VULNERABILITY ASSESSMENTS OF PROTECTED AREAS OF THE GREATER VIRUNGA LANDSCAPE VIS A VIS CLIMATE CHANGE AND OTHER THREATS TO BIODIVERSITY UNDER DIFFERENT CLIMATE CHANGE SCENARIOS

FINAL REPORT

Submitted to:

GREATER VIRUNGA TRANSBOUNDARY COLLABORATION (GVTC)

Intergovernmental Organisation-Organisation Intergouvernementale
Kimihurura-Ruganda; KG 6 AV; Building # 16 –P.O. Box 6626 Kigali Rwanda
Telephone +252 580 429 E-mail: info@greatervirunga.org

By:

Gerald Eilu (PhD)
NACOPART UGANDA LIMITED/ITFC

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Dr. Gerald Eilu
Team Leader
Email: gerald.eilu@gmail.com

EXECUTIVE SUMMARY

The study was carried out under the Greater Virunga Transboundary Collaboration (GVTC) involving the Democratic Republic of Congo (DRC), Rwanda and Uganda. The collaborative transboundary framework of programs, plans and activities is aimed at conserving the network of Protected Areas (PAs) in the Greater Virunga Landscape (GVL). The GVL covers areas and communities around the PAs of Volcanoes National Park in Rwanda; Virunga National Park in DRC and five national parks (NP) in Uganda: Mgahinga Gorilla NP, Bwindi Impenetrable NP, Queen Elizabeth NP, Rwenzori Mountains NP, and Semliki NP. The landscape is, part of the Albertine Rift, is unique and a biodiversity hot spot as it contains several species of conservation concern such as the Mountain Gorillas (*Gorilla beringei beringei*), chimpanzees, African elephants and plants such as the Giant Lobelias and Dendrosenecios.

Climate change is a major threat in the landscape with effects on biodiversity within and outside the Protected Areas. Climate Change is has compounding effects, aggravating the impacts of other threats to biodiversity. These have impacts on the livelihoods of frontline communities that struggle to cope with the wrath of crop raiding animals. It is necessary to understand what will happen to the plants and animals under these changes. This will be necessary for implementing the GVTC Climate Change Strategy with the overall objective of strengthening landscape-wide resilience to climate change and ensuring climate compatible conservation measures for sustainable livelihood in the GVL.

The purpose of this study is to strengthen the knowledge base on climate Change related aspects in order to enhance common understanding of Climate Change risks and its impacts on biodiversity and associated services as well as socio-economic systems. The specific objectives were to:

1) Assess the gaps in knowledge on Climate Change and its impacts on Protected Area management in the GVL;

2) Describe how species, ecosystems, and ecological processes within the GVL are affected by climate change to determine how ecosystem services will be affected by future changes;

3) Undertake forecast climatic conditions sufficiently robust and that take into account exposure, adaptive capacity and sensitivity components;

4) Describe how current threatening processes such as invasive species, mining, land use, diseases of humans, livestock and wildlife will change under different climate change forecasts and what these changes mean for the future of the PAs in GVL

5) Propose appropriate actions for managing and mitigating negative changes in biodiversity and ecosystem services in the GVL

The findings give a consolidated status report on VA to enable a better understanding of the cause/effect relationships behind climate change and its impact on PAs focusing on biodiversity, species, ecosystems, people, economic sectors and socio-ecological systems within specific PAs.

The methods for the Vulnerability Assessment (VA) involved participatory as well as image analysis techniques. The CARE CVCA tool that measures vulnerability to climate change at multiple levels: communities, households and individuals. The approach, examines vulnerability according to the IPCC-identified components of exposure, sensitivity, and adaptive capacity. The assessment determines the magnitude of exposure, sensitivity, and adaptive capacity using context specific indicators. The image analysis consisted of Land Use Land Cover change and land degradation hotspots assessment implemented for identifying/assessing the drivers and impacts of climate change on biodiversity and ecosystem services. Climate modelling was carried out to generate projections for the GVL.

The key gaps in knowledge on Climate Change and its impacts on Protected Area management in the GVL

How species, ecosystems, and ecological processes within the GVL are affected by climate change to determine how ecosystem services will be affected by future changes;

3) Undertake forecast climatic conditions sufficiently robust and that take into account exposure, adaptive capacity and sensitivity components;

4) Describe how current threatening processes such as invasive species, mining, land use, diseases of humans, livestock and wildlife will change under different climate change forecasts and what these changes mean for the future of the PAs in GVL

5) Propose appropriate actions for managing and mitigating negative changes in biodiversity and ecosystem services in the GVL

Drivers of Climate Change in the in the GVL: The study, as expected, shows that climate change is occurring in the GVL and is mainly driven by anthropogenic factors, especially increased land use intensity. This is driven by increased population growth and its associated demand for land for agriculture and settlement. In addition, there is unsustainable utilisation of natural resources.

Current effects of climate change on species, ecosystems, and ecological processes and potential future effects on ecosystem services: Climate change will negatively affect species, ecosystems and ecological processes in the GVL if appropriate mitigation and adaptation actions are not implemented.

Forecast of climatic conditions taking account of exposure, adaptive capacity and sensitivity: The GVL still provides a wide range of ecosystem services that vary spatially. The climate forecast for the GVL in the near future (2020-2039) under both RCP 4.5 and 8.5 generally shows an increase in both rainfall and temperature.

Changes in threatening processes under different climate change forecasts: The projected climatic conditions will thus affect several ecosystem services and processes in the GVL. These effects are more likely to occur in DRC and Uganda and under RCP 8.5 as compared to RCP 4.5.

The following actions are proposed for managing and mitigating negative changes in biodiversity and ecosystem services

Basic Sustainable Land Management Practices such as Mulching, Terracing, Planting Trees along boundaries and others must be encouraged and scaled up. In addition, alternative livelihood strategies must be identified for the most vulnerable households.

The adaptive capacity of households that are increasingly dependent on tourism related activities in the GVL is unclear. The receding Glaciers and Snowline in the Rwenzori mountains could have adverse effects on tourism making the communities Vulnerable. Community Based Enterprises such as the Rwenzori Mountaineering Services may face difficulties if visitor numbers drop. Hence, efforts need to be made to diversify the tourism products beyond the current options.

Protected Areas allover the GVL are faced with increasing population pressure and demand for resources, hence there is a need to managing the human population growth.

The Protected Areas in the GVL are faced with the threat of Alien Invasive Species. Restoration of degraded ecosystems must be treated as a matter of priority. Current measures are inadequate in many of the PAs.

Whereas the Protected Areas in the GVL are mainly mountains, research within the Afroalpine Zone on the Mountains has received very little attention. Moreover, monitoring efforts should be strengthened on the mountains. We recommend the formation of a Centre of Mountain Related research in the GVL. Ultimately, Research and Ecological Monitoring must be enhanced.

Livelihoods of communities requires additional attention. Sustaining promising/successful interventions. Mechanisms for utilizing the money for revenue sharing need to be strengthened. The issue of compensation for the communities over lost crops needs to be harmonised between the PAs.

TABLE OF CONTENTS

Content **Page**

ACRONYMS AND ABBREVIATIONS

GVTC	-	Greater Virunga Transboundary Cooperation
GVL	-	Greater Virunga Landscape
DLG	-	District Local Government
FGD	-	Focused Group Discussion
GIS	-	Geographical Information System
MDAs	-	Ministries, Departments and Agencies
CBO	-	Community Based Organisations
HH	-	Household
KII	-	Key Informant Interview
NDVI	-	Normalized Difference Vegetation Index
NGO	-	Non-Governmental Organizations
PA	-	Project Area
NP	-	National Park
NPP	-	Net Primary Productivity
S/C	-	Sub-County
UWA	-	Uganda Wildlife Authority
NFA	-	National Forestry Authority
PAs	-	Protected Areas
PAAs	-	Protected Area Authorities

1.0. INTRODUCTION

1.1. Background to the Greater Virunga Landscape

The GVL covers areas and communities around the PAs of Volcanoes National Park in Rwanda; Virunga National Park in DRC and five national parks (NP) in Uganda: Mgahinga Gorilla NP, Bwindi Impenetrable NP, Queen Elizabeth NP, Rwenzori Mountains NP, and Semiliki NP. This landscape is unique and a hot spot for biodiversity as it contains rare and charismatic species such as the Mountain Gorillas, Chimpanzees and African Elephants. Other charismatic species include the Giant Lobelias and Dendrosenecios in the Afroalpine zone on the Mountains.

1.2. Context of the assessment

The GVL is one of the most diverse landscapes in the world and is one of the world's hotspots for biodiversity. The landscape is endowed with other natural resources (water, fertile lands, minerals, oil, wood, and water, among others), on which the local communities and GDP growth prospects of the countries are partly dependent. The GVL is famous for its mountain Gorillas (*Gorilla Beringei Beringei*) and other endangered flora and fauna such as the flagship afroalpine plants, the giant Lobelias and Dendrosenecios. Biodiversity of the GVL is threatened with over exploitation of species (including poaching), illegal timber harvesting, over fishing and habitat loss, for example, resulting from exploration (and upcoming exploitation) of oil and gas e.g. in Uganda. Climate Change is also believed to exercise compounding effects, exacerbating the impacts of these threats to biodiversity and ecosystem services.

Climate change will have impacts on biodiversity (genes, species and ecosystems) with far reaching results on the Protected Areas. Where the climate has changed or destroyed habitats, there is uncertainty about the impacts on plants and animals that live in such sites. It is necessary to know how they would adjust to the changed climate.

Predictions show that climate change may lead to additional stress on habitats and ecosystems that are already stressed by anthropogenic activities. This would have major implications for the management of each of the Protected Areas within the GVL. This may result in a reduction of habitat leading to death or the migration of animals. The extent to which climate change would influence the long-term behaviour of fauna has been examined by various authors e.g. Laurance *et al*. 2004. Pressures on ecosystems include high rates of change in land use and the conversion of land associated with agricultural expansion, pollution, population growth, civil wars, and the introduction of exotic species changing the integrity of ecosystems. Significant local and global extinctions of plant and animal species, many of which are important resources for people, are projected, and if they occur, would affect rural livelihoods, tourism and genetic resources (IPCC, 2007)

Because of the numerous ways that species and ecosystems can be affected by climate change, the rapidly increasing human populations across much of the Greater Virunga Landscape, place considerable stress on many Ecosystem Services. This has immense implications for Protected Area management and for the livelihoods of communities.

The most important likely impacts of Climate Change on the human populations in the GVL include increased water stress and the often, associated changes in productivity and viability of agricultural practices. The population of Africa at risk from increased water stress alone is projected to be between 75–250 million and 350–600 million people by the 2020s and 2050s respectively (Boko *et al.* 2007), while agricultural productivity across the African continent is expected to decrease by 17–28% by the 2080s as a result of climate change (Cline 2007).

