By Soda BIZIMANA

Reg. Number: 218014505

MURAGO WETLAND ECOSYSTEM AND ITS ROLE TO ENHANCE CLIMATE-RESILIENT TO LOCAL COMMUNITY IN RWANDA

A dissertation submitted in partial fulfillment of the requirements for the degree of Master of Geo-Information for Environment and Sustainable Development;

School of Architecture and Built Environment, College of Science and Technology,

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Supervisors:

Dr. Elias NYANDWI

&

Prof. UMARU GARBA WALI

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Declaration

I, Soda BIZIMANA hereby declare that the work embodied in this dissertation entitled **"Murago wetland ecosystem and its role to enhance climate-resilient to local communities in Rwanda"** is my original work and has never been the award of any Degree, Diploma, Associateship, Fellowship or such other similar title prior to this date.

Signature: ……………………………………….. Date: ………………………………………..

Soda BIZIMANA

This thesis has been submitted for review with our approval as University

Signature: ……………………………………….. Date: ………………………………………..

Supervisor: Dr. Elias NYANDWI

Signature: ……………………………………….. Date: ………………………………………..

Programme Coordinator: Dr. Theophile NIYONZIMA

Signature: ……………………………………….. Date: ………………………………………..

HOD/ Department of Geography and Urban Planning: Dr. Jean Pierre BIZIMANA

Signature: ……………………………………….. Date: ………………………………………..

Dean/ SABE: Dr. Manlio Michieletto

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Abstract

Wetlands are important ecological zones that support the life of important fauna and flora through its water and its fertile soil. Wetland Ecosystems play an important role of protecting its environment from climate hazard and enhance the livelihood of its surrounding population. This study seeks to evaluate the status and management of Murago wetland ecosystem to enhance climate-resilient local communities. Wetland cover types and changes over time was detected using Landsat imagery ages acquired in four different years; 1984, 1995, 2002, and 2018. Focus Group discussions (FGDs) with two cooperatives members of farmers and fishers helped us to identify activities which degraded Murago wetland, and prioritize the activities which rehabilitate or protect Murago wetland environment. Field survey and observation has been done through curved line transect, walking around Murago wetland and making observations using data sheet to record information, camera to record photos, and GPS to record location coordinates.

The results showed that the total area of Murago catchment estimated at 15,881 ha was dominated by grassland in years 1984 and 2018 with estimated area of 8,591 ha and 8,425 ha respectively; whereas bare land dominates the landscape in years 1995 and 2002 with estimated surface area of 12,550 ha and 5,439 ha respectively. It was also found that 40 bird species and 21 bird species among them are water birds in the wetland. Among aquatic animals recorded in Murago wetland; they are three species of fishes Nile Tilapia (*Oreochromis niloticus*), Common catfish (*Clarias gariepinus*), and Mamba (*Protopterus aethiopicus*). The four common plant species recorded in wetland are; *Papyrus, Typha latifolia, Ludwiga abyssinica, and Polygonum pulshrum*. water hyacinth was found to be the major cause of the reduction on the number of the biodiversity in Murago wetland ecosystem. The supporting services are the most provided by Murago wetland at the rate of 69.7%; and the services provided the least are cultural services at the rate of 56.3%.

it was revealed that Murago wetland is degraded by the overexploitation mainly the agricultural activities; and he rehabilitating activities include small scale irrigation water pump, tree plantation, dams, buffer zone marked with contour ditches, progressive terraces and trenches, agroforestry, bamboo around the buffer zone, trees planted by farmers in their agriculture land,

removal of water hyacinths, training to the famers, etc. Therefore, this study contributed on community livelihood improvement, climate change mitigation, and sustainable wetland management practices as the fulfillment of the core principles of EbA (Ecosystem-based Adaptation) approach.

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ABBREVIATIONS

REMA: Rwanda Environment Management Authority

RAB: Rwanda Agriculture Board

KII: Key Informant Interview

FGD: Focus Group Discussion

EbA: Ecosystem-based Adaptation

MINAGRI: Ministry of Agriculture and Animal husbandry

MoE: Ministry of Environment

NP: Number of Patches

PD: Patch Density

NRCD: National River Conservation Directorate

USDA: United Stated Department Agency

BACL: Bugesera Airport Company Limited

CHAPTER I. INTRODUCTION

This research presents a case study on Murago wetland ecosystem and its role to enhance climate-resilient to local communities in Rwanda. The research idea was building resilience of communities living in degraded wetlands in Rwanda, using EbA (Ecosystem-based Adaptation) approaches. The negative impact of human activities and natural hazards on Murago wetland ecosystem and provided services were not yet assessed or well monitored. Based on the increasing pressure of the riparian community of the Murago wetland contributing to wetland degradation and the climate hazards (floods and droughts), the degradation magnitude should be evaluated. The result of this study will be an important contribution to community livelihood improvement and sustainable wetland management practices.

1.1. BACKGROUND

Wetlands are important ecological zones that support the life of important fauna and flora through its water and its fertile soil. According to Ramsar (2016), wetlands are the areas of marsh, fen, peat-land or water, whether natural or artificial, permanent or temporary, with water that is static or flowing, fresh, brackish or salt, including areas of marine water, and the depth of which at low tide does not exceed six meters. Wetlands often serve as a transitional zone between dry lands and areas dominated by water, including ponds and rivers, oceans and estuaries, and their floodplains and tributaries wildlife (James et al., 2008). According to the same authors, the term “wetlands” encompasses a variety of landscape features that contain or convey water and support unique plants and wildlife.

The wetland covers almost 6% of the Earth’s surface area (Mharakurwa, 2016). From the existing inland and coastal marshes, the estimation of 56 to 65% of wetlands has been converted to intense agricultural production in Europe, 27% in North America, 6% in South America and 2% in Africa (Mooney et al., 2005). Global evaluation on the conditions of wetland species showed that the proportion of species endangered amongst them are at 17% of water fowl, 38% of fresh water species, 33% of fresh water fish, 26% of fresh water amphibians, 72% of fresh water turtles, 43% of crocodilians and 27% of coral reef-building species (Ramsar Convention Secretariat, 2013).

Wetland Ecosystems play an important role in protecting their environment from climate hazard and enhance the livelihood of its surrounding population. Lower catchment and floodplains wetland buffer contribute to the natural infiltration, filtration and purification (Bergkamp et al., 2000). Wetlands buffer play an intrinsic hydrological process against extremes such as flooding during rainy periods where wetlands absorb water and reduce flood risks; and droughts in the dry season where wetlands gradually release their water and ensure the availability of water (Nabahungu et al., 2011). According to the same author, wetlands and their surrounding catchments support rural livelihood through the provision of a large range of natural resources such as reed, fresh water, vegetables and wildlife.

Major services provided by wetlands are: carbon sequestration, flood control, groundwater recharge, nutrient removal, and toxics substances retention and biodiversity maintenance (Turner et al., 1997). According to (Mooney et al., 2005), wetlands' ecosystems goods and services cover the provisioning, regulating, support of biodiversity, and cultural values. Wetlands provide water, crop farming and livestock rearing, food, climate change regulation, supporting biodiversity and well-being of the surrounding community, and recreational services (Mharakurwa, 2016). Ecosystem goods provided by wetlands mainly include: water for irrigation, fisheries, non-timber forest products, water supply, and recreation (Bassi et al., 2014)

However, wetlands are constantly degraded/ encroached by anthropic activities. Human activities exercised into the wetland complex for livelihood dependency are the one negatively affecting the wetland. Those adverse actions include agriculture, urban development, and industrial use practiced in the buffer zones of wetlands and streams. These activities cause changes in the biological, chemical and physical properties of the wetland (Boyd, 2001). Also, these activities cause wetland degradation by changing water quality, water quantity, and water flow rates. There is also, increasing pollutant inputs (USDA–ERS, 2001).

In wetland management planning, it is strongly recommended to improve the management practices within the whole catchment area, because wetland is degraded by activities within its catchment area. The Land-use types such as residential developments, transportation and others provokes potential threats to the wetland from influences in the remainder of the catchment area, and that is why, when planning for wetlands management, you should take into account the wider management implications of activities within the catchments (Ramsar, 2010).Wetland management planning requires developing a list of activities to be regulated and permitted within the notified wetlands and their catchment area (GOI, 2017). Withdrawal of water or the impoundment, diversion or interruption of water sources within the local catchment area of the wetland ecosystem; are the activities needed to be regulated to ensure that they do not lead to an adverse impact on wetlands (NRCD, 2017).

Likewise, Murago wetland has typical wetlands characteristics and threats. The soil texture in Murago wetland is mainly clay to sandy loams. These soil types reduce water infiltration rates from 5-8mm/h (RAB, 2018). Murago catchment area has an average slope of 10% (RAB, 2018). The temperature recorded from Karama and Nyamata shows that the mean maximum temperature 27.08-29.17^{o}C and mean minimum temperature of 13.99-15.65^{o}C with September and July as the hottest and coldest months respectively (RAB, 2018). The mean annual rainfall of the Murago wetland is 892.7mm recorded from Karama, Nyamata and Ruhuha Station (RAB, 2018). Many times, the rainfall deficiency during season A (October-December), and frequent mid-season B (February-May) result in serious crop destruction and household food insecurity (RAB, 2018).

Different plant species are found in the Murago wetland. The vegetation types in wetland areas are characterized by aquatic vegetation (BACL, 2018). The dominant vegetation in Murago wetland is Typha (natural vegetation) and Fallow (Farms and Natural Vegetation) (REMA, 2009b). around the Lake Kamudeberi in Murago wetland *Papyrus Sedge* and *Cyperus papyrus* are dominating (BACL, 2018). Varying proportions of other species include grasses such as *Vossia cuspida* and Common Reed *Phragmites australis,* woody shrubs of *Mimosa pigra,* and locally ferns (BACL, 2018). Murago wetland plays the role of a stopper between the upstream lakes and rivers downstream (REMA, 2009b).

