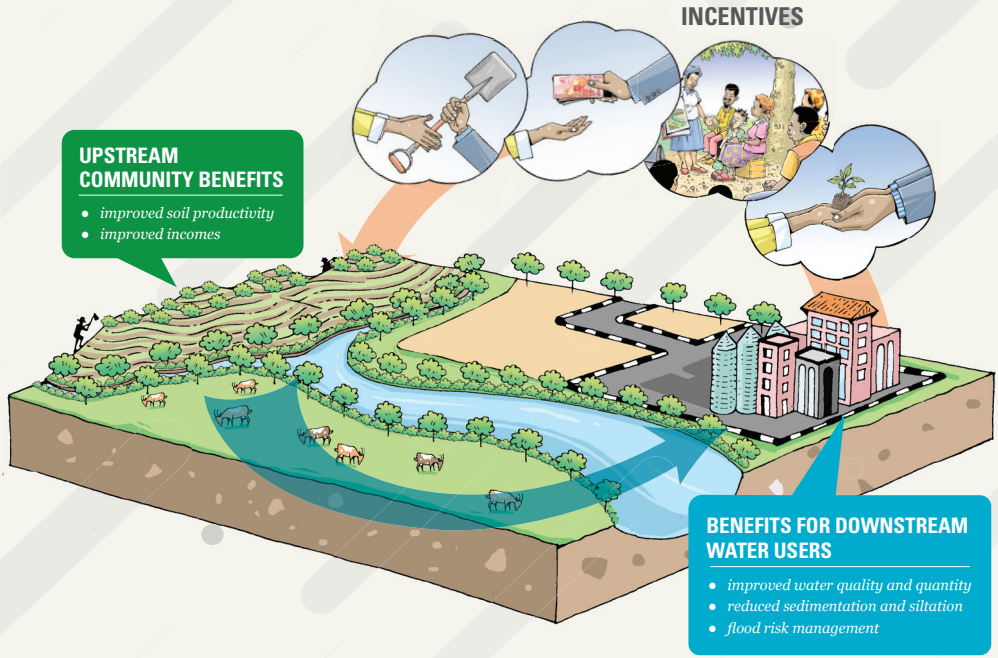

HYDROLOGICAL AND AGRONOMIC STUDY

FOR A PAYMENT FOR WATERSHED SERVICES SCHEME IN RWENZORI MOUNTAINS NATIONAL PARK, UGANDA

THE SUMMARISED VERSION - JUNE, 2018

PREAMBLE

This is an abridged version of the Hydrological and Agronomic study report that was conducted in order to inform the design and monitoring of the PWS on the Nyamwamba and Mubuku watersheds of the Rwenzori Mountains National Park.

CONTENTS

1. BACKGROUND

THE RWENZORI MOUNTAINS NATIONAL PARK (RMNP) IS A KEY NATURAL RESOURCE, SAFEGUARDING DRINKING WATER FOR AROUND 2 MILLION PEOPLE, AND SUPPLYING WATER FOR A VARIETY OF INDUSTRIAL USERS INCLUDING SEVERAL HYDROPOWER AND MINING COMPANIES.

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The watershed services of the RMNP are currently undervalued and under increasing threat from climate change and increasing intensity of land use. Current land use practices, dominated by small holder farmers in the area, includes subsistence farming. Maize, tea, sugar cane, and cotton are cultivated at the lower altitudes, and sometimes on irrigated land. The cultivated land in the high valleys has been eroded and the farm yields are limited due to fragile soils and farming techniques that accentuate soil degradation.

The undesirable land use practices including tree harvesting, and the cultivation of steep slopes and river banks are having significant effects. These activities have often led to sedimentation of water infrastructure (dams, reservoirs) thus reducing base flows and affecting hydropower production for Mubuku I, Mubuk II and Mubuku III hydropower plants on river Mubuku. Other effects include loss of soil fertility through erosion, and increased flooding. Further, the increasing occupation of riverine areas causes bank instability, significant damage and sediment loads.