Protected Areas (PAs) provide crucial ecosystem services that support livelihoods and the socio-economic development of communities. Due to insufficient protection and management, their role in mitigating Climate Change and supporting climate resilience as well as safeguarding ecosystem services such as water provision, food and energy security, is currently threatened. As a result of past and current population and economic growth across communities in the three GVL countries, the PA network and the GVL's resources are experiencing increasing pressure. Moreover, there is a concern that climate shocks may increase the pressure on national governments to degazette parts of PAs in the GVL in order to avoid food insecurity and displacement of people.

The GVTC Climate Change Strategy has the overall objective of *strengthening landscape-wide resilience to climate change and ensuring climate compatible conservation measures for sustainable livelihood in the GVL*. Implementing the strategy requires a baseline of the current effects of climate change on biodiversity. This is necessary to clarify how Ecosystem Services will be affected by future changes. It is also important to undertake forecast climatic conditions at high spatial resolution across the GVL to serve conservation planning needs. The forecasts need to be robust, taking account of exposure, adaptive capacity and sensitivity components. There is also a need to identify the tipping points of species, ecosystems, and ecological processes to stressors associated with climate change so that we can avoid crossing critical thresholds, beyond which it may be difficult and costly to restore or find substitutes for important Ecosystem Services. Similarly, there is a need to improve understanding of how current threatening processes such as invasive species, mining, land use, diseases of humans, livestock and wildlife will change under different climate change scenarios.

It is necessary to clarify how threatening processes such as invasive species, mining, land use, disease, livestock and wildlife will change under different climate change scenarios. The high spatial variability of climate across the GVL necessitates that each of the major ecosystems and Protected Areas is assessed individually for its climate change sensitivity and response. It is in this context that this study was undertaken.

1.3. Objectives of the assessment

The purpose of this study was to strengthen the knowledge base in order to enhance common understanding of Climate Change risks and its impacts on biodiversity and associated services as well as socio-economic systems. The specific objectives were to:

1) Assess the gaps in knowledge on Climate Change and its impacts on Protected Area management in the GVL;

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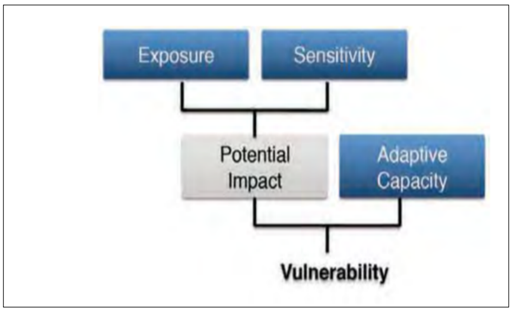
The findings give a consolidated status report on VA to enable a better understanding of the cause/effect relationships behind climate change and its impact on PAs focusing on biodiversity, species, ecosystems, people, economic sectors and socio-ecological systems within specific PAs.

2.0. APPROACH AND METHODS

2.1. Approach

The approach to this study was structured in four steps: (i) Planning and inception; (ii) Data collection; (iii) Data processing (analysis and synthesis), and (iv) Report writing and validation. Socio-economic parameters, environmental conditions, ecosystem service provision and impacts of climate change and other socio-economic and socio-ecological threats were assessed. Overall, an integrated IUCN's framework approach to vulnerability assessment according to the IPCC-identified components of exposure, sensitivity, and adaptive capacity (Figure 1) was utilized.



Source: Morgan, C. L. (2011)

Figure 1: Elements of the vulnerability assessment framework

2.2 Overview

The methods for the Vulnerability Assessment (VA) involved participatory as well as image analysis techniques. The CARE CVCA tool that measures vulnerability to climate change at multiple levels: communities, households and individuals. The approach, examines vulnerability according to the IPCC-identified components of exposure, sensitivity, and adaptive capacity. The assessment determines the magnitude of exposure, sensitivity, and adaptive capacity using context specific indicators. The indicators are essential for an adaptive capacity assessment capable of uncovering the structural causes of vulnerability (Morgan, 2011). Participatory methods were also used to select and engage different stakeholders, categories of people and individual key informants to participate in the study. Desk review of relevant documents was also undertaken. Information from different sources was triangulated to corroborate and confirm the findings of the study. GIS was used to determine and indicate the changes occurring in the specific PAs as a result climate change based on the major climatic variables of precipitation and temperature.

2.2. Study area and Methods

2.2.1. Study sites

The study was conducted in the GVL covering the seven Protected Areas (Figure 2). Two problem sub counties, S/Cs facing moderate to high levels of impacts of climate change were identified from the literature review and consultative discussions held with the PA and LG officials.

The survey was conducted among communities living in the parishes (Uganda), sectors (Rwanda) and Groupment in (Democratic Republic of Congo, DRC) adjacent to the PAs. The GVL is an interconnected chain of seven PAs that straddles the borders of Uganda, Rwanda and DRC (Figure 3) covering about 13,200 km^2 of varied habitats including glaciers and rock, montane and lowland forest, savannas, wetlands, bamboo, hot springs and active volcanoes with lava flows (Nyiragongo and Nyamulagira) (www.wcsuganda.org).

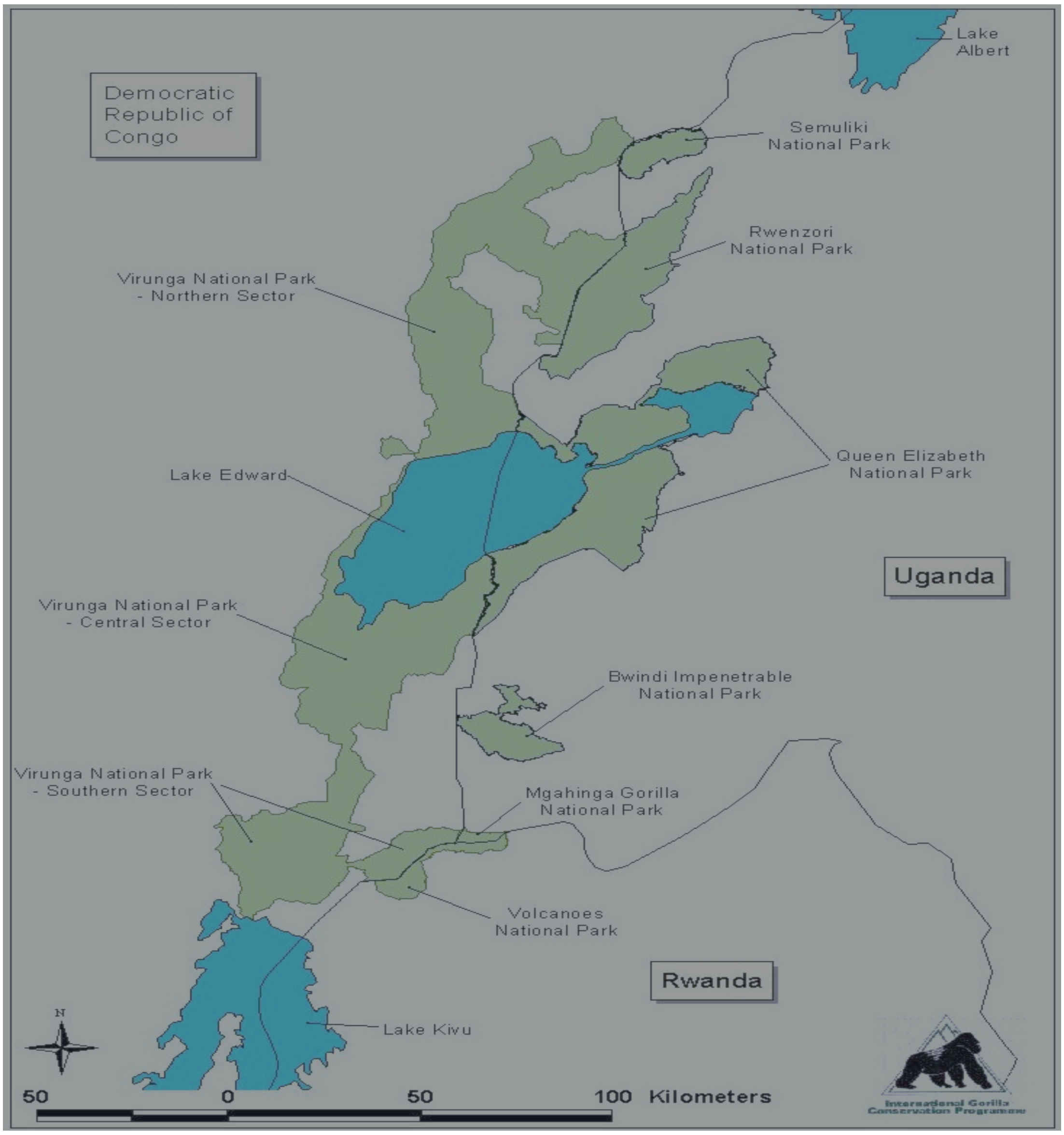


Figure 2: Map of study area from which we selected the sampling sites

2.2.2. Description of PAs of the GVL

a) Rwenzori Mountains National Park

Rwenzori Mountains National Park (RMNP) is a World Heritage site, located in western Uganda bordering the DRC to the West. It is part of the ranges, which rise from about 1670m to 5,109m, to Africa's third highest peak, Margherita at 5109m. It covers 995km^2 and was gazetted in 1991. It supports threatened, endemic, and rare species of fauna and flora. Before it was gazetted national park, it was a forest reserve where the communities had access to resources including timber, poles, hunting for bush meat, and firewood among others. After it was gazetted, communities were not allowed to access these resources creating conflicts with authorities. The communities now access some resources under collaborative resource management arrangements in selected parishes but the coverage is still low and few resources are permitted. The communities are now involved in tourism related activities such as guiding and provision of labour as porters.