Different bird species are found in the Murago wetland. Little Grebe and Great Pelican are found in Murago birding sites (Jannu Chudal et al., 2018). Migrating bird species protected by CITES have been observed in Murago wetland on the lakeshore of Lake Cyohoha North (Léon, 2012). Eighteen birds species have been found in Kamudeberi Lake located in Murago wetlands including African Fish Eagle, African Jacana, African Marsh-harrier, Black Crake, Blackcrowned Night-heron, Black-headed Heron, Great White Pelican, Grey Heron, Hottentot Teal, Lesser Jacana, Long-toed Lapwing, Marsh Sandpiper, Rufous-bellied Heron, Sacred ibis, Squacco Heron, White-faced Whistling-duck, Yellow-billed Duck, and Yellow-billed Stork (C. Nsabagasani et al., 2008).

To tackle food insecurity in Murago wetland and/or much of the areas between wetland and bottomlands are dominated by cultivated farmland, mostly made by eggplants, tomatoes, onions, sweet peppers, maize and cabbages (RAB, 2018). In addition, that area is covered by a banana plantation, built-up area, coffee plantation, dams, a forest plantation, grass land, open agriculture, clay quarry, rice plantation and sugar cane plantation (Alain et al., 2016). Lake Kamudeberi, located in the wetland is dominated by fishing and duck hunting, and it is surrounded by agricultural lands (C. Nsabagasani et al., 2008).

Murago wetland is being degraded by natural product harvesting activities in the wetland. The most destructive is such as peat bog harvesting project which has drilled 18 drill hole of 4 meters depth each throughout Murago wetland extent (Alain et al., 2016). Harvested wild goods in Murago wetland are: wild fruits, wild vegetables, thatching grass, woven goods leaf litter, livestock fodder, wild animals, wild fish (Léon, 2012). At the Kamudeberi lake, unorganized and uncontrolled fishing may destroy young fishes and limit the breeding activity (C. Nsabagasani et al., 2008). As highlighted by (Alain et al., 2016), a considerable part of the Murago wetland is invaded by aquatic and invasive plants, mostly water hyacinth (*Eichhornia crassipes*).

In addition to human activities natural hazards such as food and sedimentation (due to slope, soil types and much rainfall), and droughts (due to frequent prolonged dry seasons with high temperatures, and less rainfall) exacerbated the destruction of the Murago Wetland Ecosystem. Therefore, some measures that have been taken to prevent severe events from happening. These measures include the creation of buffer zones of 50 meters around Murago wetland (RAB, 2018). To prevent local people to disturb the wetland, a small-scale irrigation project of 24 ha was established to support small-scale irrigation (RAB, 2018). There is also an ongoing project of restoration of Murago wetland by establishing a demarcation line, where bamboo and agroforestry trees were planted on the surface area of 34 hectares around the wetland (LDCF II, 2019).

1.2. PROBLEM STATEMENT

The soil erosion, sedimentation, and overexploitation of Murago wetland and its catchment including unsustainable agriculture, over-harvesting of resources, and deforestation affect the wetland integrity. The degradation of the Murago wetland ecosystem contributes to extreme weather events such as soil erosion, siltation, and heavy precipitation. The extreme weather events exacerbate the climates change hazards (floods and droughts). Flooding and droughts affect the production of the Murago wetland ecosystem. The over-exploitation of Murago wetland, the linking spillway of Akanyaru river and the Lake Cyohoha North, may lead to the drying of the wetland and disappearance of Lake Cyohoha North (REMA, 2009b). In our knowledge, the negative impact of those human activities and natural hazards on Murago wetland ecosystem and provided services is not yet assessed or well monitored. Therefore, based on the increasing pressure of the riparian community of the Murago wetland contributing to wetland degradation and the climate hazards (floods and droughts), the degradation magnitude should be evaluated. The assessment of that wetland status is the aim of this study. The result of our study will be an important contribution to community livelihood improvement and sustainable wetland management practices.

1.3. GENERAL OBJECTIVE

To assess the degradation status and the impact of management strategies of Murago wetland ecosystem to enhance the climate-resilient of the local communities.

1.3.1. SPECIFIC OBJECTIVES

1. To assess spatial and temporal land cover changes of Murago wetland ecosystem.
2. To assess the function and services provided by Murago wetland
3. To weigh the level of degradation of Murago wetland and its impact on the riparian communities
4. To evaluate the level of rehabilitation of Murago wetlands and its impact on the riparian communities (since the initial intervention)

1.3.2. RESEARCH QUESTIONS

The specific research question for the study are:

Q1: What were the main land covers/ land uses types within Murago wetlands and how they have been changing with time during the last three decades (1984-2018)?

Q2: What are the key functions and services provided by Murago wetland to riparian population?

Q3: What are the activities which contribute to the degradation of Murago wetland?

Q4: How much is achieved by Murago wetland rehabilitation initiatives?

CHAPTER II. LITERATURE REVIEW

People transformed wetlands due to the expansion of agricultural activities and the growth of cities (Ramsar Convention Secretariat, 2013). World wetlands are being lost and degraded, as economic development resulted in increasing pressure to drain and reclaim land for agriculture (Biswasroy et al., 2011). The wetlands were degraded by diverse activities such as agriculture, fire, and plant species overexploitation (Hategekimana et al., 2007). The example of floodplain resources in the Sahel which were under increasing pressure in the year 2000, due to droughts, increasing human population, livestock pressures and rising poverty and the pressures that led to overexploitation (Bergkamp et al., 2000).

People from the surrounding communities of wetlands in lower and upper catchments are interacting with wetlands in different ways (Mharakurwa, 2016). Lower level wetlands are being affected by man activities upstream such as dam construction, watershed mismanagement, and agricultural run-off; that changes flows and water quality in wetlands (Bergkamp et al., 2000). When wetlands are concentrated with siltation, excessive water provokes floods as it is spread and distributed in both sides of the wetlands (Biswasroy et al., 2011).

Sustainable use of wetland is defined as human use of wetland so that it may yield the greatest continuous benefit to present generations while maintaining its potential to meet the needs and aspirations of future generations (Farrier et al., 2000). Watershed management in flood plain wetland is very important as it improves the protection and restoration of wetlands (Biswasroy et al., 2011). The integrated wetlands management integrates catchment, land and water use management (Bergkamp et al., 2000).

Wetlands have been described as biological supermarkets because they support extensive food webs and rich biodiversity (Nabahungu et al., 2011). Therefore, the Rwandan government sees wetlands as providing an important niche for improving food security and income through the production of rice and other commodities (Nabahungu et al., 2013). Apart from their exceptional biodiversity, wetlands in Rwanda provide a range of services that are more important to different economic sectors such as energy, water, agriculture, culture and tourism (Karame et al., 2017). Apart from harvesting and processing the present natural resources, wetland use also includes cultivation and livestock grazing and watering (Nabahungu et al., 2011).

Once wetlands are not disturbed, these ecosystems play an important role in cleaning waters (Bizuru et al., 2016). Plants in wetlands can retain nutrients, sediments and fertilizers applied on hillsides and even converted marshlands to rice cropping (Bizuru et al., 2016). Wetlands are considered water towers or earth kidneys due to the role they play in conserving and filtering water resources (Hategekimana et al., 2007).

In Rwanda, 165,000 ha of wetlands that have been developed, only 5,000 ha have been developed according to environmental and water management regulation (MINITERE, 2003). Wetlands in Rwanda cover 10.5% of the country's surface, in which 20%, 74%, and 6% of the wetland area are protected, under conditional use for agriculture; and under non-condition category (REMA, 2008). Most of the wetlands in Rwanda are being reclaimed under government schemes to grow rice as the main crop (Nabahungu et al., 2013).

Before the colonial period in Rwanda, the role of wetlands was unknown because they were considered as marginal land, and Since the 1980's, the consideration has changed to land reserve as the response to demographic pressure at the time (Hategekimana et al., 2007). Till the civil violence and mass refugee flows, Rwanda had a high population density and growth rate (Percival et al., 1998). From 1980 to 1994, wetlands agriculture was encouraged to produce food to achieve self-sufficiency (Nabahungu et al., 2013). Wetland agriculture used to be a response to food and fodder shortages during the dry season in Rwanda (Nabahungu et al., 2013).

Chemical fertilizers and pesticides have been increased for modernization and increase of agriculture production in Rwanda (Bizuru et al., 2016). The existence of natural wetlands has been threatened by unsustainable development activities such as the intensification of agriculture within wetlands, or the complete conversion of wetlands (Karame et al., 2017). The water quality of wetlands is polluted by fertilizers' farmers (Mharakurwa, 2016). The major causes of losses in the development of different forms of infrastructure, industrial effluent pollution, pollution from agricultural runoff, as well as climate change and variability (Bassi et al., 2014).

Wetland ecosystems in Bugesera have been reclaimed because of different reasons including; a natural increase of population, massive repatriation after the 1994 genocide, degradation of uplands, and rainfall irregularity coupled with agriculture transformation… tremendous wetland reclamation for water development projects such as irrigation of rice, vegetables etc.

Environmental degradation caused by massive population displacements caused serious economic losses to the whole country (Moodley et al., 2011). There have many refugees and returnees in the post-genocide camps and resettlement plots, increased competition, and reliance on the natural environment for basic needs (REMA, 2009a). Farmers have taken on some measures such as the construction of water reservoirs for irrigation use in the dry season, switching new varieties of rice that resist drought and flooding, and application of pesticides to combat pests due to serious floods of 1997-1998 and a prolonged drought of 1999-2007 resulted from the variability in rainfall frequencies and intensity (Gaspard et al., 2013).

On the steepest slopes, heavy rainfall eroded more than eleven tons of soil per hectare per year (Percival et al., 1998). Forest and woodlands have been put under pressure; the example of Nyungwe and Akagera National Forests area reduction after the genocide (REMA, 2009a). Half of the farming in Rwanda occurred on hillsides with slopes of more than 10%; these areas were vulnerable to erosion, under conditions of intense cultivation (Percival et al., 1998).