As a means of addressing the prevailing challenges, WWF is piloting a Payment for Water Services (PWS) scheme, in which the beneficiaries of the watershed service remunerate those "producing" it. A study was therefore commissioned to provide a sound justification for the development of a Payment for Ecosystem Services scheme in two watersheds (Mubuku and Nyamwamba) that have their headwaters in the Rwenzori Mountains National Park. Based on hydrological and agronomic data, mapping and modeling, the principal watershed services were assessed, priority areas and interventions were identified, and the monitoring plan was defined. The study was expected to identify areas in the watersheds that were likely to impact and benefit the primary stakeholders (hydropower, mining and water utilities, as well as farmers), and at the same time promote the conservation of the ecological systems of the Rwenzori Mountains National Park.

2. DESCRIPTION OF THE FOCAL AREA

The watersheds of Nyamwamba and Mubuku were the focal areas, with river Mubuku as the largest river draining the Rwenzori catchment. River Sebwe is a major tributary joining river Mubuku just before Mubuku irrigation Scheme and was considered as the third river in the watershed. Other tributaries for river Mubuku include Bujuku, Kyoho, Kanywankoko, Kithakena, and Ruboni.

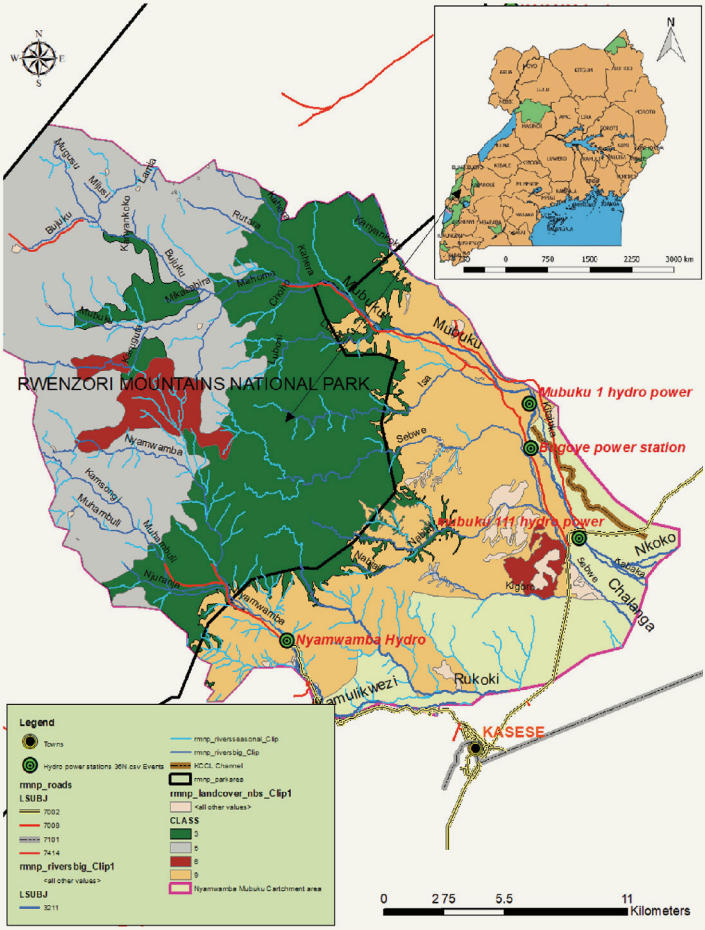

Figure 1: *Mubuku-Nyamwamba catchment showing location of hotspots area and downstream beneficiaries adjacent RMNP*

3. INFORMATION GATHERING AND SYNTHESIS

INFORMATION WAS GENERATED THROUGH SEVERAL METHODS IN ORDER TO GENERATE ANALYSIS ON THE HYDROLOGICAL AND AGRONOMIC COMPONENTS.

This study combined different methods including field level assessments, surveys and stakeholder consultations. The approaches for data gathering and synthesis varied dependent on the sub-component under investigation.