Boardwalk in Rwenzori Mountains National Park

b) Queen Elizabeth National Park

The area of Queen Elizabeth National Park (QENP) was originally the ancestral grazing area of the Basongora pastoralists. In 1952 L. George and L. Edward Game Reserves were combined and gazetted as QENP. The park is Uganda's most popular tourist destination. It has over 600 species of birds. It is famous for its tree-climbing lions and large hippo population. It covers 1,978 km^2, forming part of a much larger transboundary grassland-forest-wetland ecosystem. Its western border is contiguous with the Parc National des Virunga in the DRC. George and Edward found within the park have the most productive fisheries in Africa. A number of conflicts exist. These relate to community perceptions of being marginalized and their right to utilize parkland. The communities claim that they own part of the parkland. These include competing and conflicting land use practices (cultivation, pastoralism and wildlife protection, conflict over grazing land and water sources, cattle keeping within fishing enclaves). There is encroachment and illegal extraction of park resources.

c) Bwindi Impenetrable National Park

Bwindi Impenetrable National Park (BINP) located in South-western Uganda is the home to the mountain gorillas, constituting approximately half the World's population. Before it was gazetted as a National Park, Bwindi Impenetrable Forest provided multiple livelihoods and subsistence resources for the frontline communities. The resources included domestic wood products such as firewood, building poles, as well as other forest products such as medicinal plants, basketry materials and food (e.g. honey, edible plants and bush meat). In 1991, the forest was gazetted as a national park, which changed its conservation status and meant that access to the forest by the communities including the Batwa (the forest dwelling people) was prohibited forest creating conflict between the local community and the Park Authorities. Despite numerous efforts and programmes these conflicts, although reduced, still exist.

d) Mgahinga Gorilla National Park

Mgahinga Gorilla National Park (MGNP) covers an expanse of 33 km^2 and is the smallest park found in southwestern Uganda at the border of DRC and Rwanda. It is located on the slopes of 3 of the 6 Virunga Volcanoes: Mt. Gahinga, Mt. Sabinyo and Mt. Muhavura. It is an important habitat of Mountain Gorillas. This park together with Parc National des Virunga and Parc National des Volcans located in the DRC and Rwanda respectively make up the Virunga Conservation Area which covers 434 Km^2. The Mgahinga Gorilla NP is habitat to golden monkeys, the Black & White colobus monkeys and blue monkeys, and forest elephants among others. It has several species of birds. Surrounding the park are various local communities including the African pygmy Batwa tribe, which, many years ago survived by gathering fruits and hunting in the Bwindi Impenetrable Forest. The communities were relocated after the establishment of the park. This together with restricted access to resources is a source of conflicts.

e) Semiliki National Park

Semiliki National Park (SNP) is located in Bundibugyo District, western Uganda. It covers 219 km^2 and is part of the Central African Congo Basin forest system of the DRC, being separated from the Ituri forest of the DRC only by the Semliki River. It is separated from the rest of East Africa by the Rwenzori Mountain range and with most of it located within the Albertine Rift, the western arm of the Great Rift Valley. It is included within the Eastern Afromontane biodiversity hotspot. It has a high diversity of plant and animal species. Most of the plant and animal species in the park are also found in the Congo Basin forests, with many of the species reaching the eastern limit of their range here. Four distinct ethnic groups live near the park – Bamba farmers live along the base of the Rwenzori while the Bakonjo cultivate the mountain slopes. Batuku cattle keepers inhabit on the open plains and Batwa pygmies, traditionally hunter gatherers, live on the edge of the forest.

f) Virunga National Park

Virunga National Park (ViNP) is located in eastern DRC. Virunga is Africa's oldest national park. It is a UNESCO World Heritage Site and is known for its wildlife-rich vegetation mosaic, active and dormant volcanoes. It is home to the critically endangered mountain gorillas. It contains more species of mammals, reptiles and birds than any other PA in Africa, and possibly in the world. Several plant species occur, many of which are endemic to the Albertine Rift. Virunga is Ramsar site (wetlands of international importance). Despite its status as protected wilderness, the park has been under threat for more than two decades by armed groups that engage in poaching, deforestation and other unsustainable and illegal resource exploitation. As a result, Virunga has been included on the List of World Heritage Sites in Danger. Currently, all five of DRC's World Heritage Sites are listed as in danger. The park is under attack from oil exploration with concessions covering 85 per cent of its territory having been designated, and exploration companies are on its doorstep. Risks from pollution and destabilization, which could destroy the GVL, may follow the oil related activities.

g) Volcano National Park

Volcanoes National Park (VoNP) lies in northwestern Rwanda and borders Virunga National Park in the DRC and Mgahinga Gorilla National Park in Uganda. It has mountain gorillas. It is home to five of the eight volcanoes of the Virunga Mountains including Karisimbi, Bisoke, Muhabura, Gahinga and Sabyinyo. The park was first gazetted in 1925, as a small area bounded by Karisimbi, Visoke and Mikeno, intended to protect the gorillas from poachers. It was the first National Park to be established in Africa. Subsequently, in 1929, the borders of the park were extended into Rwanda and into the Belgian Congo, to form the Albert National Park, covering 8,090 km^2. In 1960, the park was split into two, and upon Rwandan independence in 1962 the new government agreed to maintain the park as a conservation and tourist area. The park was halved in 1969, and between 1969 and 1973, 1,050 ha of the park, was cleared to grow pyrethrum.

2.2.3. Target population

The assessment targeted the following key stakeholder categories using the methods stipulated in Table 1:

I. Greater Virunga Transboundary Collaboration
II. Ministries, Departments and Agencies (MDAs)
III. Local Governments
IV. Protected Areas
V. Development partners and CSOs
VI. Community groups
VII. Households

2.2.4. Sampling Design

a) Sample size and selection of Households

A representative random sample of 656 households was selected to participate in the 2 studies. A total of 656 household questionnaires returned from 7 protected areas (95 in RMNP, 98 in QENP, 100 in BINP, 100 in MGNP, 99 in Semiliki NP, 64 in Virunga NP and 100 in Volcanoes NP). The overall response rate was above 80% targeted for this study. The distribution of the sample size per protected area is presented in Table 1.

b) Inclusion and exclusion criterion for households

All households located adjacent to each protected area were eligible to participate in the study. Households were represented by a household head or adult member of the household (found at home at the time of the survey). However, both male and female were encouraged to participate in the study. Out of 656 HHs representatives, 52.7% were males and 47.3% were females.

Table 1: Sample size distribution per protected area

Protected Areas (PA)	Target Number of Households
Rwenzori Mountains National Park (RMNP)	95
Queen Elizabeth National Park (QENP)	98
Bwindi Impenetrable National Park (BINP)	100
Mgahinga Gorilla National Park (MGNP)	100
Semiliki National Park (SNP)	99
Virunga National Park (ViNP)	64
Volcanoes National Park (VoNP)	100
Total sample size (n)	**656**

c) Selection criterion for key informants

Key informants are people who are knowledgeable on the subject matter, experienced and have been directly involved in the biodiversity conservation activities or programming within the GVL. Purposive sampling was used to select the KIs based on documents reviewed and consultative discussions with GVTC, PAAs and LGs.

2.2.5. Data collection methods

a) General overview

Vulnerability Assessment: Assessment of vulnerability to determine factors that make biodiversity, species, populations and ecosystems vulnerable to climate change and other threats was undertaken. Land use/cover/vegetation assessments in the PAs within the GVL were done. To describe how species, ecosystems, and ecological processes within the GVL are currently affected by climate change to understand how ecosystem services will be affected by future changes, data on environmental baselines (water, forests, pasture lands, agricultural lands, wetlands, rivers etc.), socio-economic baselines, impacts of climate change and respective interventions, adaptive capacities and management measures as well as mitigation measures were collected.

Land use/cover change and vegetation assessments: Remote sensing and GIS techniques, especially satellite image classification was executed to obtain the status of the land use land cover in the area upon which the natural resource base of the PAs was established over time. The focus on land use/cover classes included among others forests, wetlands, grasslands, water bodies etc. Special focus was given to the analysis of land use and land cover dynamics in the GVL PAs and frontline communities. The generated land-use/cover maps were validated using field observation data through ground truthing. A post classification change analysis was conducted. In order to compare time-series, independently classified land cover maps were compared with each other after image classification using the matrix operation of ERDAS Imagine 2010. The results are presented numerically in table matrices and/or graphically to show the spatial distribution of change patterns. GIS modelling was used to assess the land degradation severity and mapped to aid in developing appropriate interventions. All these GIS and Remote Sensing techniques generated information on the status and dynamics of land use/land cover environmental conditions.

Participatory Rural Appraisal techniques: These tools were used to assess the land use practices and provide information on the specific ecosystem goods and services including, provisioning (e.g. fuel wood, timber, food, fiber, water medicines), regulating (e.g. erosion regulation, landslide and flood control and supporting (e.g. pollination, soil fertility enhancement, cultural heritage, tourism and recreation). Based on the CARE CVCA approach participatory methods were used to measure exposure, sensitivity and adaptive capacity at the following levels: communities, households and individuals.

Hydrological and water quality assessment: The water quality and quantity assessment (based on secondary data) was aimed at assessing adaptation and mitigation measures or services such as freshwater supply, erosion control, and flood control. The baseline environmental parameters included those related to the following ecosystem goods and services such as water (quality and quantity), freshwater biodiversity (fish and aquatic insects), fuel wood, erosion control, flood control and regulation.

Forecast climatic conditions that take into account exposure, adaptive capacity and sensitivity components: Forecasting climatic conditions in the GVL were accomplished through climate modelling. This entailed the use of an appropriate model and climate scenarios. Based on the forecast, the vulnerability of the ecosystems in terms of exposure, adaptive capacity and sensitivity was assessed. Confidence in model estimates is higher for some climate variables (e.g., temperature) than for others (e.g., precipitation) and these were therefore considered in assessments.

How threatening processes will change under different climate change forecasts and what these changes mean for the future of the PAs: A review of literature, key informant interviews, field visits to hotspots and analysis of satellite images were conducted to determine processes that currently threaten the biodiversity and ecosystem services in the GVL. Upon identification, approaches for determining their dynamics over time were developed. Land use dynamics were assessed through analysis of satellite images using Remote Sensing and GIS techniques. The dynamics were then complimented with an assessment of the drivers upon which a prediction of the direction of the drivers in the future (increasing, neutral or decreasing) will aid in forecasting what the trend of the processes will take based on the climate change forecast. Some of the drivers may be obtained from results of a related study.

Proposing appropriate actions for managing and mitigating negative changes in biodiversity and ecosystem services: Taking into consideration the identified knowledge gaps on the impacts of climate change on biodiversity and ecosystem services together with the forecast trends, and in consultation with key stakeholders in the Greater Virunga Landscape, appropriate actions for managing and mitigating negative changes in biodiversity and ecosystem services in the GVL are proposed.

b) Literature review
Information on communities and ecosystems, climate risks and actions undertaken to address the effects climate related risks was obtained through review of literature in form of project documents, general management plans, and journal articles.

c) Key informant interviews
Consultative discussions were held with the Representatives of the Protected Area Authorities (PAAs), institutions/ MDAs, conservation organizations, NGOS, CBOS and LGs. A key informant interview guide was used to guide the discussions on the following aspects;

- Three aspects of VA i.e. Exposure, Sensitivity and adaptive capacity Vulnerability of the biodiversity (flagship species), ecosystems and local communities/households living adjacent to the PAs.
- Existing gaps in knowledge about the Climate Change and its impacts on the management of PAs in the GVL;
- How the current threatening processes such as invasive species, mining, land use, diseases of humans, livestock and wildlife will change under different climate change forecasts and what these changes mean for the future of the PAs in GVL;
- Current mitigations measures/interventions and best practices
- Key Recommendations/appropriate actions for managing and mitigating negative changes in biodiversity and ecosystem services in the GVL

d) Site visits and digital photography
Site visits were conducted to ascertain existence, current status, levels of vulnerability/risks and mitigation measures. The visits were conducted to selected ecosystems and sites within the PAs and adjacent community lands/settlement. For example, land use changes, flagship species and interventions by stakeholders were documented. Also the existence and magnitude of the current threatening processes such as invasive species, mining, land use, diseases of humans, livestock and wildlife that will change under different climate change forecasts and what these changes mean for the future of the PAs in GVL were ascertained.

e) Household Surveys
Semi-structured household questionnaire were administered to a representative random sample of 656 household heads or in their absence, any adult responsible member found at home at the time of the survey.