Forestry and water scarcity were also serious. Forests cover only 7% of the country (Percival et al., 1998). From 1986, 91% of wood consumption was for domestic use, and farmers replaced animal and crop wastes for scarce fuelwood (Percival et al., 1998). The government of Rwanda started a reforestation campaign of planting eucalyptus trees, which consume large amounts of water and nutrients (Percival et al., 1998). Water resource were constrained as watersheds and wetlands were lost (Percival et al., 1998). By the late 1980s, environmental scarcity caught up with Rwandan agriculture (Percival et al., 1998). The ability of food production decreased while population growth was stressing (Percival et al., 1998).

In 2001, MINAGRI developed a masterplan of marshlands development, soil conservation and watersheds protection (Hategekimana et al., 2007). In May 2003, the same Ministry did a study that came up with a classification of wetlands of international importance classified as Ramsar sites and in 2005, the government of Rwanda ratified the Ramsar Convention on wetlands (Hategekimana et al., 2007).

For better management of wetlands to cultivate wetlands, farmers have to look for authorization from the district authority. According to the law determining the use and management of marshlands in Rwanda, wetlands are publically owned, whereas the uplands are privately owned

(REMA, 2009b). They are allowed to cultivate only if they follow the cultivation protocol from the local government (Nabahungu et al., 2013).

CHAPTER III. METHODOLOGY

3.1. STUDY AREA DESCRIPTION

Murago wetland is located in Eastern Province, Bugesera District at the latitude of 2° 13.836'S and longitude of 30° 1.820'E. This wetland touches 17 Villages of Musenyi, Shyara and Mareba Sectors intersecting Murago wetland ecosystem.

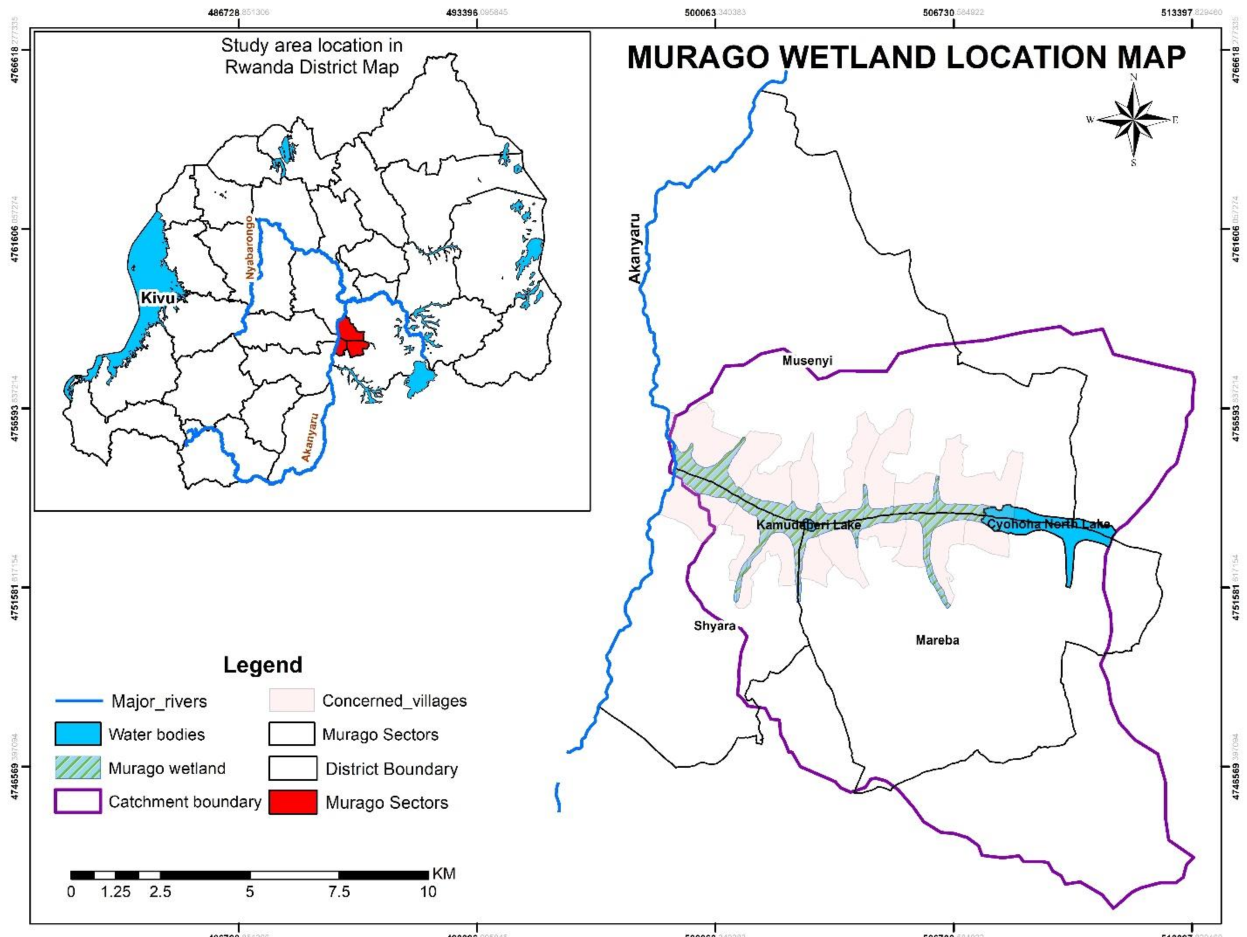


Figure: 1. Location map of Murago wetland in Rwanda and its catchment areas

Murago wetland has two parts in terms of use; one part located in the upper part near the Lake Cyohoha North is considered to be fully protected and the second one in the lower part, near Akanyaru River is used under conditions. The total surface area is estimated at 798.64ha (REMA, 2009b).

According to the (NISR, 2012) Report, the population size of Mareba, Musenyi and Shyara Sectors, are 22,377; 29,248; and 13,390 respectively. In total there are around 65,015 of the population who utilize Murago wetland ecosystem to generate income in their daily life.

A total of 111 bird species gathered in 38 families were recorded in Kinyovi, Nyirantuntu, Murago waterway and waterbirds of Kamudeberi Lake (C. Nsabagasani et al., 2008). A total of 15 wetland plant species have been recorded in different wetlands of the western part of the country including, Gashanga, Kidogo, Rumira and Murago (BACL, 2018).

Within Murago wetland, there are different socio-economic activities such as the cultivation of rice, harvesting of grasses for livestock farming, small-scale irrigation water pumps and fishing activities. Around the wetland in the buffer zone and upper catchment is the cultivation of vegetables, tomatoes, onions, carrots, banana, fishes, fetching water, grasses for livestock farming, cabbages, eggplants (Intoryi), sugarcane, reeds (Urubingo), avocadoes, mangoes, and the fresh water fetching. Moreover, other intervention activities that have been put in place as tree plantation, dams, buffer zone marked with contour diches, progressive terraces and trenches, agroforestry, bamboos around the buffer zone, trees planted by farmers in their agriculture land, removal of water hyacinths, trainings to the famers, etc.

3.2. DATA COLLECTION

The mixed-method evaluation of status and management Murago wetland ecosystem involved a sequential explanatory study design of both quantitative and qualitative research. This study has collected quantitative data to assess function and services by the wetland, and the analysis of maps and images to track the historical changes of the wetland landscapes with explanation of qualitative data to understand socio-economic and wetland status. To respond to the research question and its corresponding research objectives two types of data were collected as follows: Primary data were collected using 5 data collection methods including, field rapid assessment survey, a questionnaire administered using survey, Key Informant Interview (KII), Focus Group Discussion (FGD) and Secondary data analysis using GIS technology to produce and to analyze feature of wetland land cover changes on maps.

A number of hundred (100) respondents participated in three meetings organized in concerned sectors. However, the data collection was done with the intermediate help of the local leaders due to the COVID-19 pandemic. Two assistant researchers were used, one with a background in GIS and another in Biology.

3.2.1. Desk-based data gathering

3.2.1.1. Spatial data collection: vector and raster

To detect significant land cover changes, satellite images have been chosen in four different periods starting from 1984 to 2018. The images were selected based on a minimum number of 7 bands to easily identify different land cover classes such as grassland, water, bare land and built-up area.

All images were downloaded from the United States Geological Survey (USGS) resource repository (https://earthexplorer.usgs.gov/). Moreover, they were originally downloaded in separate files, were first stacked, thus assembling the bands into a single TIFF file. The first image was Landsat-5 acquired on 20th June 1984, the second one was Landsat-7 acquired on 23rd September 1995, the third is Landsat-8 acquired on 17th August 2002, and the last one is Landsat-5 acquired on 20th July 2018. Selected bands for land cover classification includes visible (red, green and blue) and infrared (one near-infrared and two short-wave infrared bands). All images classified were acquired with 30m resolution and projected in Universal Transverse Mercator (UTM) with WGS-84 datum.

The images between June (the beginning dry season) and September (the end of the dry season) are assumed to have the same spectral radiance since they are almost having the same cloud-free. The first image of 1984 has been assumed to be the image captured when the situation has not yet been aggravated in Murago wetland, while the satellite imagery of 1995 has been considered to be the period where the situation has been worsened. The satellite imagery of 2002, is the image representing when the situation started to be improved during the imidugudu settlement program where the government of Rwanda resettled the people from high risks zone such as wetlands and high slopes terrain to village site settlements. The image of 20018, is the one representing the situation in Murago wetland after intervention activities in the place.

A cross-check of the corresponding landscape features was performed by referring to Google earth data using the time slider tool. A supervised classification was performed using QGIS 3.4. For each of the four images, four land cover classes were determined including; grassland, water, bare land, and built-up area.

3.2.2. Field work preparation

3.2.2.1. Study areas delineation and sampling design

Murago catchment has been delineated and digitized using Rwanda topographic map in the background, to know the extent of the study area boundary.

To get the sample size in the survey, we used simple random sampling to give equal chances for all in the study area. According to the (NISR, 2012) Report, the population size of Mareba, Musenyi, and Shyara Sectors are 22,377; 29,248; and 13,390 respectively. The number of cells in Mareba, Musenyi, and Shyara Sectors is 5, 4, and 5 Cells respectively. The total population size in the three sectors is 65,015.