3.1 Hydrology assessment

Collecting water samples: Sampling along the rivers followed a longitudinal gradient from upstream to downstream areas. The sampled points included;

- Upstream areas (inside the park) representing areas with limited disturbances;
- Below heavily silted areas as a result of human activities (including mining, cultivation, stone quarrying, watering of livestock and car washing);
- On tributaries before they join the major rivers to assess the amount and quality of water the tributary drains into the main river;

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- Before the dams to assess how much water is in the river before it is diverted into the dams;
- After the dams have diverted water from the system;
- After the diverted water has returned to the system;
- Before the irrigation scheme.

3.1.1 Assessing water quality

The quality of water was determined by assessing: dissolved oxygen (mg/l), pH, electrical conductivity (µS/cm), turbidity (NTU), Oxidation-reduction potential (ORP, mV), total dissolved solids (TDS) and Temperature using a Horiba U-50 Multiparameter Water Checker. A Spectrophotometer was used to analyze water samples for Ions and nutrients such as phosphates and nitrates in the laboratory. Microbiological variables assessed onsite were total coliforms and E.coli as indicators of fecal contamination[1]. For the biological indicators, samples of benthic macro invertebrates were taken using a kicknet sampler as indicators of pollution in the sampled sites.

3.2 Water resources analysis and simulation

Historical data on flows was obtained from the Directorate of Water Resource Management (DWRM) to provide insight in how the catchment response has changed overtime due to land cover changes. In order to ascertain the proportion of water in the streams contributed by ground water supply and overland flow, Base flow separation was carried. This was done using the "Local Minimum Method" (Sloto and Crouse, 1996)[2]. Suspended sediments in the rivers were measured and related to stream flow through sediment rating curves[3].

3.3 Land cover change analysis

In order to investigate forest loss at watershed level, multi-temporal analysis of satellite imagery was carried out. Some of the key considerations for the analysis were to use data for sufficiently large period to be able to detect change, and with an adequate spatial

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1 *Pollution from microorganism found in the gastrointestinal tract of animals*

2 *Sloto R. A. and Crouse M. Y.,1996; HYSEP: A computer program for streamflow hydrograph separation and analysis, US Geological Survey, Water Resources Investigation Report, pg. 96-4040*

3 *A sediment rating curve is used to obtain the value of sediment concentration for a given discharge*

resolution to monitor environmental change. GlobCover2009[4] (GlobCover, 2011) product was used as the land cover input for the model. Landsat imagery for the period 2000 to 2014 were analyzed for forest cover changes.

3.4 Agronomic assessment

3.4.1 Focus Group Discussions:

Five Focus Group Discussions (FGDs) were conducted with six water use groups to understand: the status and trends regarding biophysical capitals that have impacts on productivity and degradation; trends of degradation; and challenges to farming systems productivity and farm or landscape wide interventions already adopted.

3.4.2 Farm-level assessments:

These were conducted to validate information gathered from the FGDs. Transects were laid in different zones characterized by varying intensities of human actions. 20x10 m plots were established along transects perpendicular to the rivers at 100 meter intervals, up to a distance of 1km away from the river. Information recorded included land use, vegetation types, land use practices, as well as prevailing challenges.


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3.5 Stakeholder Mapping

The stakeholders were identified through of mix of the "w group" and "reputational" approaches. The stakeholders included both the small and large-scale users of the water, stewards of the watershed such as private land owners and government agencies responsible for protecting

4 *http://due.esrin.esa.int/globcover/LandCover2009/GLOBCOVER2009_Validation_Report_2.2.pdf*

the watershed and management of water resources. Other stakeholders included government agencies such as local governments, directorate of water resources and the National Environment Management Authority.