2.2.8. Data analysis
Data were analysed using quantitative and qualitative techniques. Data were managed as follows: Data from the household questionnaire were entered into EpiData 3.02 owing to its advantage of having data checks and auto skips to minimize entry errors. Qualitative data obtained from FGDs and KIIs were typed in MS-Word 2013. Household data were screened using visual and computer aided checks in order to identify errors and missing cases. Data were exported to STATA 12 and the Statistical Package for Social Scientists (SPSS version 20).

Quantitative household data were analysed using descriptive statistics (i.e. mean, frequency, percentage, proportions and totals/absolute numbers and cross tabulated values) generated in STATA 12 and SPSS 20. Multiple response analysis was done in SPSS 20. Qualitative data were analysed using qualitative techniques (thematic analysis, discourse analysis and content analysis). Overall, the process involved data reduction, displaying data and drawing conclusions.

3. RESULTS AND DISCUSSION

3.1 Socio-economic and demographic characteristics of households

A total of 656 households (i.e. 95 in RMNP, 98 in QENP, 100 in BINP, 100in MGNP, 99 in Semiliki NP, 64 in Virunga NP and 100 in Volcano NP) participated in the study. The main socio-economic and demographic characteristics analysed for influencing vulnerability of populations to climate change were age, household size, annual income gender, education level and marital status.

Most respondents were males (53%). Nearly half had primary education (48%). Most respondents were married or ever lived together (91%). The average household size was 5.8 persons. The average age of respondents was 43 years with annual income of USD 550, which translates to about USD 46 per month or USD 1.5 per day (Table 2).

Agriculture (86%) was the main source of income for households living adjacent PAs (Table 3). For example, households adjacent to RMNP (89%), QENP (87%), BINP (86%), MGNP (94%), Semiliki NP (85%), Virunga NP (69%), and Volcanoes NP (88%) are mainly engaged in agricultural activities (Figure 3).

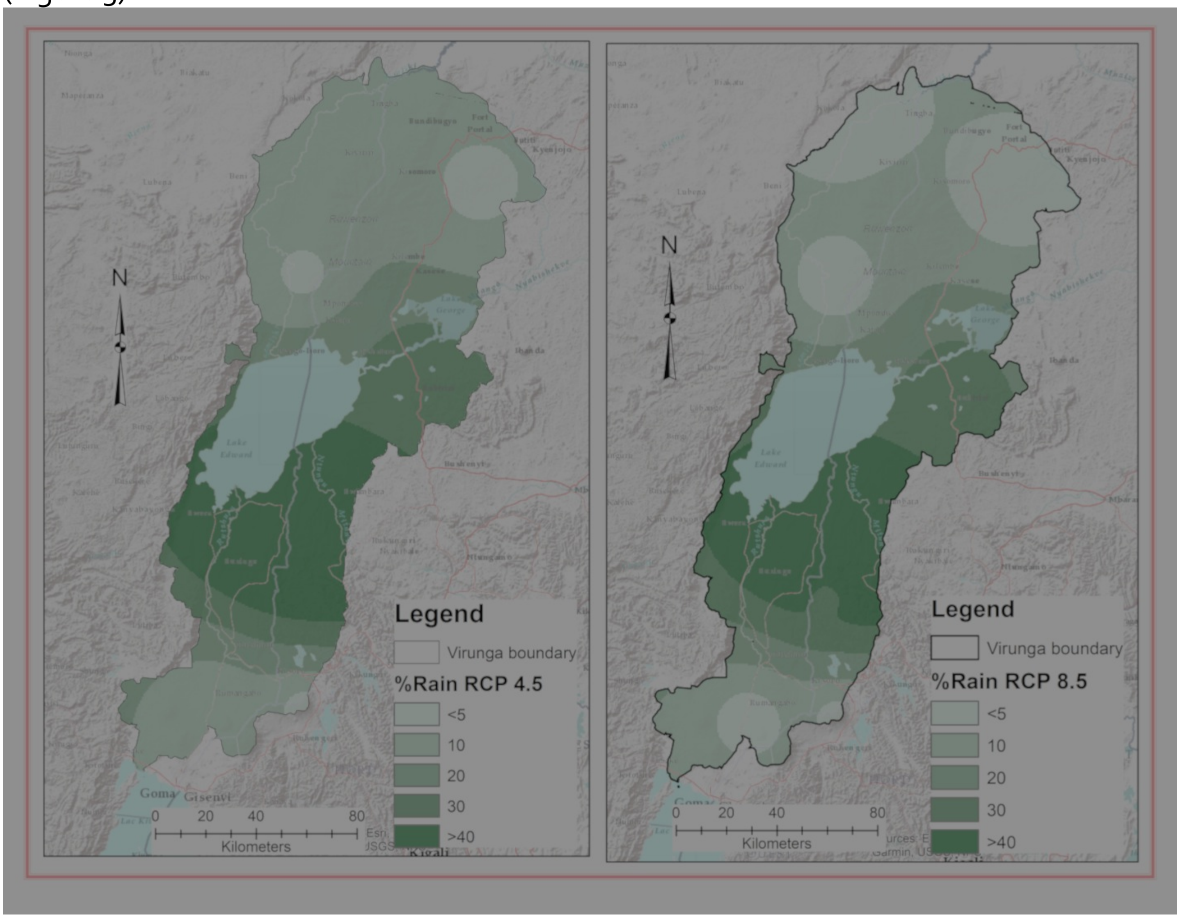


Figure 4: Projected rainfall change for the near future for RCPs 4.5 and 8.5

3.2.2. Projected temperature change for the near future for RCPs 4.5 and 8.5

In terms of temperature (Figure 5), the majority of the region is likely to experience an increment in average temperature ranging from 1-1.4°C. Some areas in the southern part of Lake George and eastern part of Lake Edward are likely to experience increment of 1.8-2.3°C. Small pockets in the north-east of Lake Kivu are likely to experience <1°C increment in average annual temperature for both RCPs. It is also necessary to note that there more patched which are likely to experience less than < 1°C of increment for RCP 4.5, particularly in the northern and southern part of the region.

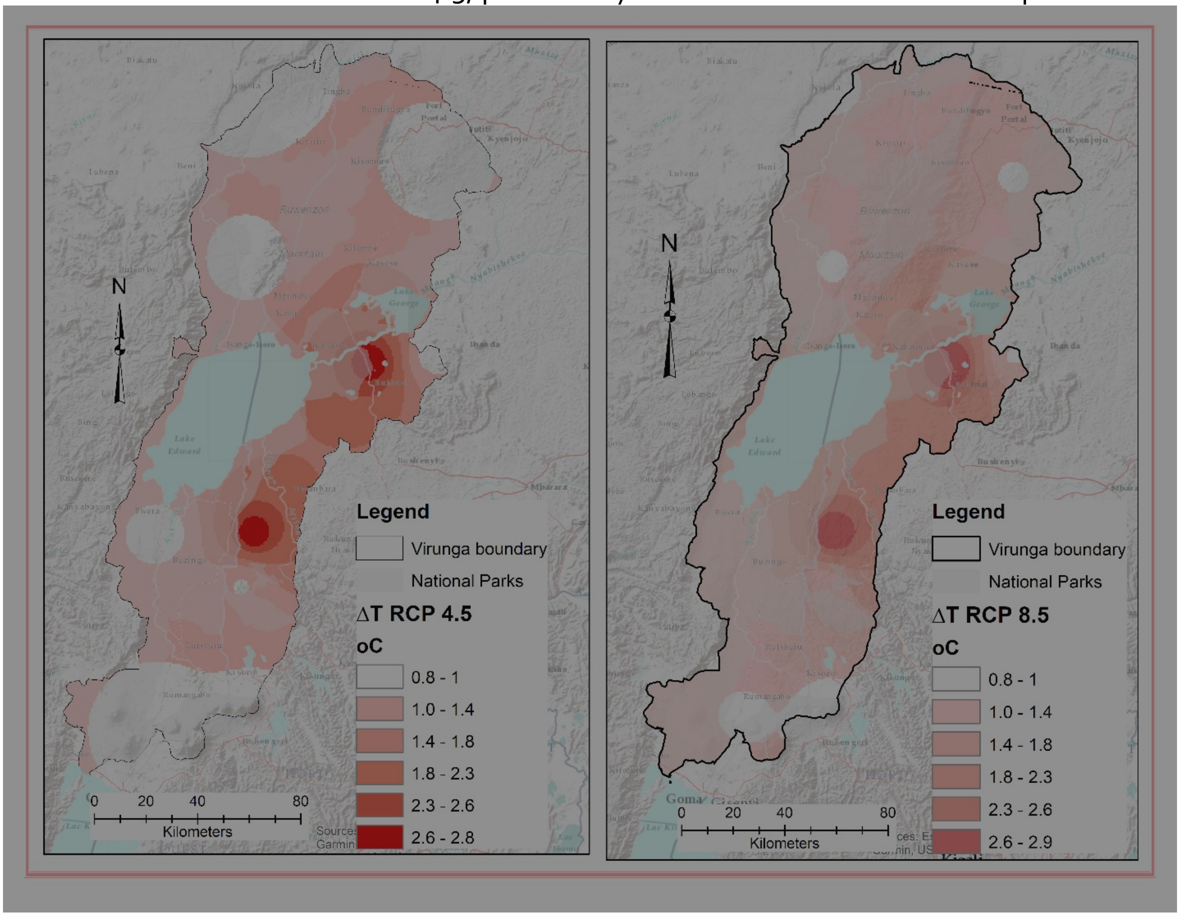


Figure 5: Change in average annual temperature in GVTC in the near future fir RCP 4.5 and 8.5

3.3. Exposure to climate related risks

Households living adjacent PAs within the GVL experienced a range of climate change risks including drought, landslides, flooding and soil erosion (Table 6). The severity of climate related risks experienced by households varied across the PAs. Overall, most of the households experienced drought (85%) as the main climate risk they were exposed compared to other risks. However, drought was reportedly more severely experienced by households adjacent RMNP (88%), followed by MGNP (77%) and QENP (76%). Landslides were severest in RMNP (78%) and MGNP (68%). Flooding was ranked as the severest risk to households adjacent SNP (79%), soil erosion in ViNP (61%) (Table 5). For instance continuous flooding of Rivers such as Nyamwamba and Mobuku in Kasese as well as Lugo and Kirumya in Bundibugyo in the months of May-October every year has become a phenomenon. The floods are usually destructive in nature; sweeping bridges, killing people, destroying plants and animals. The park management is affected when floods sweep away tourism infrastructures like bridges and access routes to tourist sites and other development activities in the region (Figure 6).