As proposed by (Sekaran ,2010), where it is suggested that to cover a large area, the sample size should be large than 30 and less than 500, which would be appropriate for our large study area. To complete the questionnaire, face to face interview has been used, because the interest or motivation of the respondents may be too low and this may hamper the research in general.

The sample size has been selected purposively from the population size of 65,015 inhabiting 14 Cells of Mareba, Musenyi and Shyara Sectors. Specifically, people who had their cattle, fishing and farming activities in and around Murago wetland before and after the restoration activities were selected. The age limit was over 40 years old, who have been living around Murago wetland since1984 to date. The recognition of the ethical standard which involves the respect of vulnerable population and voluntary participation of the respondents was taken into consideration. Therefore, a total of 100 respondents fulfilling the above conditions participated in the study.

3.2.2.2. Questionnaire design

Two sets of questionnaires were designed for field observation and interview. A quantitative questionnaire targeted hundred people in 17 Villages intersecting Murago wetland ecosystem were interviewed. In each Village, around five to six people were respondents. As the inclusion criteria, all people above 18 years old, living in concerning Sectors and precisely in all 17 Villages intersecting Murago wetland ecosystem and its catchment. A field rapid assessment questionnaire has been designed to record key biodiversity species within Murago wetland as key indicators for climate change. The two questionnaires are attached in the appendices part.

3.2.2.3. Checklist for KII and FGD

The KII checklist and Questionnaire you used, was validated after a (long) process: the draft zero has been developed referring to services and functions provided by Murago Wetland, degrading and intervention activities in Murago Wetland Ecosystem. The elaborated questionnaires were reviewed and approved by the supervisors. The corrected questionnaires were pre-tested at a pilot project, and then adjusted. The adjustment version that was used for data correction are shown in annexes II & III.

3.2.3. Field Data Collection

3.2.3.1. Field Observation

The observation was done using a field rapid assessment survey. We used this technique to record vegetation and animal species using wetland monitoring form. Via a curved line transect, we walked along Murago wetland observing and recording data using tools such as a camera and GPS to collect both photos and geographical coordinates respectively. To get enough data, the field observation has been done within four days, twelve hours a day.

3.2.3.2. Questionnaire survey

Questionnaires were administered during field surveys and were conducted in three sectors of Mareba, Musenyi, and Shyara Sectors covering the study area. The 100 study participants were answering questions based on services and functions provided by Murago wetland ecosystem.

3.2.3.3. Conduct of Key Informant Interview (KII) and FGD

The interview has been conducted on different key informants' categories: central and local government institutions, one professional from Rwanda Environment Management (REMA), One from Rwanda Agriculture Board (RAB), two district-level professionals (Bugesera District Environmentalist and District Director of Agriculture and Natural Resources) and Agronomists from Mareba, Musenyi and Shyara sectors. In total 12 key informants have been selected purposively and interviewed. The interview guide was drafted based on degrading and intervention activities in Murago wetland ecosystem to evaluate and to analyze if Murago wetland is under pressure.

The consultation using Focus Group discussion (FCD), in two groups of 15 peoples each, from two farmers' cooperatives members and executive committee, where I was a facilitator with an observer who recorded the conversation. The participants were the members of the cooperatives Umucyo and Isano located in the study area where their agricultural activities are based in and around the wetland. The FGD guide was helping to prompt question to trigger participants to provide the functions and services provided by Murago wetland. By helping them to develop the problem tree, where I have been able to ask them to tell me the core problem, its root causes, and the effects. After developing the problem tree, the participants have been asked to propose mitigation measures to protect Murago wetland environment while ensuring that the contribution of the wetland to the socio-economic development of the neighboring community. Thereafter, the meeting helped to identify activities which degrade Murago wetland, and prioritize the activities that rehabilitate or protect of Murago wetland environment.

3.3. DATA ANALYSIS

3.3.1. Remote Sensing data analysis

Using land sat images, we have been able to detect the level of changes in land cover. The selected metrics are used and together provide comprehensive means and describing the landscape. Indices such as Class Area (CA), Number of Patches (NP), and Patch density (PD) are useful for quantifying the number and amount of habitat types and, thus, characterizing class dominance and composition in the landscape. Landscape configuration can be assessed by using the Total Edge Contrast Index (TECI), Contrast-Weighted Edge Density (CWED), Landscape

Shape Index (LSI) and Aggregation Index (AI) given that these indices were judged suitable for characterizing spatial arrangement of landscape habit types (McGarigal et al., 2002).

LM INDEX	DESCRIPTION	UNIT
I. Landscape composition		
Class Area (CA)	Sum of the areas of all patches of the corresponding patch type	Ha
Number of Patches (NP)	Number of patches of the corresponding patch type	None
Patch Density (PD)	Number of patches of the corresponding patch type divided by total landscape area.	Number/ 100 Ha
Largest Patch Index (LPI)	Area of the largest patch of the corresponding patch type divided by total landscape area(m2) multiplied by 100.	%
II. Landscape configuration		
Total Edge Contrast Index (TECI)	Sum of the lengths of each edge segment involving the corresponding patch type multiplied by the corresponding contrast weight, divided by the sum of the lengths (m) of all edge segments involving the same type.	%
Contrast Weighted Edge Density (CWED)	Sum of the lengths of each edge segment involving the corresponding patch type multiplied by the corresponding contrast weight divided by the total landscape area.	m/ha
Landscape Shape Index (LSI)	LSI equals 0.25 (adjustment for raster format) times the sum of the entire landscape boundary and all edge segments within the landscape boundary involving the corresponding patch type, divided	none

	by the square root of the total landscape area.	
Aggregation Index (AI)	AI equals the number of like adjacencies involving the corresponding class.	%

Table: 3. Landscape Metrics Index (Mugiraneza et al., 2019)

Landscape metrics were derived from FRAGSTATS version 4.2.1, a spatial pattern analysis program for quantifying landscape structure (McGarigal et al., 2002). The landscape patterns were computed and analyzed at class and landscape levels. In total, eight indices were generated for characterizing the study area's land scape evolution between 1984 and 2018.

Spatial-temporal land cover change dynamics are most of the time coupled with fragmentation and conversion of existing land cover. Indices such as CA, NP, and PD are useful for quantifying the number and amount of habitat types, and thus characterizing class dominance and composition in the landscape. Landscape configuration can be assessed by elucidating TECI, CWED, LSI and AI given that these indices were judged suitable for characterizing spatial arrangement of landscape habitat types. The level of fragmentation is easily tracked by counting the change in the number of patches. The landscape is assessed by examining the patch dominance between two timespan periods.

3.3.2. Field Data (Observations, KII, FGD) Analysis

Excel sheet and SPSS 16.0 software have been used to calculate and analyze frequencies of ecosystem services, mean and standard deviation after determining the skewness of data, which means that data were normally distributed. Through walking, a number of animal and vegetation species observed has been counted and enumerated. The transcripts were analyzed to find out common themes related to the degradation and rehabilitation of Murago wetland ecosystem. With an irritated process while reading transcripts and responses, the team managed to identify the main issues behind Murago wetland degradation.

This study recognizes the ethical standard which involves the respect of vulnerable populations and voluntary participation of the respondent. To make sure that this was fulfilled informed consent was given to each eligible participant within our sample size.

CHAPTER IV. RESULTS

4.1. SPATIAL-TEMPORAL LAND COVER TYPES DISTRIBUTION AND THEIR CHANGE

The generated land cover maps are visually portraying the increase and decrease in bare land and built-up. The most difficult classes to distinguish were bare land and built-up as they are confused. Whereas the contrast between grassland and bare land is satisfactory. After summarizing the classification results, landscape metrics results are presented at the landscape level and class level.