3.6 Identification of hotspot areas

Results of the forest cover change, vulnerability to erosion, the channel erodibility and the agronomic survey were considered in the mapping of the hotspot areas. From the satellite-based forest loss analysis, it was confirmed that critical areas are the higher elevations in the agricultural area and steep slopes. For these areas, the topographic factor of the Universal Soil Loss Equation (USLE)[5] was used to understand how they affect erosion. The topographic factor was derived based on the satellite-based digital elevation model. The spatially distributed calculation was based on Böhner and Selige (2006)[6] and Moore et al (1991)[7]. Channel erodibility was another factor considered. This was indicated using the Stream Power Index (SPI), which describes a channel's ability to move sediment, thus its potential to incise, widen, or aggrade. The SPI is based on slope and drainage area (Moore et al., 1991) and has implications for flood hazard assessments and riverine erosion.

In addition, the likely effect on the delivery of the ecosystem service to the potential buyer was considered. The potential effects include low flows, high peak flows and sediment loads. These were related to: hydropower production potential for Mubuku I, Mubuku II and Mubuku III on river Mubuku; Reservoir sedimentation for Mubuku irrigation scheme on river Sebwe; and sediment loads for the municipal water supply on river Mubuku and river Nyamwamba. In relation to this, three groups of measures were analyzed: terracing interventions, agroforestry practices and mulching practices. These were studied under different implementation levels, giving priority to the steepest slopes in each sub-basin. For example, a 5% implementation of terracing in the watershed means that terraces are implemented on 5% of the steep slopes in the agricultural area of the watershed.

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5 *The USLE is a method used to predict their long-term average annual rate of erosion based on rainfall pattern, soil type, topography, crop system and management practices.*

6 *Bohner J. and Selige T., 2006; Spatial prediction of soil attributes using terrain analysis and climate regionalization.*

7 *Moore I.D., Grayson R.B., Ladson A.R., 1991; Digital terrain modeling- A review of hydrological, geomorphological, and biological applications. Hydrol Processes 5:3-30*

4. THE MAJOR FINDINGS

4.1. The hydrological assessment

Discharge measurements:

Flow measurements were taken as an indicator of the amount of water available in the watershed and amount diverted for the various uses. River Mubuku had the highest discharge values ranging from 2.35 to 10.55 m^3/s at the point above Bugoye dam. The discharge on river Nyamwamba varied from 1.654 m^3/s at the site above the railway bridge to 4.38m^3/s at the Masule foot bridge. River Sebwe discharge varied from 0.384m^3/s at the point below the irrigation dams to 1.654m^3/s at the site near the park boundary.

Environmental flows:

Environmental flows were measured to ascertain the quantity, timing, and quality of water flows required to sustain freshwater ecosystems and the human livelihoods and wellbeing. The water flow rate that remained in river Mubuku after diversion of water for hydropower generation for Bugoye power limited was 0.6m^3/s compared to 10.5m^3/s prior to the diversion, which is below the environmentally recommended rate8 of 10% (1.05 m^3/s). For river Sebwe, the flows before and after the dam for the Mubuku Irrigation Scheme were 1.5 and 0.4 m^3/s respectively, and thus the volume left in the stream was slightly higher than the recommended 10 % (0.15m^3/s).

Water quality variation:

The pH of both Nyamwamba (6.84 to 7.79) and Mubuku (7.87 to 7.84) rivers are generally neutral and the temperatures increase downstream. Dissolved oxygen, total coliforms and E.coli counts increased downstream, with high concentrations in areas near human settlements, thus an indicator of poor sanitation facilities. For river Nyamwamba, the turbidity along the altitudinal gradient increases downstream (7.2 to 98.5 NTU) as a result of human activity while it is generally low (0.7 to 10.5 NTU) for river Mubuku. For river Mubuku,

8 Environmental flow is the water considered sufficient for protecting the structure ad function of a ecosystem and its dependent species.

electrical conductivity and organic matter progressively increased along a downstream gradient while the levels of organic pollution were low. Generally, the diversity of aquatic insects was high in relatively pristine sites inside the park compared to sites outside the park.