Figure 6: Broken Bridge due to flooding on River Lugo that originates from Rwenzori National Park and drains Semiliki River through Semiliki National Park–Kisuba Sub-county –Bundibugyo District

The amount of water flowing from the Mountain down streams have decreased over time leading to reduced water volume of River Mobuku in Kasese District. Currently the Mobuku irrigation scheme is experiencing a reduction in water supply and this likely to affect agricultural activities being undertaken in the scheme.

Temperatures increases are vivid and noticeable in most PAs, it is reported that from the year 2015-2016 temperatures in the Stanley plateaus had increased. Unpredictable rainfall seasons are becoming a common phenomenon. The rain seasons have changed in the years. There used to be 2 known seasons i.e. dry and wet but the current rain and dry season trends suggest a mega shift. In the month June 2019 the rains are falling yet it used to be dry indicating a major shift in the rainfall patterns.

3.3.1. Economic activities prone to climate-related hazards

Several economic activities are undertaken by the households around the PAs. Although agriculture was generally mentioned as the major income generating activity for households around all the PAs, the economic activities that are mainly prone to climate-related hazards was crop farming (97%), followed by livestock keeping (47%), Transport service e.g. Boda-Boda (26%), Business/trade (25%), Charcoal burning (13%), Extraction of resources from the park/PA (12%) and Craft making (12%) among others (Table 6). Majority of households (98%) believed that with eminent prevalence of climate related risks are affecting their sources of livelihoods, they were most likely prone (likely to be affected) to changes climatic related hazards (Figure 6).

Table 5: Climate change risks households are exposed to in GVL

Protected Area/Park	Perceptions/HHs experienced Climatic hazards and perturbations experienced	Climatic hazards and perturbations experienced			
		Drought	Landslides	Flooding	Soil erosion
RMNP	Yes (No. of HHs)	49	82	36	84
	Yes (%)	51.6	86.3	37.9	88.4
	Mean Severity Rank (%)	88.2	78.4	70.3	78.5
QENP	Yes (No. of HHs)	96	1	3	42
	Yes (%)	98.0	1.0	3.1	42.9
	Mean Severity Rank (%)	76.3	20.0	46.7	45.5
BINP	Yes (No. of HHs)	92	2	45	96
	Yes (%)	90.0	2.0	45.0	96.0
	Mean Severity Rank (%)	49.5	10.0	54.2	59.5
MGNP	Yes (No. of HHs)	98	45	13	93
	Yes (%)	98.0	45.0	13.0	93.0
	Mean Severity Rank (%)	77.3	68.3	38.5	73.0
SNP	Yes (No. of HHs)	85	40	80	68
	Yes (%)	85.9	40.4	80.8	68.7
	Mean Severity Rank (%)	77.2	58.8	78.9	75.3
ViNP	Yes (No. of HHs)	46	38	39	42
	Yes (%)	71.9	59.4	61.9	65.6
	Mean Severity Rank (%)	49.6	55.8	55.5	60.5
VoNP	Yes (No. of HHs)	92	23	26	87
	Yes (%)	92.0	23.0	26.0	87.0
	Mean Severity Rank (%)	30.0	42.2	32.7	38.6
Overall	**Yes (No. of HHs)**	**558**	**231**	**242**	**512**
	Yes (%)	**85.1**	**35.2**	**37.0**	**78.1**
	Mean Severity Rank (%)	**63.4**	**65.0**	**61.0**	**62.6**

3.4 Land use/land cover, Ecosystems and Ecosystem Services in the GVL

3.4.1. Land use/land cover

The protected Areas in the GVL are characterised by a number of land use/land cover types including montane forests, grasslands/woodlands, wetlands, and agricultural farmlands among others. Forests and trees influence the availability of other ecosystem services such as fresh water provision and soil erosion control because they provide permanent vegetative cover compared to agricultural farmlands. Land cover change (LUCC) analysis of the GVL shows the distribution of land-use/cover in GVTC landscape for the time period of 2003, 2012 and 2019. Forest, farmland, grassland and water bodies were the dominant land-use/cover in 2003 accounting for about 77.5% of the total area (Table 7). Other land-use/cover categories within the landscape are shrubland, bush land, wetland, bare land, woodland, built-up area, woodlot, and tea plantation.

Table 7: Land-use/land cover statistics of GVLC for the year 2003, 2012 &2019

CLASS_NAME	AREA 2003	AREA 2012	AREA 2019	Percentage area 2003	Percentage area 2012	Percentage area 2019
Bareland	430.82	360.89	471.29	2.00	1.67	2.18
Built-up area	93.25	103.90	104.62	0.43	0.48	0.48
Bushland	1403.74	474.47	1152.40	6.50	2.20	5.34
Farmland	5163.14	5623.53	5724.50	23.92	26.06	26.53
Forest	5716.42	6205.98	5292.35	26.49	28.76	24.52
Grassland	3245.99	3345.95	2319.20	15.04	15.50	10.75
Shrubland	1312.36	1321.96	1723.41	6.08	6.13	7.99
Tea Plantation	35.74	77.24	112.20	0.17	0.36	0.52
Water body	2595.02	2595.02	2595.02	12.02	12.02	12.02
Wetland	1138.48	610.12	931.18	5.28	2.83	4.31
Woodland	397.23	837.04	1151.37	1.84	3.88	5.34
Woodlot	48.44	24.53	3.08	0.22	0.11	0.01
Total	21580.63171	21580.63171	21580.63171	100	100	100

The areas of the four dominant land-use/covers (Forest, farmland, grassland and water bodies) have reduced following a quadratic trend for the last 16 years; with a peak around 2010. Among these four dominant land-use/covers only farmland has increased linearly with time, forest and grassland slightly reduced in 2019, while water bodies remain constant. It is possible that the observed land use/land cover change is attributed to the high demand for land by the increasing human population leading to encroachment on forest, grassland and wetland ecosystems in and around the Protected Areas in the GVL.

3.4.2 Main drivers and actors in land use/land cover change

Human population increase and climate change are the major drivers for the land use change in the GVL. Individuals, households and communities depend on the main ecosystems in the PAs within the GVL for various livelihoods. The main ecosystems on which human populations depend within the GVL are forests, grasslands, wetlands, water bodies (lakes, rivers and streams) and agricultural lands are threatened by degradation or modification resulting from the increasing demand of ecosystem goods and services of the human population.

Consequently, the regulatory functions of these ecosystems such as flood control, soil erosion control, regulation of landslides and water purification are declining. The decrease in ecosystem services is, aggravated by torrential rains (in areas where unsustainable agricultural crop farming practices are undertaken). Soil erosion and siltation of water bodies resulting from unsustainable crop farming practices and reduced forests through encroachment and deforestation are threatening the supply of fresh and clean water for the individuals, households and communities especially those dwelling down-slopes.

Although agriculture is the main economic activity and source of income in the GVL (Figure 3 and Table 3), the increasing human population is further contributing to declining land productivity that has led to reduction in food supply. It is evident that the resultant food shortage has not only prompted expansion of agricultural farmlands to fragile ecosystems in the landscape such as riverbanks, swamps and steep slopes leading to the observed land use/land cover changes. Inevitably, interference with slope stability has led to increased magnitude of various climate-related risks and hazards that populations are reportedly exposed to such as soil erosion, landslides and flooding (Table 5).

3.4.3 Ecosystems

The most common ecosystems in the GVL are:

i. Wetlands

Under RCP4.5 and RCP8.5 scenarios, there is expected increase in annual precipitation. Under climate change conditions and due to the alteration of regional precipitation patterns, lakes and wetlands are exposed to greater nutrient loads, which can ultimately lead to water quality deterioration. Lake Mulehe in Kisoro district in Uganda has already experienced one eutrophication event, where the water turned green because of stimulated growth blue-green algae resulting in massive death of fish.

Intense extreme precipitation events are expected to occur and cause more erosion on the hill-slopes and re-suspension of sediments, ultimately resulting in higher concentrations of sediments and nutrients in the lakes and wetlands. These extreme events will increase contaminant discharge and affect non-point pollution by mobilizing them over agricultural land and increasing nutrient concentrations in receiving wetlands and lakes, consequently degrading the water quality.

In the event of less precipitation, there is still increased risk of eutrophication by lowering minimum flows. Less water volume will be available for dilution of pollutants. As a result, increased concentrations of contaminants can cause deoxygenation, by lowering dissolved oxygen concentration (DO) and increasing biochemical oxygen demand (BOD). Consequently, the risk of eutrophication, especially in water bodies with limited re-aeration capacity, will be increased.

Temperature of the region is likely to increase averagely by 1-1.4°C under RCPs 4.5 and 8.5 scenarios. Increasing air temperature will increase water temperature and lead to deterioration of water quality conditions by accelerating the eutrophication processes in water bodies, which can cause environmental and health-related issues.

Air temperature and temperature in water bodies are in equilibrium. Hence one of the immediate reactions to climate change is expected to be alterations in lake temperature. When water temperature and nutrient concentrations increase, algae growth is stimulated, leading to water eutrophication and algal blooms. As concentrations of phosphorus and nitrogen increase in lakes, cyanobacteria become increasingly dominant. Cyanobacteria are a group of bacteria that grow in any type of water and use sunlight to create food and survive. Because of their colour, they are commonly known as 'blue-green algae'. They grow quickly and bloom in warm, nutrient-rich environments. Once water temperature rises above 25°C, the growth of cyanobacteria accelerates.

As the inflow to a lake gets warmer as a result of higher temperature, the water column will stratify more intensely, decreasing nutrient availability in the surface water. In this case, cyanobacteria will obtain nutrients from deeper depths and accelerate nutrient release in water. Higher temperatures will accelerate microbial activity in the sediments at the bottom of the lake. In this case, the release rate of internal phosphorus will increase, and will contribute to a significant portion of the total nutrient load in the water. Therefore, under climate change conditions, the release of nutrient loadings from internal sources could still make water eutrophic, even if external sources of nutrients, such as non-point pollution from agricultural land are restrained.

Warming of both air and water temperature under climate change favours increasing survival and breeding of anopheles mosquitoes that are responsible for the spread of malaria. Environmental degradation, especially drainage of wetlands, has brought change in climate leading to areas that used to be cold and practically had no malaria to have severe malaria outbreaks. This, coupled with movements of people to and from areas with high malaria prevalence, like Kampala (Uganda), has propelled malaria to even higher levels. People living in areas with low malaria prevalence such as the highlands of Kigezi are prone to severe due to low immunity.

ii. Agricultural lands

Climate change is likely to be exacerbating the land degradation problems in the area. For example, flash floods that occurred in Kirundo subcounty of Kisoro District (Uganda) killing 3 people, destroying 20 houses and several hectares of crops washed away in September 2011 while those that occurred in Muko subcounty of Rubanda District killed 17 people, destroyed 15 homes and crops in September 2017.