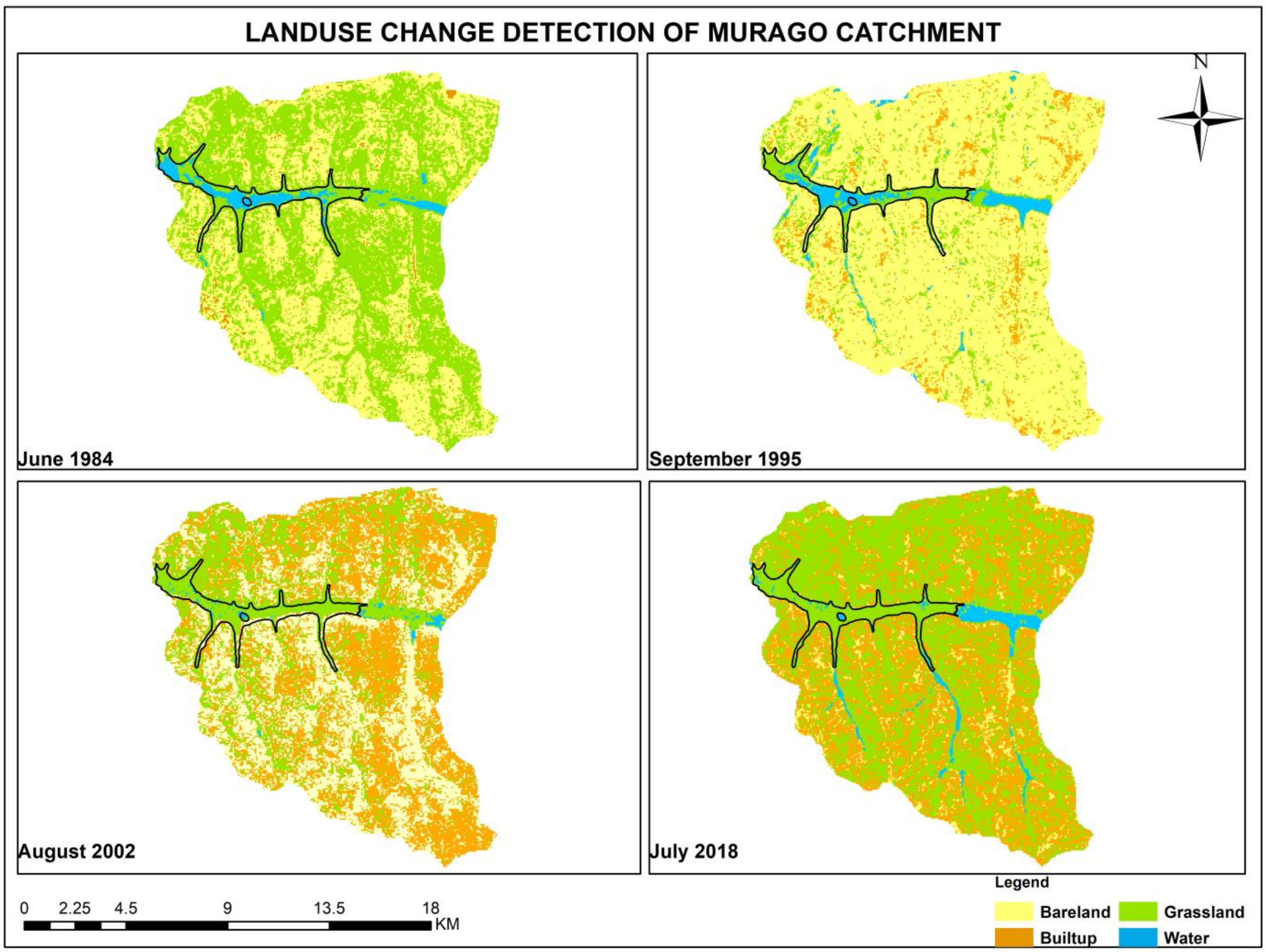


Figure: 4. Murago catchment classified images

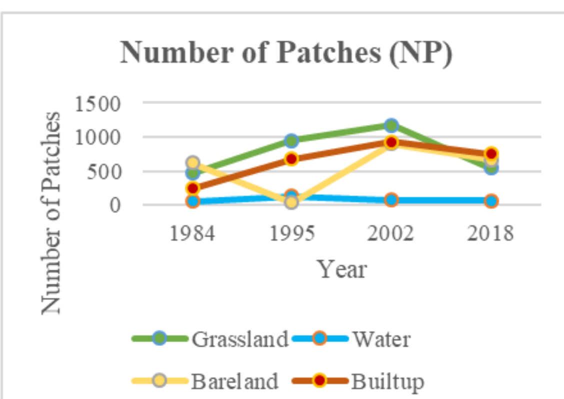
These maps are presenting four land cover classes including grassland, water, bare land, and built-up. Generally, all land cover classes have known a period of increase and decrease. Grassland has decreased from 1984 to 1995, whereas from 1995 to 2018 has continuously increased. Water in wetland and lakes decreased to disappear in 1995, while from 2002 to 2018 water has known a significant increase. Bare land and built-up have had a high level of similarity in spectral radiance, thus, both of them have known a confusion in their classification. From 1984, bare land and built up has greatly decreased, whereas, from 2002 to 2018, bare land and built up has decreased in size.

Table: 1. Land cover class area and net change percentage

Land cover class	Land cover class area in (ha)				Net change in (%)			
	1984	**1995**	**2002**	**2018**	**1984-1995**	**1995-2002**	**2002-2018**	**1984-2018**
Grassland	8591.456	1874.5185	4028.909	8424.716	-78.1816	114.9304	109.1066	-1.94076
Water	406.9289	52.59791	95.3794	421.5491	29.25577	-81.8663	341.9708	3.592814
Bareland	6696.4	12550.397	5438.714	6193.047	87.42008	-56.665	13.86969	-7.51676
Builtup	186.2335	935.3447	6329.85	838.2248	402.243	576.7399	-86.7576	350.0935

The total area of Murago catchment is estimated at 15, 881 ha. The landscape is dominated by grassland in years 1984 and 2018 with an estimated area of 8,591.456 ha and 8,424.716 ha respectively; whereas 1995 and 2002, the grassland has been reduced with an estimated area of 1874.5185 and 4028.909 ha respectively.

Bare land dominates the landscape in years 1995 and 2002 with an estimated surface area of 12,550.397 ha and 5,438.714 ha respectively, while in 1984 and 2018, bare land was small in size with estimated surface area of 6696.4 and 6193.047 ha respectively.



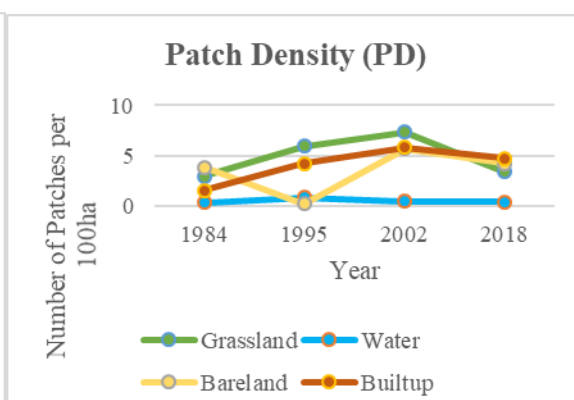


Figure: 5. Number of Patches, Patch Density, Largest Patch Index, Landscape Shape Index, Total Edge Contrast Index, Contrast Edge Weighted Index, and Aggregation Index

4.2. FUNCTION AND SERVICES PROVIDED BY MURAGO WETLAND AS PERCEIVED BY RIPARIAN POPULATION

Ecosystem services provided by wetlands are; provisioning, regulating, cultural, and supporting services. Frequencies and percentages in the table below are the results of 100 respondents who answered the questionnaire during the interview.

Table: 2 Frequency table

	Provision		**Regulation**		**Culture**		**Support**		**Overall ecosystem services**	
Responses	**Freq.**	**%**	**Freq.**	**%**	**Freq.**	**%**	**Freq.**	**%**	**Freq.**	**%**
Yes	764	57.7	1726	59.0	1182	41.2	391	69.7	4063	56.9
No	542	40.9	1189	40.6	1615	56.3	150	26.7	3496	41.1
Not sure	19	1.4	12	0.4	72	2.5	20	3.6	123	2.0
Total	**1325**	**100**	**2927**	**100**	**2869**	**100**	**561**	**100**	**7682**	**100**

In provisioning services, 57.7% of all respondents confirmed that provisioning services are available, 40.9% of respondents approved the absence of the service, while 1.4% were not sure whether provisioning services are present or not. In regulating services, 59 % of respondents answered yes to confirm the presence of regulating services, 40.6% answered no to disapprove of the presence of regulating services in Murago wetland, and 0.4% of respondents doubted on the presence of regulating services. In cultural services, 41.2% of respondents said cultural services are present 56.3% of respondents said that there are no cultural services while, 2.5% were not sure whether cultural services are present or not. In support services, 69.7% of interviewees responded yes on the presence of support services, while 26.7% answered no on the absence of regulating services and lastly, 3.6% of all respondents were not sure whether supporting services are present or not.

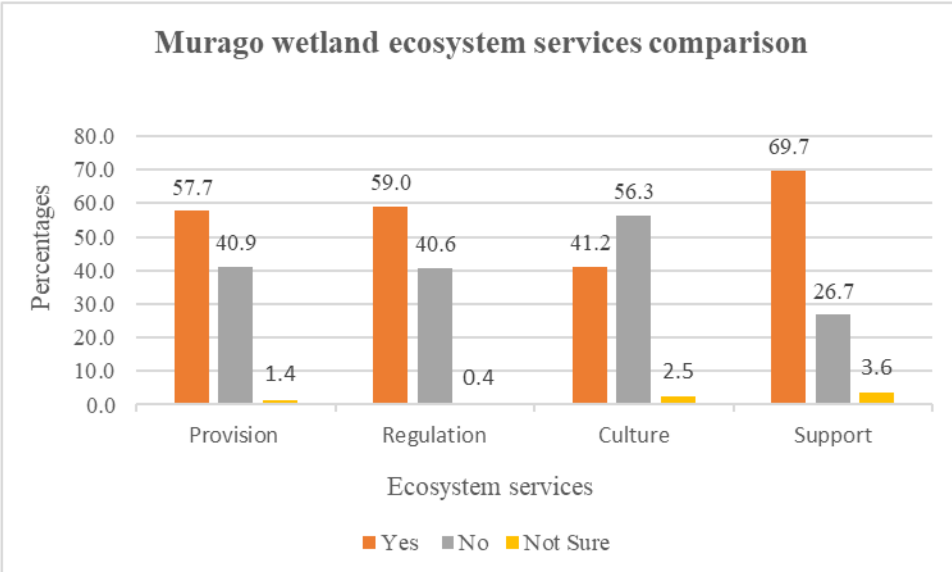


Figure: 6. Murago wetland ecosystem services comparison

Briefly, the results from respondent show that supporting services are provided the most in Murago wetland at the rate of 69.7%; and the services providing the least are cultural services at the rate of 41.2% of all respondents.

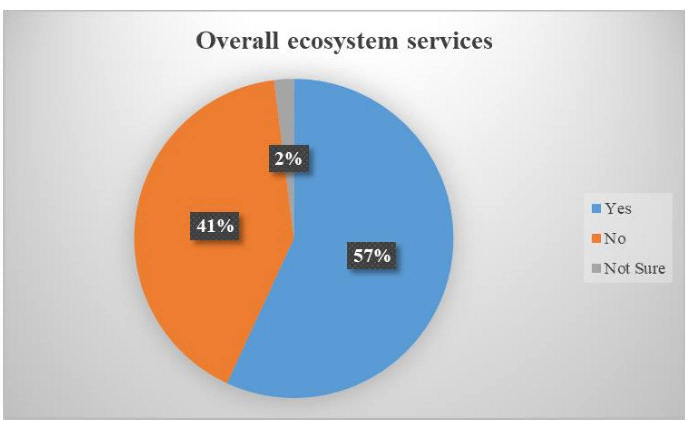


Figure: 7. Murago wetland overall ecosystem services

For overall ecosystem services in Murago wetland, the result shows that all of the services provided by Murago wetland are available at the rate of 57% of yes respondents and not provided at the rate of 41% of all respondents who answered no response and 2% were not sure of the answers for the questions asked.