4.2 Forest cover change

The analysis of forest cover using the Landsat imagery between 2000 and 2014 revealed major forest loss in the areas bordering the park and some forest loss detected in the high mountainous areas within the park (about 650 ha). More than 4% of the land had been converted from forest to agriculture over the 15-year period with the greatest loss evidenced at very steep slopes of greater than 50%. Forest loss due to agriculture is estimated at 70 ha per year with the prevailing years experiencing higher loss values than the previous years (Figure 1).

Figure 2: *Annual forest loss below 2500 meters altitude*

4.3 The Agronomic assessment

The major economic activity is crop farming with limited livestock integration and minimal brick making. Farming is conducted on small fragmented pieces of land estimated at a range of 0.2 – 1.2 acres per household. The largest area is under intercrops (Figure 2) with coffee and bananas as the major cash crops, and cassava and beans as the major food crops.

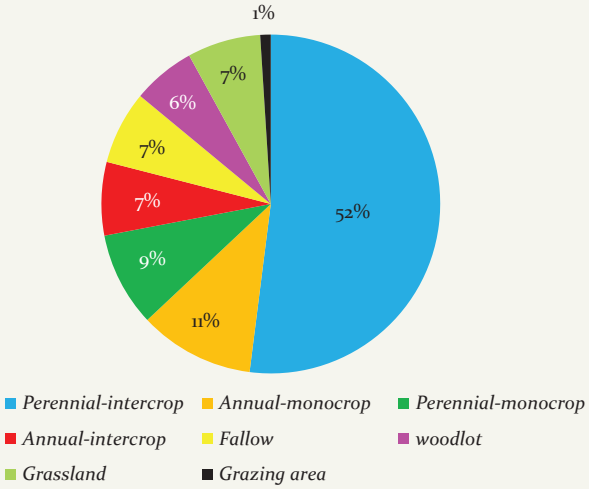

Figure 3: *Land use types according to agronomic survey*

The area is experiencing land degradation mainly as a result of soil erosion escalated by very steep terrain, over cultivation of the small land holdings and declined soil fertility. Further, the high demand for fuel wood has triggered tree cutting in the communities.

A number of government and non-government actors have initiated interventions to address the land degradation problem. The emphasis has been in sustainable land management practices such as fallowing, grass strips, tree planting and terracing. However the adoption of these practices was still very low with only few proportions of farms reported to be implementing the practices. Out of the few households implementing SLM practices, 18% carry out fallowing, 16% carryout Grass strips, 14% carryout tree planting and 11% carried out terracing as shown in Figure 3.

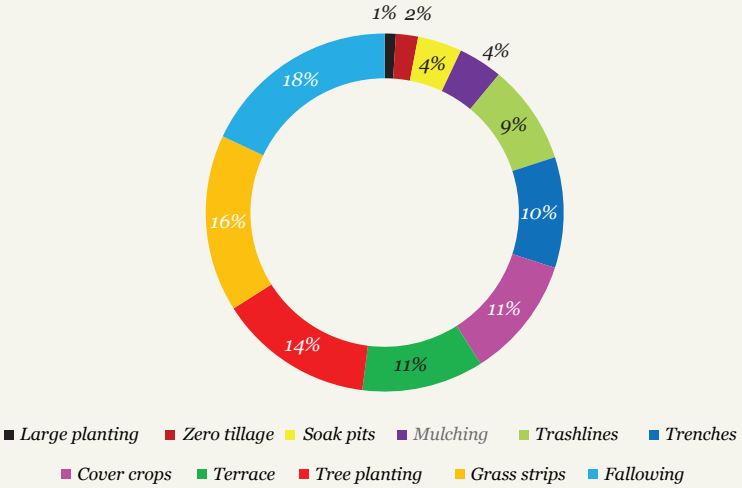

Figure 4: *Percentage of farms on which different SLM practices were implemented*

4.4 The identified stakeholders in the design and implementation of the PWS Scheme

The major stakeholders are categorized under the following;

- Potential suppliers or sellers of watershed services: these include the local communities whose activities interfere with the watershed services, government agencies such as Uganda Wildlife Authority and National Forestry Authority who are stewards of the vegetation in the landscape.
- Potential buyers of watershed services: these include the private sector and government agencies that directly benefit from the watershed. The hydro power companies include Mubuku I, Mubuku II ad Mubuku III and National Water and Sewerage Corporation representing utility companies.
- Partners/potential arbiters. These include government agencies such as the Directorate of water resources, National Environment Management Authority who regulate the use of water resources in the country. Other players include Kasese District local Government and other natural resource based NGOs within the watershed.