We are likely to witness more areas being degraded and becoming unsuitable for crop growing, especially on the hillslopes, due to extreme weather event like storms. However, even the valleys that are currently the main stay for agriculture are likely to be sedimented with unfertile or polluted soil. Frequent droughts are likely to drastically reduce crop yields, reduce water availability for human, livestock and plant use and increase wind erosion. Unpredictable and unreliable variability weather is likely to affect farmers greatly as they will not know when to plant crops. The present knowledge of synchronizing crop growing with weather events has been used for several generations so that it is now very difficult to change.

Conversion of natural habitat to agriculture in the GVL (as part of the Albertine Rift) has already claimed up to 38% of the suitable habitat of the average endemic species. Climate change is expected to worsen the situation by causing on average to a 75% loss of the remaining range of endemic species by 2080. Putting these two together means that on average only about 16% of species original suitable habitat would remain in 2080. Most of these areas of suitable habitat are predicted to shift upslope in the mountains.

However, on a positive note, there is likely to be significant overlap between the current and future suitable habitat for most species in the region, and nearly 68% of overlapping areas are already protected. This means that for these species the overlap will allow movement to new areas as well as species survival in the existing overlap areas. Up to 31 species are predicted to lose all or most suitable habitat by 2080, or do not have any overlap between current and future predicted ranges. These species will need more direct conservation action if they are to be conserved.

iii. Montane forests and woodlands

Montane forests and woodlands are generally well protected in the PAs. They are often immersed in cloud. This cloud immersion affects every aspect very aspect of the forests from hydrological cycle to the species of plants and animals. This immersion makes the forests sensitive to climate. Changes in temperature and rainfall due to climate change makes altitude shifts in the climate optimum for mountain ecotones. This suggests complete replacement of high altitude alpine zones by lower altitude ecosystems, pushing the latter to near extinction. There is also expected to a reduction in low level cloudiness with the coming climate changes. The coming climate changes appear likely to upset the current dynamic equilibrium of the forests. Results will include biodiversity loss, altitude shifts in species' ranges and subsequent community reshuffling, and possibly forest death. Difficulties for montane forests species to survive in climate-induced migrations include no remaining location with a suitable climate, no pristine habitat to colonise, migration rates or establishment rates that cannot keep up with climate change rates and new species interactions. One example is study in the Volcanoes National Park (Musana and Mutuyeyezu 2011) showing that Mountain Gorillas depicted a seasonal use of vegetation zones. One group of gorillas had an altitudinal range of 2,400-2,600m while another ranged between 2,900-3,050m, but the two groups most commonly occupied the lower forest belt. Hence, the results showed that mountain gorillas had complicated seasonal movement patterns. Long-term data show a correlation between mountain gorilla movement and seasonal changes. This variation in use of vegetation zones can depend on the availability of food sources, which is a function of seasons and altitudinal climate zone.

Apart from changes in temperature, precipitation, and cloudiness, other changes include dry seasons, droughts and intense rainstorms, all of which increase degradation to the forest. Because montane species occupy such small areas and tight ecological niches, they are not likely to colonize degraded sites. Fire, drought and non-native plant invasions are likely to increase the effects of any climate change damage in the montane forests. In terms of Hydrology, frequent contact of clouds on vegetation make vegetation gain an additional water source by stripping water out of passing clouds, either through direct contact or through condensation. This can be significant during the dry seasons or droughts. Also, frequent presence of clouds, reduce evapotranspiration, further reducing water stress. These forests provide additional water to normal rainfall. Reduction in the cloudiness due to climate change is therefore likely to result in changes in the hydrological regime like the lowering of water levels in montane wetlands. This is already detected in the swamps of MGNP.

iv. Impacts across habitat types

There are climate change related effects that are likely to affect more than one habitat type simultaneously. Examples include changes in the relative abundance of habitat types such as the encroachment on forested sites i.e. degraded versus intact habitat types.

v. Savannahs, Grasslands and pasturelands

The extent of savannahs and grasslands in terms of losses or gains to specific plant functional types, are likely to remain largely unchanged under climate change scenarios. However, there are complex interactions between plant functional types, fire and herbivores. Increase in atmospheric CO_2 favours typically woody C3 plants due to CO_2 fertilization, such effects may be counteracted by the benefits of increased temperature on C4 grasses (further complicated by interactions with water availability, water use efficiency, fire and herbivores.).

vi. Lakes, rivers and streams

Climate change driven changes to freshwater ecosystems are likely to occur directly (from precipitation changes, rising temperatures and CO_2 concentrations, and indirectly, due to changes to upstream hydrological and precipitation regimes. Increased freshwater inputs following heavy rains and rapid snowmelt may lead to increased sedimentation and nutrient loading in aquatic ecosystems. Reduction in runoff, particularly in the north of the GVL, may have important impacts on rivers and lakes such as Edward, George and Albert. This will affect runoff (64%), hydrology, erosion and siltation rates. The combination of increased runoff and greater evaporation is likely to result in large fluctuations in the size of water bodies in the area at seasonal and inter-annual time scales.

3.4.2. Ecosystem services

Greater Virunga Landscape (GVL) is one of the most biodiverse habitats in Africa as it harbours famous national parks and species such as the Mountain Gorilla (*Gorilla gorilla beringei*), but also the highest human density in Africa, reaching up to 800 people per square km. According to the Millennium Ecosystems Assessment report (2005), there are four categories of ecosystem services namely: provisioning services, regulating services, supporting services, and cultural services. Such ecosystem services are the benefits of nature to households, communities and economies. Overall, there are various ecosystem services that a wide range of stakeholders, are benefiting from in the GVL and these range from non-wood and wood products. Overall, maintenance of biodiversity, food and fibre provision, water supply, purification and regulation - all of which have a bearing on human well-being (Kasangaki et al. 2012). Most communities living around protected areas in the GVL depend on PAs for livelihoods by accessing resources such as firewood, medicinal plants, handicraft materials and water because these resources have increasingly become scarce outside protected area systems[1]. Most respondents (80%) derived from VoNP are fresh air, shade from strong sunshine, malaria prevention, tourism revenues, good harvests, rainfall for agriculture and water supply through water harvesting as the main ecosystem services. The common ecosystem services harnessed from Rwenzori and Semiliki National parks are summarised in Table 7. Under the current climatic conditions, these services and products are available. With the projected changes in climate, continued availability of such ecosystem services become threatened.

3.4 Sensitivity

3.4.1 Effect of changes in climate on households

Within the last 10-15 years Majority of the households had noticed changes in climatic factors including rainfall (95%), drought (83%), temperature (78%) and winds (77%). The severity of changes in climate was generally perceived high. The most highly ranked change noticed was change in rainfall patterns (91%), followed by drought occurrence (63%), high prevalence of strong winds (57%) and general increase in temperatures (54%) among others (Table 8). The observed

[1]Kasangaki et al. 2012. Capturing the benefits of ecosystem services to guide decision-making in the Greater Virungas Landscape of the Albertine Rift Region. ARCOS, University of Cambridge and WWF-US. Project Technical Report to MacArthur Foundation.

changes in climatic factors had negatively affected households. The most commonly reported effects of changes in climate were Low crop yields (90%), inadequate food/food insecurity (81%), loss of farmlands (67%) and emergence of human wild conflicts (41%) among others (Table 9).

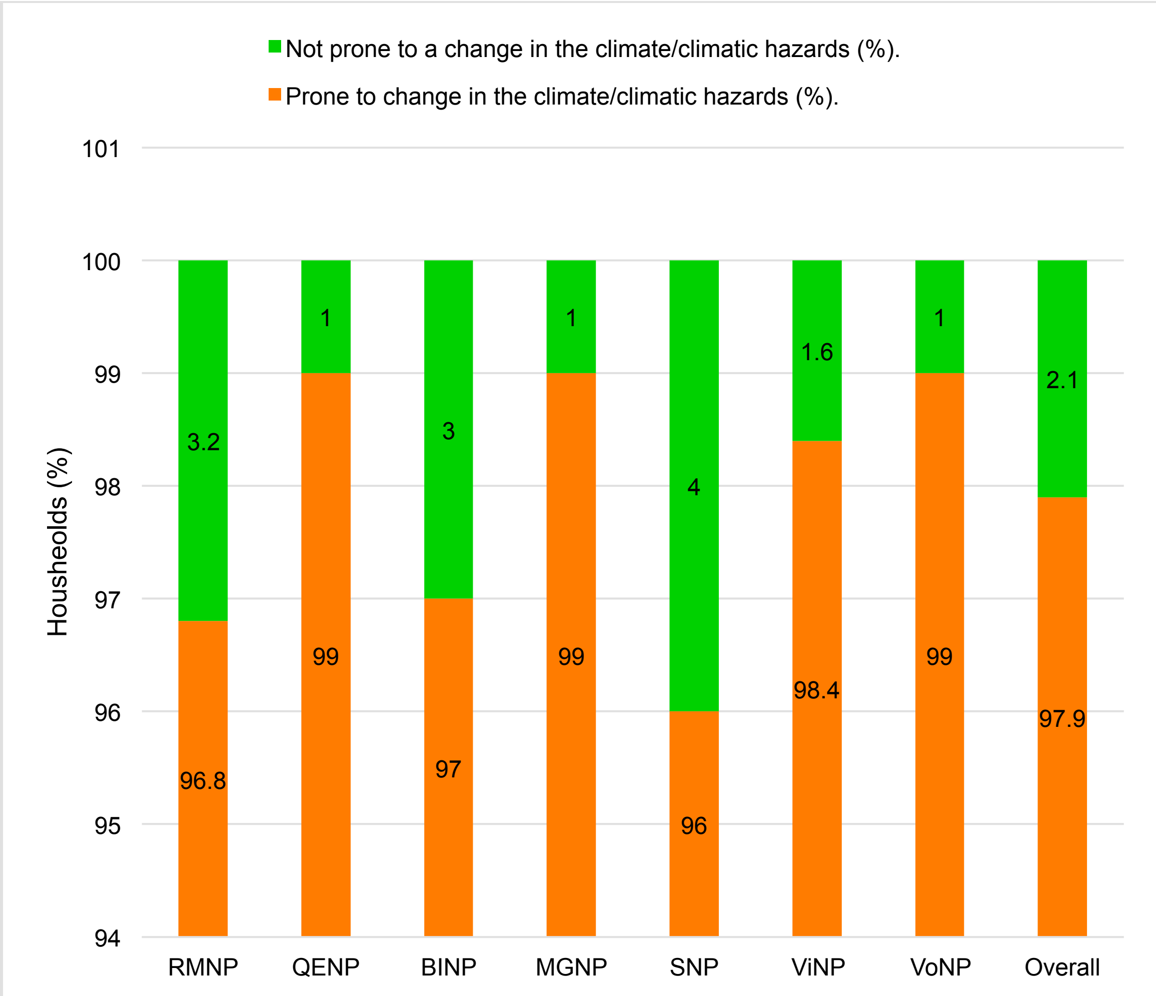


Figure 6: Perceptions of households about their susceptibility to climatic hazards

3.4.2 Drivers of high sensitivity to climate related risks in the GVL

There are a number of factors that render the Pas in GVL sensitive to changing climate conditions. These include:

(i) Topography

The landscape is generally mountainous with elevation ranging from about 600 m to 5109m a.s.l at Margerhita on the Rwenzoris. Additionally, it is also steep in nature. Such a landscape is inherently sensitive to any changes in climate. A case in point is its susceptibility to water erosion, especially after the vegetation cover has been disturbed, usually in the up-slope and mid-slope. On the other hand, the topography makes the down-slope more sensitive to flooding and silt deposition.