Table. 3. Statistics of responses

	Overall **Yes**	Overall **No**	Overall **Not sure**
Mean	40.6300	34.9600	1.2300
Std. Deviation	7.60470	8.29618	2.74820
Minimum	24.00	11.00	.00
Maximum	62.00	53.00	20.00

The mean and standard deviation for yes and no responses showed that the results are normally distributed while mean and standard deviation for not sure responses results are not normally distributed.

The Focus Group Discussion (FGD) has been conducted with two cooperatives; UMUCYO cooperative for farmers and ISANO cooperatives for fishing practices. Murago wetland is a water regulator that stores water and irrigates its buffer zones. Water from the wetland is used for irrigation mostly in agricultural activities such as irrigation of rice, maize, vegetables and so forth. Also Murago wetland water is used for building construction, livestock farming and sometimes for domestic use. Before 1994 the genocide against Tutsi in Rwanda, there were planted natural vegetation *such as Typha latifolia and cyperus Papyrus* in the Murago wetland. After the genocide people cultivated sweet potatoes and colocasia. The government sensitizes the people to gather themselves in cooperatives to cultivate Murago wetland.

One part of the wetland is cultivated while the other is prepared for future cultivation. In 2007, the Umucyo cooperative has been founded and in the same year, they harvested 12 tons of maize.

Natural materials such as *Typha latifolia* and *Cyperus papyrus* are being harvested in the wetland to use them as organic manure and food for livestock. Fiber harvested within the wetland is used for the handcraft of mats. *Cyperus papyrus* is used to make baskets.

Murago wetland serves thousands of its surrounding population. In December 2012 and 2014, flash flooding and drought happened respectively in the area and caused the famine. The Vice Mayor of Bugesera District at that time advised cultivating sweet potatoes as a quick response to the famine. Seventy (70) hectares of rice and sixty (60) hectares of vegetables have been cultivated. There were only two seasons, season C where they grow maize and season B where they grow fruits and vegetables. Nowadays, there is season A where they grow rice in the wetland and beans around the buffer zone, season B where they grow rice in the wetland and eggplant (*Solanum melongena*) around the buffer zone, and Season C where they grow maize in the wetland and tomatoes around the buffer zone. Fishes are the main animal products being harvested in Murago wetland. Pests that appeared to be in Murago wetland are snakes, mice, mosquitos and so forth.

Conflict of interests and overlapping responsibility between government institutions (REMA, RAB, and so forth). The law confirms that the wetland can be used for agriculture purpose, only grazing is prohibited. The wetland buffer zone should be used for the interest of both REMA and MINAGRI. There is a joint planning at national level including concerned Institutions such as REMA, Ministry of Environment, RAB, and MINAGRI.

In 1999-2000, Cyohoha North Lake disappeared as well as agriculture practices due to unsustainable use of the Murago wetland ecosystem. After restoration activities such as planting trees and water Hyacinth removal in 2000-2004, the rainfall rebuilt the lake. The whole wetland has been proposed to be fully protected. Murago wetland should be the continuity of Cyohoha North Lake and Akanyaru River.

On the field survey we used a field rapid assessment to collect the data that is why we assessed and focused on a small portion of species like fishes, and birds which are key indicators for the effectiveness of habitats. Forty bird species were recorded and a total of 137 individuals among them 21 bird species are water birds. Among animals recorded in Murago wetland; three species of fishes Nile Tilapia (*Oreochromis niloticus*), Common catfish (*Clarias gariepinus*), and

Mamba (*Protopterus aethiopicus*). Also some butterflies, reptiles, and insects have been recorded. The four common plant species recorded in the wetland are; *Papyrus papyrus, Typha latifolia, Ludwiga abyssinica, and Polygonum pulshrum*. Water hyacinth was found as threats to wetland.

Figure 8: African Jacana, a bird species found in Murago wetland

Murago wetland provides different ecosystem services: in terms of service provision the fresh water and food products in and around Murago wetland: rice, vegetables, tomatoes, onions, carrots, banana, fishes, fetching water, grasses for livestock farming, cabbages, eggplants (Intoryi), sugarcane, reeds (Urubingo), avocadoes, mangoes, etc. Murago wetland provide regulation services such as pollination. In cultural services there are opportunities for formal education such as researchers and training for local farmers.

Figure: 9. Murago wetland the source of fresh water on the left side and eggplants field on the right side (Photo caption: Author)

4.3. THE MOST DEGRADING ACTIVITIES

The Focus Group Discussion (FGD) revealed that the Murago wetland is degraded by overexploitation mainly the agricultural activities. Through MoU signed in 2006 between the district and farmers' cooperative Umucyo; the agreement says that the cooperative has the right to use all Murago wetland area for agricultural practices.

The government expropriated people's agricultural activities from the wetland buffer zone without any other alternatives as to the replacement for their daily activities, and this has been always pushing them to return to practice the same activities in the buffer zone. According to the District Director of Agriculture and Natural Resources, the government failed to prevent people from cultivating in the buffer zone; as surrounding communities are used to waking up early in the morning, they cultivate and sow. In Rwandan culture, you can't remove what has been sowed because it is considered as making pollution. Using chemical fertilizers in few years, the fertile soil is being degraded and change into dust.

Figure: 10. Agricultural activities in the buffer zone at the left side and Gullies observed in the catchment at the right side (Photo caption: Author)

Through the field observation, different threats to the wetland have been observed and recorded such as the cultivation of the buffer zone, harvesting different types of vegetation in the wetland, gullies in the catchment, no rain water harvested, inundation, water pollution by agriculture activities, lack of sufficient drainages, etc.

Figure: 11. The destructed road connecting Shara Sector and Musenyi Sector (Photo caption: Author)

The District Director of Agriculture and Natural Resources said that a Chinese company tried to construct the feeder road connecting Shyara Sector and Musenyi Sector through Murago wetland. One day after the completion of the road, the water cleared sediments and rocks that have been put under water to support it.

4.4. WETLAND REHABILITATION STATUS

After a long time of degrading activities in Murago wetland, intervention activities have been started for its restoration. The rehabilitating activities include small scale irrigation water pump, tree plantation, dams, buffer zone marked with contour ditches, progressive terraces and trenches, agroforestry, bamboos around the buffer zone, trees planted by farmers in their agriculture land, removal of water hyacinths, training to the farmers, etc.

In 2019, interventions have been started in Murago catchment to protect Murago wetland ecosystem. Stakeholders provide diverse support, local government provides support through advises; RAB provides selected crops to the farmers, and WFP looks for clients such as FATUMA and MAYANGE RICE to buy yields. Pepper is using organic farming (roasting) and it lasts for a longtime but it helps farmers and Murago wetland protection. Organic farming is not sufficient for all people. REMA also provides fish seedling and looks for markets to provide fish products. Cooperative ISANO of Fisher-men took initiatives of removing *Typha latifolia* and water hyacinth *(Eichhornia crassipes)* from Murago wetland.

REMA started with planting agroforestry trees such as *Markamia lutea*, avocado (*Persea gratissima*), *Grevillea robusta*, cassiya (*Cassia spectabilis*), and bamboos in Nyagihunika, Gitagata, and Mayange Cell of Musenyi Sectors. RAB provides agroforestry trees (fruits), such as mangos *(Mangifera indica)*, and papaya *(Carica papaya)* trees. There have been sensitization and training of farmers on the modern agroforestry plantation activities. HIMO planted trees in the government forests. Communities in Murago catchment started planting trees in their land parcels

Figure: 12. Dams for Small Scale Irrigation Schemes in the upper catchment of Murago wetland (Photo caption: Author)

Water pump and small-scale irrigation schemes have been put in place to protect the Murago wetland ecosystem. There are water pumps machines in Rugarama and Gasagara for small-scale irrigation. For food security and environmental control, more than three hundred (300) solar panel machines have been provided by REMA for small-scale irrigation.

CHAPTER V. DISCUSSION

5.1. MURAGO LAND-COVER CHANGE

In 1984, the landscape is dominated by grassland with an estimated area of 8,591.456 ha. Bare land was small in size with an estimated surface area of 6696.4 ha. Grassland has decreased from 1984 to 1995. Water in wetland and lakes decreased to disappear in 1995.

Before the colonial period in Rwanda, the role of wetlands was unknown because they were considered as marginal land, and Since the 1980's, the consideration has changed to land reserve as the response to demographic pressure at the time (Hategekimana et al., 2007). Till the civil violence and mass refugee flows, Rwanda had a high population density and growth rate (Percival et al., 1998). From 1980 to 1994, wetlands agriculture was encouraged to produce food to achieve self-sufficiency (Nabahungu et al., 2013). From 1986, 91% of wood consumption was for domestic use, and farmers replaced animal and crop wastes for scarce fuelwood (Percival et al., 1998).

In 1995, the grassland has been reduced by an estimated area of 1874.5185. Bare land dominates the landscape with an estimated surface area of 12,550.397 ha. From 1995 to 2018 grassland has continuously increased. Rwanda was ravaged by civil war, genocide, mass migrations, economic crisis, diseases, return of refugees and environmental destruction (Moodley et al., 2011). The genocide in Rwanda destroyed human resources, social and cultural structure, development facilities and natural resources which had acute consequences on the environment (Moodley et al., 2011). There have been many refugees and returnees in the post-genocide camps and resettlement plots, increased competition and reliance on the natural environment for basic needs (REMA, 2009a).

Environmental degradation caused by massive population displacements caused serious economic losses to the whole country (Moodley et al., 2011). The government focused on the resettlement of people by making land available (Moodley et al., 2011). Forest and woodlands have been put under pressure; the example of Nyungwe and Akagera National Forests area reduction after the genocide (REMA, 2009a). Forestry and water scarcity were also serious.