4.5 Identification of Hotspot areas

The agronomic survey revealed a positive relation between degradation level and slope. Steep slopes of Topographic factor (LS) higher than 1.0 and areas where the Standardized Precipitation Index (SPI) index was higher than 0.5 were selected. Based on these indicators, hot spot areas were mapped (Red shade) as shown in Figure 4.

Figure 5: *Priority areas for intervention of sustainable land and water management practices.*

4.6 Implementation of Land Management practices and potential downstream benefits

Mubuku I, Mubuku II and Mubuku III Powerplants; The impact of terracing, agroforestry and mulching practices on hydropower production was analyzed for the three power plants, and it revealed a potential increase in hydropower production with increasing implementation levels of the activities (Figure 5). The power plants would benefit through reduction in sediment concentration levels. Consequently, the abrasive damage on turbine equipment can be reduced, leading to a potential saving in maintenance and replacement costs. Temporal shut-downs of the plant due to extreme flows with very

high sediment loads can be reduced. There can also be an increase of low flows in the dry season that would lead to increased power production during the season.

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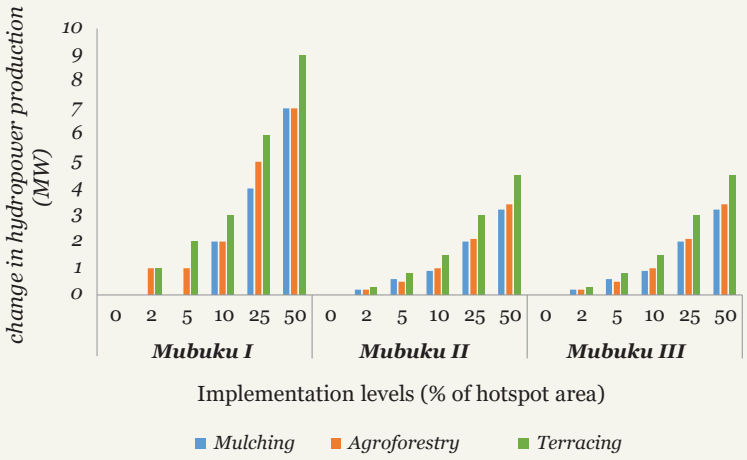

Figure 6: *Change in hydropower production with varying implementation levels land management practices*

Mubuku Irrigation Scheme: The dam from which water is diverted for irrigation and the irrigation reservoir that buffers some of the water from the irrigation scheme require regular desilting. Reducing sediment loads in the Sebwe River will reduce the frequency of desilting and consequently the costs of carrying out the activities. Figure 6 shows that sediment loads can be reduced with increase in implementation levels of the three land management practices.

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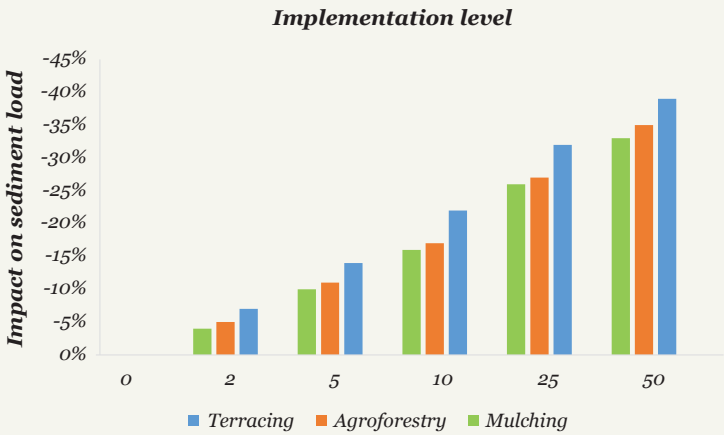