(ii) Soils

The GVL covers the Virunga and Mt. Rwenzori region and as such, the soils are influenced by the mountains. The soils are generally fragile and in the Virunga region are often very rich in nutrients because of their volcanic ash content. They are very fertile and thus support agricultural activities. They support the growth of crops including Irish Potatoes, Sorghum, Peas and beans. However, the soils are loose, and unstable. Such soils are thus vulnerable to erosion and landslides, especially where land management measures have not been appropriate.

(iii) **Increasing population density**

The GVL is characterised by a rapidly increasing population. The high population density, for example in the mid and up-slope where it is over 300 people per sq.km and growth rate in the landscape presents a challenging and extremely high demand for ecosystem services especially from natural resources within and outside the Protected areas as alternative sources of livelihoods. Due to the increased demand for resources, communities encroach on forests uphill, wetlands and swamps down slope as they convert these lands to agricultural crop farmlands and for settlement. Land shortage is increasingly making these areas sensitive to climate change. The high population densities are also increasing the sensitivity through exacerbating soil/land degradation through over-cultivation. Additionally, the high populations are increasing the demand for fuel thus leading to rampant deforestation for fuelwood and charcoal derived from within and outside the Protected Areas.

(iv) **Deforestation**

Within the GVL, deforestation has been rampant. The seven PAs within the GVL are isolated by cropland and settlements. These are testimony to the long history of forest loss in the region.

(v) **Feeling of alienation of local people from natural resources**

The value attached to natural resources and or ecosystems in general influences the sensitivity of EbA targets to climate change. People who care less about the natural resources like forests and wetlands are more sensitive to climate change hazards. In the GVL, the relations of communities with the staff of PAs have improved in many cases, but remain sour in some of the adjacent communities. What the park staff may define as genuine law enforcement is perceived as harassment, as people ate sometimes arrested and punished for indulging in illegal activities. As much as the dependence of the communities on park resources is high, the local communities sometimes feel they are not part of the resource system and as such cannot care for it.

vi) **Wildfires**

Wild fires are a common phenomenon and are particularly caused by prolonged drought and increased human activities in the parks. More fire outbreaks will likely lead to changes in vegetation composition as certain plants become more competitive with decreasing moisture and increasing fire frequency which will in turn affect plants and animal distributions. For instance there are reports of increased wild fires, for example in RMNP that destroyed large parts of park land especially at higher altitudes.

vii) **Landslides**

In 2015-2016 there were widespread Landslides and floods, involving extensive destruction of property and lives. Constant floods and landslides have the potential to impact the socio-economic and physical welfare of communities living in risky areas. Response to the effects of floods is likely to result into new adaptive responses such as encroachment on naturally existing resources which has a possibility of affecting a broader environment.

3.5 Adaptive capacity

Adaptive capacity refers to capacities and resources used to deal with impacts and recover from damage. Adaptive Capacity focuses on the capacities and resources that increase the resilience to adverse climate change impacts and thus aid in the recovery from the damage. The focus areas are in knowledge, technology, institutions and economy. As already noted, climate change is occurring in the GVL leading to a number of impacts such as soil erosion, landslides, disease outbreaks, flooding and drought among others. In adapting to it, there are a number of capacities and resources aimed at enhancing resilience to climate change through adaptation. One of the major resources to deal with climate change is the institutional resources. Institutions are playing a very vital role in providing policy, technical and financial resources to adapt to climate change. The institutions include both government and non-governmental organizations. However, the key actions are taken at the individual and household levels.

3.5.1 Management of changes in climate among households

Majority of the households coped with the climate related risks through implementation of different measures including planting trees on farm (99%), along the land boundary (45%), establishing trash lines (38%), terracing (30%), mulching (28%), fallowing the land (12%), Small-scale irrigation on farm (12%), and crop rotation (10%) among others (Table 10). Despite numerous measures undertaken by communities against climate related risks, the measures mentioned were reportedly effective up to only 61%. Although the level of effectiveness of actions undertaken ranged between 60-64% among households adjacent all the PAs, most of the households living adjacent the PAs perceived generally that measures against soil erosion and drought are the most effective compared to actions against landslides and flooding (Figure 6).

Table 10: Measures undertaken by households to cope with climatic related hazards

Main actions undertaken by households to cope with all climatic hazards and perturbations (Drought, Landslides, Flooding and Soil erosion)	Overall Climatic hazards and perturbations (Drought, Landslides, Flooding and Soil erosion), (%), n=627.	Rank the effectiveness of the action undertaken by Households
Tree planting on farm/gardens*	98.9	1st
Tree planting along the land boundary*	44.5	2nd
Trash lines*	38	3rd
Terracing*	30.1	4th
Mulching*	28.2	5th
Fallowing land	11.6	6th
Small scale irrigation on farm	11.6	6th
Contour bands stabilized with grass/vegetation	11.2	7th
Crop rotation	10.4	8th
Planting fodder crops for livestock e.g. Elephant grass	9.4	9th
Planted improved crops varieties	8.6	10th
Avoided deforestation in PAs	7.3	
Dug trenches/drainage channels/water channels	7.3	
Avoid deforestation outside PA	6.4	
Involvement of local community in planning and monitoring of conservations projects	4.8	
Left river banks uncultivated	4.3	
River bank protection by planting	3.8	
Stopped cultivation on steep slopes	2.7	
Conservation education/Awareness	2.6	
Retaining indigenous trees on farm	2.2	

Construction of Culverts/Bridges	2.1	
Leave swamps uncultivated/Conserve wetlands	2.1	
Acquired land in other areas	1.8	
Used Stone walls	1.3	
Applied organic fertilizers e.g. FYM	1.1	
Other specify	1.1	
Rainwater Harvesting & Storage e.g. in Reservoir tanks	1.1	
Intercropping/Mixed cropping/plant cover crops	0.5	
Membership to conservation group	0.3	
Clean cooking & heating e.g. biogas	0.3	
Engaged in IGAs	0.2	
Applied inorganic fertilizers bought from shops	0.2	
Clean lighting e.g. solar power/solar lights	0.2	
Remove invasive species	0.2	
Food storage	0.2	

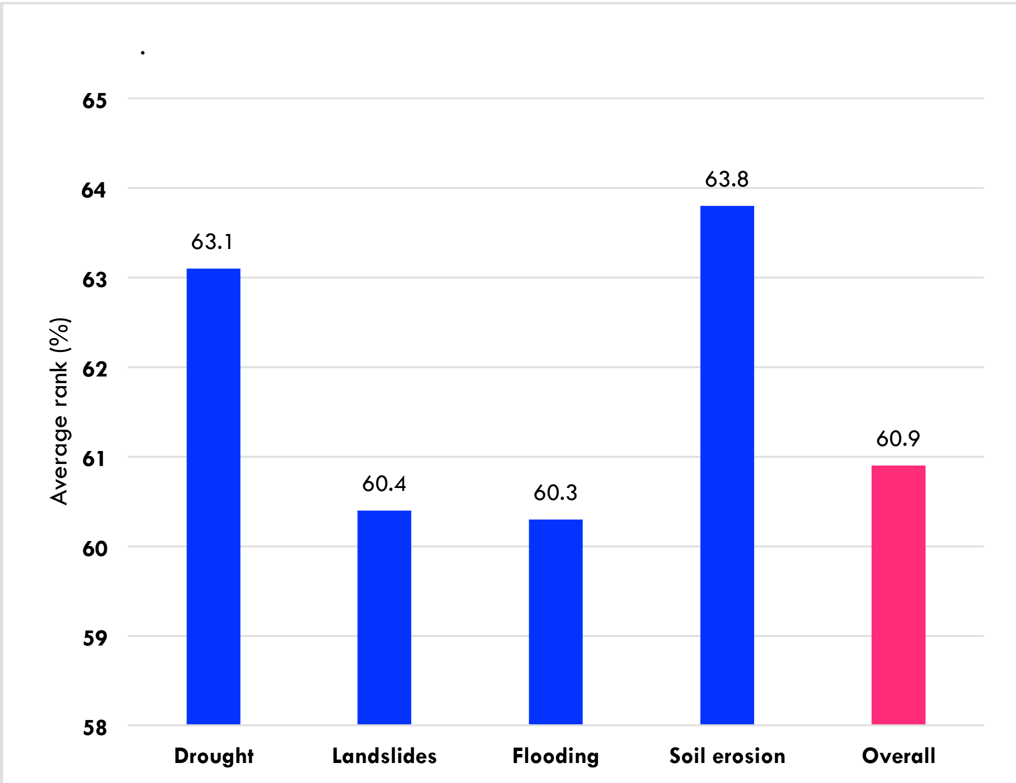


Figure 6: Perceived effectiveness of actions undertaken by HHs to cope with climate-related hazards

The main actions undertaken by the households to cope with effects of drought were tree planting on farm/gardens (68%), tree planting along the land boundary (21%), and small-scale irrigation on farm (15%), crop rotation (9%) and planting improved crop varieties (8%). Majority of the measures undertaken by households to cope with effects of drought (adaptive capacity to drought) were ranked to be about 63% effective (Table 11a). The main actions undertaken by households to cope with the impacts of landslides were tree planting on farm/gardens (64%) followed by tree planting along the land boundary (52%). These measures were ranked to about 69% effective against landslides among others. The actions undertaken by households to cope with landslides were ranked as 60 effective within the GVL (Table 11b). Similarly, households cope with the impacts of flooding by establishing trash lines (53%) that were ranked 63% effective. Overall, the effectiveness of the actions undertaken by households to cope with flooding was ranked 60% effective within the GVL (Table 11c). Households also cope with impacts of soil erosion by mulching (29%) terracing (27%) tree planting on farm/gardens (21%) and Trash lines (15%). These measures were ranked as 60%, 70%, 31% and 66% effective respectively at coping with the impacts of soil erosion. Overall, mulching was ranked 60% more effective in overcoming impacts of soil erosion compared to other measures (Table 11d).