Forests cover only 7% of the country (Percival et al., 1998). Water resource were constrained as watersheds and wetlands were lost (Percival et al., 1998).

The government of Rwanda started a reforestation campaign of planting eucalyptus trees, which consume large amounts of water and nutrients (Percival et al., 1998). Since 1992, the Bugesera district has been characterized by a declining trend with a remarkable variability in rainfall frequencies and intensity which resulted in serious floods in 1997-1998 and a prolonged drought in 1999-2000 (Gaspard et al., 2013).

In 2002, the grassland has been reduced by an estimated area of 4028.909 ha. Bare land dominates the landscape with an estimated surface area of 5,438.714 ha. From 2002 to 2018 water has known a significant increase whereas from 2002 to 2018, bare land and built up has decreased in size. Bugesera district has been seriously hit by the drought from 1999 to 2007, and the whole area would dry for almost six months every year (Gaspard et al., 2013). The onsets and offsets of the rainfall patterns were no longer predictable due to the irregularity of rainfall every year (Gaspard et al., 2013). In 2001, MINAGRI developed a masterplan of marshlands development, soil conservation and watersheds protection (Hategekimana et al., 2007). In May 2003, the same Ministry did a study that came up with a classification of wetlands of international importance classified as Ramsar sites and in 2005, the government of Rwanda ratified the Ramsar Convention on wetlands (Hategekimana et al., 2007).

The landscape is dominated by grassland in the year 2018 with an estimated area of 8,424.716 ha. Bare land was small in size with an estimated surface area of 6193.047 ha.

Rwanda’s government started to think of intervention within Murago wetland ecosystem. According to the law determining the use and management of marshlands in Rwanda, wetlands are publically owned (REMA, 2009b). This means that to cultivate wetlands, farmers have to obtain authorization from the district authority (Nabahungu et al., 2013), and they are allowed to cultivate only if they follow the cultivation protocol from the local government (Nabahungu et al., 2013).

Restoration of Murago wetland by demarcation line, bamboo and agroforestry plantation (Prog et al., 2019). The creation of buffer zones of 50 meters around Murago wetland (RAB, 2018). To prevent local people to disturb the wetland, a small-scale irrigation project of 24 ha was established to support small-scale irrigation (RAB, 2018). There is also an ongoing project of restoration of Murago wetland by establishing a demarcation line, where bamboo and agroforestry trees were planted on the surface area of 34 hectares around the wetland (LDCF II, 2019). Restoration of Murago by water hyacinth and other invasive species removal (Prog et al., 2019).

5.2. PROVIDED FUNCTIONS AND ECOSYSTEM SERVICES BY MURAGO WETLAND

The result found for ecosystem services in Murago wetland, shows that all of the services provided by Murago wetland are available at the rate of 57% of yes respondents and not provided at the rate of 41% of all respondents who answered no response and 2% were not sure of the answers for the questions asked.

These results confirm that the services are still provided in Murago wetland ecosystem and this is explained by intervention activities being implemented in the area. Restoration of Murago wetland by demarcation line, bamboo and agroforestry plantation (Prog et al., 2019). The creation of buffer zones of 50 meters around Murago wetland (RAB, 2018). To prevent local people to disturb the wetland, a small-scale irrigation project of 24 ha was established to support for small-scale irrigation (RAB, 2018). There is also an ongoing project of restoration of Murago wetland by establishing a demarcation line, where bamboo and agroforestry trees were planted on the surface area of 34 hectares around the wetland (LDCF II, 2019). Restoration of Murago by water hyacinth and other invasive species removal (Prog et al., 2019).

The result found in field survey shows that, 40 bird species were recorded and a total of 137 individuals among them 21 bird species are water birds. Among animals recorded in Murago wetland; three species of fishes Nile Tilapia (*Oreochromis niloticus*), Common catfish (*Clarias gariepinus*), and Mamba (*Protopterus aethiopicus*). The four common plant species recorded in the wetland are; *Papyrus papyrus*, *Typha latifolia*, *Ludwiga abyssinica*, *and Polygonum pulshrum*. Water hyacinth was found as threats to wetland.

These data have been collected in Murago wetland ecosystem only, while the literature in the following paragraphs is the data that have been taken in four different ecosystems including Kinyonyi, Nyirantuntu, Murago waterway and water birds of Kamudeberi Lake.

Mareba road indicates Murago wetland as a birding destination (Jannu Chudal et al., 2018). Migrating bird species have been observed in Murago wetland (REMA, 2009b). At Murago wetland you may see interesting species such as the Lesser Jacana and Purple Swamphen (RDB, 2019). A total of 111 bird species gathered in 38 families were recorded in Kinyovi, Nyirantuntu, Murago waterway and water birds of Kamudeberi Lake (C. Nsabagasani et al., 2008). Birds' species of Accipitridae, Ploceidae, Ardeidae, Emberizidae and Antidae families are more represented in Akanyaru wetlands (C. Nsabagasani et al., 2008).

A total of 15 wetland plant species have been recorded in different wetlands of the western part of the country including, Gashanga, Kidogo, Rumira and Murago (BACL, 2018). The surveyed plant species are dominated by Papyrus sedge (*Cyperus papyrus*) and Giant Reedmace (*Typha latifolia*) (BACL, 2018). Other species including grasses such as *Vossia cupsida* and common reed (*Phragmites australis*), wood shrubs (*Mimosa pigra*), and locally ferns (BACL, 2018). Other swamp and aquatic species includes *Polygonum pensylvanicum, Persicaria pensylvanica, Cyperus alternifolius, Polygonum coccineum, Setaria glauca, and pistia stratiotes* (BACL, 2018).

5.3. THREATS AND INTERVENTIONS

Normally, flash floods are used to happening in Murago wetland as it is used to happening in other wetlands all over the world. The flash flood that is used to happen is caused by rain in the Murago catchment, large quantities of water from the Akanyaru River and rainwater from houses' roofs that are not harvested. However, obviously, the flash flood of December 2012 and 2014 has been exacerbated by the overuse of the wetland and poor agriculture practices.

Human activities that are exercised in Murago wetland and its catchment cause unusual flash floods in Murago wetland ecosystem when there is heavy rainfall. Lakes and wetlands in Bugesera are completely unprotected and the primary threat lies in unmanageable land use and degradation associated with unsustainable agricultural practices and brick making (Jannu Chudal et al., 2018). fishing activities in Murago wetland are uncontrolled and unsustainable (*Ection 1:*, 2019). During drought periods, water shortages are a very big problem to the surrounding local community of Murago wetland (*Ection 1:*, 2019). Water hyacinth (*Eichhornia crassipes*) is one of the most invasive waterweeds and threat to ecosystem services found in Murago wetland (*Ection 1:*, 2019).

These human activities that are stressing Murago wetland, are supported by the low speed in implementing intervention activities such as Insufficiency of progressive terraces in Murago catchment, mismanagement of wetland buffer zones and antiseptic fosses which are not sufficient in quantity and quality, removal of the natural vegetation on the land surface, lack of rain water harvesting practices, and lack of skills and knowledge in developed agriculture practices.

CHAPTER VI. CONCLUSION, RECOMMENDATIONS AND SUGGESTIONS FOR FURTHER RESEARCH

6.1. CONCLUSION

The environmental degradation of Murago wetland has been aggravated to the extent of its disappearance. The conservation and environmental planning has started changing the situation and the restoration activities of LDCF II project have continuously brought the degraded wetland to restored wetland. The LDCF II project has demonstrated the possibility of improving wetland community relations. Murago wetland ecosystem had an incredible refresh, though the problem of severe floods and droughts is still taking place.

This research shows that the management of Murago wetland and community livelihood got an incredible improvement. The analysis of satellite images revealed that Murago wetland got a tremendous refresh through the increase of water cover area, and the grass land with the decrease of bare land and built-up surface area. The assessment done shows that Murago wetland ecosystem avails its functions and services in general, while the FGD (Focus Group discussion) and KII (Key Informant Interview) revealed that in past years some services and functions were losing whereas nowadays they are active. The result of our study will be a good contribution to community livelihood improvement and sustainable wetland management practices as the fulfillment of the core principles of the EbA approach. it provides statistics of human and wetland interactions.

However, the results of this study should be considered with caution due to a certain number of study limitations. The images have been acquired in June, July, August and September months of climatic seasons in Rwanda. The long dry season starts in June and it ends in August, while September is the start of short rainy season. The first image dated in 1980’s period was the oldest available on the USGS repository and it was the period with which the wetlands were not yet disturbed. The limited possibility of capturing details due to the use of the medium resolution of satellites imagery. The 30 m resolution Landsat imagery from the USGS web portal, cannot allow to capture patches of wetland degradation or rehabilitation. Images from different dates were selected based on the availability of cloud-free imagery and that would not allow comparing results with the same date/season. The seasonal variation could not be captured without several cloud free images within a short period of the year (like every ten days).

The field rapid assessment intended to capture and record bird, fish and vegetation species as the key indicators of climate change. To conclude that these species have been affected or not it should require baseline data of the foresaid species captured before the years ago. However, there is no study or inventory of biodiversity species in Murago wetland, that has been conducted before.

6.2. RECOMMENDATIONS

The problem of severe floods and droughts is still happening in Murago wetland. Therefore, I recommend that:

1. The government to accelerate the LDCF II project restoration activities, which have not yet started.

2. Though some interventions have been put in place, but still they are not feasible and these need to be addressed in particular. For example; the restriction on the use of agriculture practices in buffer zones has not yet carried out as people still use the buffer zone for agricultural purpose; this is because people who have been expropriated in the buffer zone have not been given alternatives of where they should move their activities to.

3. Community sensitization and awareness should speed up so that it would facilitate the participation of the riparian community in wetland restoration.

4. Rwanda should have to continue strengthening environmental governance, conservation, and rehabilitation of critical ecosystems that underpin the food security and economic growth.