Figure 7: *Impact of land management practices on the sedimentation load*

Municipal Water Supply: Although water availability exceeds water demand in Mubuku and Nyamwamba watersheds, the water flows are still low. With the implementation of the three practices, flows during the dry season are likely to increase. Peak flows that result into shut downs can also be reduced. This is demonstrated in figure 7 and figure 8 that show how the measures influence peak and low flows. There will also be a reduction in sediment yield due to the upstream investments. Increased and consistent water supply coupled with reduced sediment load can be relevant for both Kasese town and other communities.

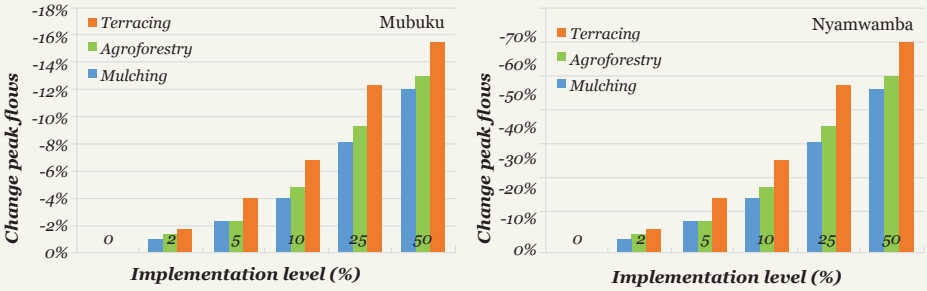

Figure 8. *Expected impact of land management practices on peak flows*

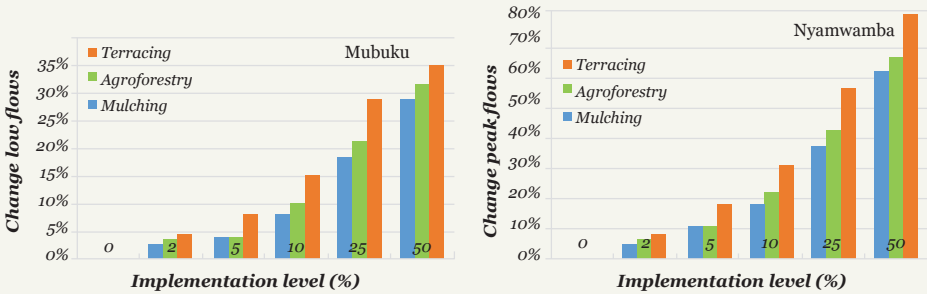

Figure 9. *Expected impact of land management practices on low flows*

CONCLUSIONS

A PRELIMINARY ASSESSMENT WAS CARRIED OUT ON THE HYDROLOGICAL AND AGRONOMIC FACTORS THAT DETERMINE THE POTENTIAL OF A PES SCHEME IN THE MUBUKU AND NYAMWAMBA WATERSHEDS DRAINING FROM THE RWENZORI NATIONAL PARK. THE FOLLOWING CONCLUSIONS CAN BE DRAWN:

- Hydrology: These predictions of the water quantity and quality have a critical bearing on the functioning of the watershed and services delivered to the downstream users:
  - *Water quantity;* Environmental flows for R. Mubuku after diversion of water for hydropower generation were below the recommended and thus not favourable to sustain aquatic biodiversity as well as human wellbeing. For River Sebwe, the flows before and after the dam for the Mubuku Irrigation Scheme was slightly higher than the recommended rate, and thus favourable to sustain aquatic biodiversity and human wellbeing.
  - *Water quality;* The level of dissolved oxygen and the total coliforms and E.coli counts that increased downstream were indicators of poor sanitation facilities
- Forest cover changes: Forest loss over the period 2000 to 2014 was mainly in the areas bordering the park as well as the high mountainous areas within the park. Very steep slopes of greater than 50% had been greatly affected with most of the areas converted to agriculture. This makes the area vulnerable to soil and land degradation thus affecting the delivery of the ecosystem service.
- Agronomy: While the farmers grow both perennial and annual crops, the area experiences land degradation as a result of soil erosion, cultivation of small land holdings and declining soil fertility. There was limited utilization of land management practices such as terracing, trenches and mulching. This escalates the problem given the terrain of the area, thus increased degradation of the watershed.
- Stakeholders: The potential players in the categories of sellers, buyers and arbiters were identified. The roles and responsibilities of the different stakeholders need to be clarified to facilitate a well-functioning PES Scheme.

- Hotspots: Steep slopes were majorly identified as the hotspots, which should be the priority targets for implementation of land management practices. The potential effect of degraded areas on the delivery of the ecosystem service for the downstream users was the basis for assessing the likely outcome of implementing the different land management practices. Considering the implementation of mulching, terracing and agroforestry, there were varying benefits to Mubuku I, Mubuku II and Mubuku III Powerplants, Mubuku Irrigation Scheme and the Municipal water supply.
- Potential benefits on downstream services with implementation of terracing, agroforestry and mulching practices
  - The land management practices have potential to increase hydropower production with increasing implementation levels of the activities
  - Sediment loads can be reduced with increase in implementation levels of the land management practices thus reducing the frequency of desilting the rivers and consequently the costs of carrying out irrigation activities
  - The water flows in both Mubuku and Nyamwamba rivers is still low. Implementation of the land management practices is likely to increase flows during the dry season.

RECOMMENDATIONS

1. The farming system is majorly an integration of coffee as the major cash crop with banana, cassava and beans as major food crops. Therefore, any interventions to improve sustainable land management must take into account this farming system and preference of these commodities. The land management practices below may be considered as components of PES in upstream communities to reduce sediments and siltation as well as improve productivity of the farming systems;
   i. Promotion of practices including *fanya chini* or *fanya juu* trenches, grass strips, soak pits, mulching, zero tillage practices.
   ii. Landscape vegetation restoration programs such as tree planting on bare areas as well as river banks to improve vegetation cover and protect river banks from erosion.
   iii. Promote fertility improvement and productivity enhancing technologies. These include integration of livestock which improves and optimizes local nutrient and biomass cycles. The animals are fed with fodder crops and their dung are integrated into the soil to improve soil fertility. The other practices include compost manure

In addition to the farm management practices, efforts could also be committed to:

- Promoting energy efficient/energy saving technologies like improved stoves, briquettes and biogas so as to reduce on the number of trees cut for fuel wood and charcoal burning;
- Training in farm management and energy efficient technologies, capacity building and empowerment of major actors in farming systems and energy consumption such as women and school children.

2. A business case analysis should be carried out to quantify potential benefits in terms of crop yield and livelihood improvement following the adoption of different land management practices
3. A business case should be designed for the downstream stakeholders to fully participate in the scheme. This should be supported by a detailed cost-benefit analysis of the different interventions and management scenarios.

REPORT

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HYDROLOGICAL AND AGRONOMIC STUDY

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HYDROLOGY

The prediction of water quality and quantity have a critical bearing of the functioning of the watershed services delivered to downstream users

AGRONOMY

There is limited utilization of land management practices such as terracing, trenches, and mulching which leads to reduced soil fertility

FOREST COVER CHANGES

Forest loss over the period between 2000-2014 was mainly in areas bordering the park which makes the area vulnerable to land degradation

STAKEHOLDERS

The roles of the potential ecosystem services buyers, sellers and arbiters need to be clarified to facilitate a well-functioning PES scheme

HOTSPOTS

Steep slopes were majorly identified as the hotspots which should be priority targets for the implementation of land management practices

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