3.5.2 Actions to mitigate negative changes in biodiversity and ecosystem services

In order to prevent and overcome observed threats of climate change in the landscape, it is proposed that ecosystem based adaptation (EbA) measures should be undertaken. Such measures include but are not limited to enhancing availability of wood and non-wood products, energy, water and sustainable land management measures aimed at improving land productivity. On-farm tree planting (100%), controlling deforestation in PAs (41%), reducing deforestation outside PAs (32%), terracing and crop rotation were most (≥25%) reported measures for mitigating negative changes in biodiversity and ecosystem services (Table 12).

Table 12: Main recommendations by households in GVL

Actions recommended to prevent and overcome impact of Climate Change hazards and perturbations	Percent of Cases (n=656)
Tree planting on farm/gardens	100
Control deforestation in PAs	41.0
Terracing	33.4
Control deforestation outside PA	32.0
Crop rotation	30.1
Mulching.	25.8
Tree planting along the land boundary	21.3
Apply organic fertilizers e.g. farm	20.2
Small scale irrigation on farm	18.2
Contour bands stabilized with grass	13.3
Trash lines	12.8
Retaining indigenous trees on farm	12.4
Clean cooking and heating e.g. biogas	11.6
Apply inorganic fertilizers	10.7
Infrastructure development e.g. Roads, bridges	10.7
Provide alternative source of water	10.5
Plant improved new crops varieties	10.0
Acquire land in other areas	9.9
Fallowing land	8.7
Stopped cultivation on steep slopes	7.9
Planting fodder crops for livestock	7.6
Strengthen membership to biodiversity conservation groups	7.4
Leaving river banks uncultivated	6.0
Enforce River banks buffer areas	5.9
River bank protection by planting grass on buffer	4.9

zones	
Clean lighting e.g. solar power	4.0
Other	3.2
Dig trenches & contain wild animals from the park	2.2
Sensitization of people to protect the environment	0.8
Compensate farmers	0.2
Fence the protected areas	0.2
Wetland conservation	0.2
Engage local people in GVTC projects	0.2

4.0 CONCLUSION AND RECOMMENDATIONS

4.1. Conclusions

In general, zones with high exposure are particularly prone to disasters. These include poverty, low education, low adoption rates of intervention measures and inadequate access to information about climate change. Poor communities have limited alternative income sources rendering them less adaptable to climate change. The low education levels also could be contributing to the poverty.

Access to information, if not well addressed, hinders adoption of interventions to climate change hazards and risks. Drought affects the communities that have not planted any trees on their land or around their homes. The landslides or floods may affect many people who have terraced or dug trenches on their land respectively.

Drivers of Climate Change in the in the GVL: The study, as expected, shows that climate change is occurring in the GVL and is mainly driven by anthropogenic factors, especially increased land use intensity. This is driven by increased population growth and its associated demand for land for agriculture and settlement. In addition, there is unsustainable utilisation of natural resources.

Current effects of climate change on species, ecosystems, and ecological processes and potential future effects on ecosystem services: Climate change will negatively affect species, ecosystems and ecological processes in the GVL if appropriate mitigation and adaptation actions are not implemented.

Forecast of climatic conditions taking account of exposure, adaptive capacity and sensitivity: The GVL still provides a wide range of ecosystem services that vary spatially. The climate forecast for the GVL in the near future (2020-2039) under both RCP 4.5 and 8.5 generally shows an increase in both rainfall and temperature.

Changes in threatening processes under different climate change forecasts: The projected climatic conditions will thus affect several ecosystem services and processes in the GVL. These effects are more likely to occur in DRC and Uganda and under RCP 8.5 as compared to RCP 4.5.

4.2. Recommendations

Basic Sustainable Land Management Practices such as Mulching, Terracing, Planting Trees along boundaries and others must be encouraged and scaled up. In addition, alternative livelihood strategies must be identified for the most vulnerable households.

The adaptive capacity of households that are increasingly dependent on Tourism related activities in the GVL is unclear. The receding Glaciers and Snowline in the Rwenzori mountains could have adverse effects on tourism making the communities Vulnerable. Community Based Enterprises such as the Rwenzori Mountaineering Services may face difficulties if visitor numbers drop. Hence, efforts need to be made to diversify the tourism products beyond the current options.

Protected Areas allover the GVL are faced with increasing population pressure and demand for resources, hence there is a need to managing the human population growth.

The Protected Areas in the GVL are faced with the threat of Alien Invasive Species. Restoration of degraded ecosystems must be treated as a matter of priority. Current measures are inadequate in many of the PAs.

Whereas the Protected Areas in the GVL are mainly mountains, research within the Afroalpine Zone on the Mountains has received very little attention. Moreover, monitoring efforts should be strengthened on the mountains. We recommend the formation of a Centre of Mountain Related research in the GVL. Ultimately, Research and Ecological Monitoring must be enhanced.

Livelihoods of communities requires additional attention. Sustaining promising/successful interventions. Mechanisms for utilizing the money for revenue sharing need to be strengthened. The issue of compensation for the communities over lost crops needs to be harmonised between the PAs.

5.0. BIBLIOGRAPHY

Ayebarea, S., A.J. Plumptre, D. Kujirakwinjaa, D. Segana (2018). Conservation of the endemic species of the Albertine Rift under future climate change. Biological Conservation 220 (2018) 67–75.

BINP (2014): BINP General Management Plan 2014 – 2024. Bwindi Impenetrable National Park. Uganda Wildlife Authority (UWA). April 4, 2014

Carr, J.A., Outhwaite, W.E., Goodman, G.L., Oldfield, T.E.E. and Foden, W.B. 2013. Vital but vulnerable: Climate change vulnerability and human use of wildlife in Africa's Albertine Rift. Occasional Paper of the IUCN Species Survival Commission No. 48. IUCN, Gland, Switzerland and Cambridge, UK. xii + 224pp.

Fahey, D.W., S.J. Doherty, K.A. Hibbard, A. Romanou, and P.C. Taylor. 2017. Physical drivers of climate chang. In: climate Science Special Report: Fourth National Climate Assessment, Volume 1 [Wuebbles, D.J., D.W. Fahey, K.A. Hibbard, B.C. Stewart, and T.K. Maycock (eds.). U.S. Global Change Research Program, Washington, D.C., USA, pp.73-113, doi: 10.7930/J0513WCR.

FAO 2011. Questionnaire for Mapping Land degradation and Sustainable Land Management (QM) v2. Food and Agriculture Organization of the United Nations, Rome, Italy.

Fungo, B. 2011. A Review Crop Raiding Around Protected Areas: Nature, Control and Research Gaps. Environmental Research Journal, 5 (2): 87-92.

Galabuzi, C and Tumwesigye, A (2009): Current Knowledge, Attitudes and Practices of Local Communities Surrounding Rwenzori Mountains National Park. Rwenzori Mountains Conservation and Environment Management Project (RMCEMP) Survey Report.

Kalpers, J., Gray, M., Asuma, S., Rutagarama, E., Makambo, W. & Rurangwa, E. 2011. Buffer Zone and Human–Wildlife Conflict Management. Pp. 105–137 in: Gray, M. & Rutagarama, E. (eds.) 20 Years of IGCP: Lessons Learned in Mountain Gorilla Conservation. Kigali (IGCP).

Kasangaki et al. 2012. Capturing the benefits of ecosystem services to guide decision-making in the Greater Virungas Landscape of the Albertine Rift Region. ARCOS, University of Cambridge and WWF-US. Project Technical Report to MacArthur Foundation.BINP (2014): BINP General Management Plan 2014 – 2024. Bwindi Impenetrable National Park. Uganda Wildlife Authority (UWA). April 4, 2014

Laurance, W. F., Useche, D.C., et al., Eilu, G., et. al. (2011). Global warming, elevational ranges and the vulnerability of tropical biota. Biological Conservation 144: 548–557.

Lindeque, L. 2010. Training Manual for the Assessment of Land Degradation and Sustainable Land Management, based on the LADA/WOCAT mapping methodology. LADA field paper.

MGNP (2014): MGNP General Management Plan 2014-2024. Mgahinga Gorilla National Park. Uganda Wildlife Authority (UWA). April 4, 2014.

Mugizi, T.F., Gizaw, G., Gussarova, G., Nemomissa, S., Popp, M., Masao, C.A., Tigist Wondimu, Abdi, A.A., Mirré, V., Muwanika, V., Eilu, G., and Brochmann, C.

(In prep). Afro-alpine flagships revisited: parallel adaptation, intermountain admixture and shallow genetic structuring in the giant senecios (Dendrosenecio).

Musana, A. and Mutuyeyezu, A. 2011. Impact of climate change and climate variability on altitudinal ranging movements of Mountain Gorillas in Volcanoes National Park, Rwanda. Unpublished Externship Report: Rwanda. The International START Secretariat, 2000 Florida Avenue NW, Suite 200, Washington DC 20009, USA in collaboration with: The Pan African START Secretariat, Institute of Resource Assessment, University of Dar es Salaam, Tanzania.

Plumptre, A. J., Davenport, T.R.B., Behangana, M., Kityo, R., Eilu, G. Ssegawa, P., Ewango, C., Meirte, D., Kahindo, C., Herremans, M., Peterhans, J.K., Pilgrim, J.D., Wilson, M., Languy, M. and Moyer, D. (2007) The Biodiversity of the Albertine Rift. Biological Conservation 134: 178–194.

Plumptre, A.J., Kujirakwinja, D., Treves, A., Owiunji, I., Rainer, H., 2007. Transboundary Conservation in the Greater Virunga Landscape: its importance for Landscape Species. Biological Conservation 134, 279–287.

QENP (2012): QENP General Management Plan. (2011 - 2021). General Management Plan. Uganda Wildlife Authority (UWA). 26th July 2012.

RMNP (2004): RMNP General Management Plan. (2004). General Management Plan. Uganda Wildlife Authority (UWA). 29th June, 2004.

State of Conservation periodic Report for Rwenzori Mountains National Park World Heritage Property – Uganda, Submitted to World Heritage Centre, UNESCO, January 2014

Uganda Bureau of Statistics. 2016. The National Population and Housing Census 2014. Kampala, Uganda.

Uganda Wildlife Authority, BINP General Management Plan 2014 – 2024

Uganda Wildlife Authority, MGNP General Management Plan 2014-2024

UN DPA & UNEP, 2015. Natural Resources and Conflict. A guide for mediation Practitioners. Series report No. 6. 101 pp.

USAID, Technical Report, (May 2017) Climate Risks To Conservation In Uganda, An Assessment of Selected Regions

UWA, Queen Elizabeth National Park, Kyambura wildlife reserve and Kigezi Wildlife Reserve, (2011 - 2021) General Management Plan.