5. Studies on wetlands are very crucial to increase the knowledge and awareness on protecting wetland ecosystems.

6. Research and capacity building should be supported by the government and its partners.

6.3. SUGGESTIONS FOR FURTHER RESEARCH

For the limitations found in the study, I suggest that:

a. It would be more important to look for the images of the same month, however the possibility of getting clear images of 30 m resolution and cloud cover free were almost impossible though the downloaded images gave good results to refer to.

b. It would be good if further studies would use fine spatial and temporal resolution satellite images from image service providers.

c. The full inventory of biodiversity species in Murago wetland.

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APPENDICES

I. Field rapid assessment form

MURAGO WETLAND MONITORING FORM _Field Rapid Assessment

COMPILER'S Name: Email:	
YEAR OF ASSESSMENT:	**COUNTRY:**
Wetland CRITERIA MET:	**Wetland NAME:**
STATE WILL BE JUDGED BY <u>SPECIES</u> OR <u>HABITAT</u>? (circle one)	**QUALITY OF ASSESSMENT:** (circle one, at end representative data of assessment) data Good – based upon reliable and complete or representative data Medium – based upon reliable but incomplete or partially Poor – based upon little, or potentially unreliable or unrepresentative,

<u>STATE</u> – KEY SPECIES (POPULATIONS) AT THE SITE
Please list the bird species that trigger IBA criteria at the site, that are also easy to monitor
For A2 and A3 species, it is usually easier to assess the Habitat of the relevant EBA/biome, than to assess the many individual species

Bird ,fishes,butterfly,etc species name	**Original population size**	**Current population size**	**Units**	**Comments**
e.g. Angry Pitta *Pitta cholerica*	900	600	Calling males	Original (baseline) population of 900 based on first survey, in 1980s.

<u>STATE</u> – HABITATS OF THE KEY by identified animals
Please list the habitat types that are of greatest importance for the Murago wetland trigger species.
See overleaf for a list of major habitat types
Current % of the habitat remaining is scored as follows: *Good* (>90% of original extent remains); *Moderate* (to 70–90%); *Poor* (to 40–70%); *Very poor* (to <40% of original extent).
Current habitat quality scored depending on the quality of the remaining habitat, as follows: *Good* (overall >90% of optimum), *Moderate* (70–90%), *Poor* (40–70%) or *Very Poor* (<40%).

Major habitat type	**Current % remaining**	**Current habitat quality**	**Comments:** Description of the causes of habitat loss/gain. Mention the key bird populations likely to be affected
e.g. papyrus papyrus	e.g. Moderate	e.g. Moderate	Quarter of the original forest has been converted to agricultural plantation. The remaining forest is more accessible to invasive species, so reducing habitat quality. Angry Pitta impacted by

II. ***Questionnaire for Quantitative data***

QUESTIONNAIRE FOR ASSESSMENT OF MURAGO WETLAND

GENERAL INFORMATION

Names of the respondent:

Sex:

Age:

Profession:

Institution:

Phone number:

Sector…………………., Village…………

Provisioning services

Categories	Questions
Provision of fresh water	Does the wetland provide a source of fresh water? **Yes | No** Does the wetland store fresh water for human use? **Yes | No** Is the wetland a net source of pollution, degrading fresh water provision? **Yes | No**

Provision of food	What is grown in the wetland, either formally or from informal harvesting? **Yes | No** Are animals are harvested from the wetland? **Yes | No** Are livestock using the wetland? **Yes | No** If yes, specify;
Provision of fiber	Are any natural materials such as wood, fiber, straw, animal fiber (wool/hide/sinew/antler/other) taken from the wetland? **Yes | No**
Provision of fuel	Is any material taken from the Murago wetland and used as fuel for domestic or other uses? **Yes | No**
Provision of genetic resources	Are any native or rare strains of plants and animals, wild and domesticated, which could contribute genetic diversity for human uses (for instance for drug manufacture, improving resilience of domestic animals and plants, horticultural trade, etc.) **Yes | No**
Provision of natural medicines and pharmaceuticals	Are there any plants, animals or their parts derived from the wetland which are harvested and used for their medicinal properties? **Yes | No**
Provision of	Are there any plants, animals or their parts are derived from wetland that

ornamental resources	are collected and used/sold for their ornamental properties? **Yes | No**
Clay, mineral, aggregate harvesting	What substances are extracted or dug up from the wetland for construction or other human uses? **Yes | No**
Waste disposal	Does the wetland provide a location for the disposal of liquid, solid or other waste materials? **Yes | No**
Energy harvesting from natural air and water flows	Are any technologies (water wheels, wind turbines, etc.) used to capture natural flows of energy through or across the wetland? **Yes | No**
Regulating services	
Air quality regulation	Is there a source for airborne pollutants? **Yes | No** Does the wetland habitat structure help to settle out airborne pollutants? **Yes | No** Does the state of the wetland make it a source of air pollutants (microbial, particulate or chemical)? **Yes | No**
Local climate regulation	Does the wetland habitat structure provide shade for humans? **Yes | No** Does the wetland have areas of standing water with or without vegetation that will be generating evapotranspiration and

	consequently reducing air temperatures? **Yes | No**
Water regulation	Do the topography, permeability and roughness of the wetland enable it to store water during high rainfall/discharge and top slowly release it back to surface waters or to groundwater? **Yes | No** Does the wetland regulate discharges during dry periods to buffer low flows during dry weather? **Yes | No**
Flood hazard regulation	Does the wetland regulate, store and retain floodwaters? **Yes | No** Does the wetland store rainfall and surface water that might contribute to flooding and damage to property or ecosystems downstream? **Yes | No**
Pest regulation	Do natural predation and other ecological processes in the wetland regulate and control pest organisms? **Yes | No** Is the wetland a source of pests (for example rats thriving in dirty water systems)? **Yes | No**
Regulation of human diseases	Do natural predation and other ecological processes in the wetland regulate organisms that may cause human diseases? **Yes | No** Are fecal deposits, bacteria or other potentially pathogenic microbes immobilized by processes in the wetland? **Yes | No** Is the condition of the wetland contributing to the negative spread of populations of disease vectors (such as mosquitoes)? **Yes | No**

Regulation of diseases affecting livestock	Do natural predation and other ecological processes in the wetland regulate organisms that may cause diseases in livestock? **Yes | No** Are fecal deposits, bacteria or other potentially pathogenic microbes immobilized by processes in the wetland? **Yes | No** Is the condition of the wetland contributing to the negative spread of populations of disease vectors (such as mosquitoes or snails)? **Yes | No**
Erosion regulation	Does the wetland vegetation provide protection from erosion for the soils? **Yes | No** Are there any signs of erosion, such as bare earth, in the wetland? **Yes | No**
Water purification	Do physico-chemical (sunlight exposure in shallow waters, detention of water in aerobic and anaerobic microhabitats) and biological processes in the wetland result in the breakdown of organic, microbial and other pollutants in the water passing though? **Yes | No** Are suspended solids deposited? **Yes | No** Is there a noticeable change in the quality, such as the turbidity, of water entering and leaving the wetland? **Yes | No**
Pollination	Do populations of pollinating organisms (butterflies, wasps, bees, bats, etc.) in the wetland contribute to pollination within the wetland? **Yes | No**

	Do pollinators using the wetland also help to pollinate nearby crops, gardens, allotments, etc.? **Yes | No**
Salinity regulation	Does the hydrology of the wetland help prevent saline water contaminating freshwaters? **Yes | No** Does the presence of freshwater in the wetland prevent the salinization of soils? **Yes | No**
Fire regulation	Does the configuration of waterbodies (ditches, streams, etc.) help to prevent the spread of fires? **Yes | No** Is there water at or near the soil surface that restricts the spread of fire? **Yes | No** Are organic rich or peat soils drained and susceptible to fire and burning? **Yes | No**
Noise and visual buffering	Is there a source (busy road, industry, construction, etc.) and receptor (houses, wildlife, etc.) for noise pollution? **Yes | No** Does wetland ecosystem structure, particularly tall trees and reeds, provide visual screening as well as suppress noise transmission? **Yes | No**
Cultural services	
Cultural heritage	Does the wetland system have cultural importance, either due to its natural character or traditional uses? **Yes | No**

Recreation and tourism	Is the wetland used for organized or informal recreational purposes? Is there infrastructure provided for access and recreation? **Yes | No** Are their wider tourism/ecotourism benefits flowing from these uses? **Yes | No**
Aesthetic value	Does the wetland provide aesthetic benefits through the desirability of siting houses of commercial development adjacent to it? **Yes | No** Does the presence of a wetland have a significant impact on property prices? **Yes | No** Is the wetland depicted in many works of art? **Yes | No**
Spiritual and religious value	What spiritual and/or religious values do people derive from the wetland? **Yes | No** Does the wetland play any part in traditional religious ceremonies? **Yes | No**
Inspirational value	Are there any particular myths or other folklore associated with the wetland? **Yes | No** Do any wetland animals appear or are featured in local stories and myths? **Yes | No**

	Does the wetland inspire people to create music or other forms of art? **Yes | No** Have particularly ways of designing and building developed which reflect the wetland? **Yes | No**
Social relations	Have communities formed around the wetland and its uses, including for example fishing (subsistence, commercial and recreational), cropping or stock management, walking and jogging, birdwatching and photography, etc.? **Yes | No**
Educational and research	Is the wetland used for any educational purposes, organized or informal, ranging from school-level visits to university research and teaching? **Yes | No** Are there any public awareness or educational materials present? **Yes | No**
Supporting services	
Soil formation	Do accretion processes (both sedimentation of mineral material and the buildup of organic material) on the wetland result in the formation of soils? **Yes | No**
Primary production	Do photosynthetic processes on the wetland produce organic matter and store energy in biochemical form? **Yes | No**
Nutrient cycling	Do wetland processes biochemically transform nutrients (for example

	nitrification/denitrification)? **Yes | No** Are nutrients settled out in particulate forms, changing the characteristics of water passing through the system? **Yes | No** Are there abundant invertebrates and detritivores that are decomposing and cycling organic material? **Yes | No**
Water recycling	Does the structure of the wetland retain water in tight cycles (for example recapture of vapor produced by evapotranspiration)? **Yes | No**