ECONOMIC VALUATION OF ECOSYSTEM SERVICES OF KIGALI CITY WETLANDS COMPLEX ECOSYSTEM SERVICES IN RWANDA

FINAL REPORT

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Economic Valuation of Ecosystem Services of Kigali City Wetlands Complex in Rwanda

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List of Abbreviations

AGC	Above Ground Carbon
ALU	Area of Land of Use
ARCOS	Albertine Rift Conservation Society
BGC	Below Ground Carbon
CIP	Crop Intensification Programme
CO2	Carbon dioxide
CS	Consumer Surplus
CSO	Civil Society Organisation
DAP	Di-Ammonium Phosphate
DDS	District Development Strategies
DP	Development Partners
ES	Ecosystem Service
ESP	Ecosystem Services Partnership
FGD	Focus Group Discussion
GDP	Gross Domestic Product
GIS	Geographic Information System
GoR	Government of Rwanda
IPCC	Intergovernmental Panel on Climate Change
IUCN	International Union of Nature Conservation
KII	Key Informant Interview
LPG	Liquefied Petroleum Gas
MIFOTRA	Ministry of Public Service and Labour
MINAGRI	Ministry of Agriculture and Animal Resources
MINALOC	Ministry of Local Government
MINEACOM	Ministry of Trade, Industry, and East African Community Affairs
MINEDUC	Ministry of Education
MINICOFIN	Ministry of Finance and Economic Planning
MINIRENA	Ministry of Natural Resources and Forest
MINISANTE	Ministry of Health
MOE	Ministry of Environment
MYICT	Ministry of Youth and ICT
NB	Net Benefit
MININFRA	Ministry of Infrastructure
PS	Producer Surplus
PVC	Present Value Cost
RDB	Rwanda Development Board
REMA	Rwanda Environment Management Authority
RICA	Rwanda Institute for Conservation Agriculture
RNRA	Rwanda Natural Resources Authority
RwF	Rwandan Francs
SSP	Strategy Support Programme (e.g., the Rwanda SSP)
TEEB	The Economics of Ecosystem Services and Biodiversity
WTP	Willingness To Pay

EXECUTIVE SUMMARY

Introduction and aims of the valuation study

Wetland is a generic term for all the different wet habitats implying that it is land that is wet for some period of time, but not necessarily permanently wet. According to the convention on wetlands of international importance, known as the Ramsar convention, a wetland "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 the depth of which at low tide does not exceed six meters." Rwanda's wetlands consist of marshes, lakes and rivers and water, they represent about 14.9% of the national territory. Wetlands provide a number of ecosystem services for instance they offer surface water detention which yields flood protection services; stream flow maintenance that yields water supply services; nutrient transformation that yields water quality services; sediment and other particulate retention which is also associated with water quality service; provision of habitat for fish which is associated with subsistence and commercial fishing; provision of habitat for wildlife which is associated with recreation and tourism, and biodiversity protection and conservation; carbon storage and sequestration which is associated with climate stability among. Despite these ecosystem services that wetlands offer, they suffer serious degradation mainly due to infrastructure development, over-use, land conversion, pollution, water withdrawal, climate change, eutrophication, pollution, and the introduction of invasive alien species and the main reason for the continued loss and degradation of wetlands throughout the world is because they (wetlands) have been traditionally considered to be of little or no value, or even at times to be of negative value. This lack of awareness of the value of conserved wetlands and their subsequent low prioritization by the decision-making process has resulted in the destruction or substantial modification of wetlands at an unrecognized social cost. This study therefore seeks to establish the exchange and utilitarian value of Kigali City wetlands complex so as to make them visible thereby making them comparable to other land uses. This, can aid in decision making regarding the appropriation of the wetlands complex. In this proposed study the main objective is to carry out a total economic valuation of ecosystem services of Kigali City wetlands. The study will involve the development of a replicable methodology for ecosystem services assessment and total economic valuation and providing key and actionable recommendations for ecosystem mainstreaming in various sectors of development.

Approach and Methodology

We used a modified version of the Wilson Troy model of ecosystem valuation which entails; delineation of the wetland boundaries and this was based on three fundamental parameters that define a tropical freshwater wetland-presence of hydric soils, presence of hydrophytic vegetations (mainly the presence of phragmites), and levels of permanence or periodic inundation of the areas; delineation was then followed by typology development which was an exercise involving identification of the land use and land cover found within the wetland delineated boundaries, this was largely conducted through a thorough review of the literature in which five main land uses were identified and they included; water bodies, papyrus(phragmites), other vegetations, grassland, and crop lands.

Ten ecosystem services were also prioritised for valuation in this exercise. Typology development was then followed by data collection using purposive sampling, and use of secondary data. Purposive sampling deployed key informant interviews, focus group discissions, and stakeholder workshop. Data collection stage was followed by mapping of land use change between 2012 and 2018. Scenario analysis was conducted for policy and management options, a business-as-usual scenario and the Kigali City Wetland Master Plan scenario. A cost benefit analysis assessment was conducted for the baseline economic values for the next 30 years based on per unit hectarage available for each land use category and the related ecosystem services provision, a discount factor of 10% per annum was applied to establish present values of both benefits and costs over the 30-year period for each of the two scenarios

Results and Discussions

Ten ecosystem services were considered for valuation, and as indicated in the methodology section, this results section covers the findings from the data collection strategy section, i.e., estimation of the baseline economic values, and scenario analysis. Four provisioning ecosystem services were considered for baseline economic valuation and they all yielded a total of over $US 22 million per year, these four provisioning ecosystem services included; domestic water supply, water for livestock, crop farming, bricks making, grass harvesting, papyrus products, Similarly, five regulating services were valued and these together were valued at approximately $US 499 million and they included; water purification, sediment control, flood control, carbon storage & sequestration, and habitat for biodiversity. Finally, one (tourism and recreation) cultural ecosystem services were also estimated and it has a potential of $US 83,333 annually. Cost benefit analysis of the business-as-usual scenario has a net present value costs of $US 1.8 billion while an implementation of the wetland master plan has a net present value benefits of $US 1.9billio over a period of 30 years (2020-2050) and at 10% annual discount rate.

Policy Implications

- Crop farming offers more than 14 thousand households opportunity for income and nutrition, they would stand as losers if another management alternative that does away with crop is implemented and still some of them would lose out if a portion of the wetland is harnessed for another land use other than crop farming. Under the BAU, crop farming will produce the second greatest economic benefit of all the ecosystem services after carbon storage and sequestration due to the presence of carbon on various carbon pools, moving away from the status quo would lead to an annualized loss of benefits of over $US 10 million. Overall, the opportunity cost of crop farming under the wetland master plan includes conservation, and tourism and recreation, both of which would give economic value of $US 1.37 billion over the 30 years period.

- As both population growth and quality of life increases, demand for building and construction materials such as bricks will increase. Commercialized bricks making yield one of the highest per unit benefits of the wetland resource harnessing.

- The wetland currently offers a cross section of the city dwellers the opportunity to harvest grass for livestock feeding, this earns an annual value of $US 12,720. Based on the assumptions made of no land use movement /change regarding grassland landcover across the two management scenarios, there are no incremental benefits or costs associated with a shift to either of the two options considered.

- The wetland's natural vegetation, mainly phragmites offers the local community opportunities for mulching, making handicrafts among others that are worth around $ US 130 thousand, and if the wetland master plan is implemented then it there will be an annual incremental benefit of papyrus economic benefits worth $US 228 thousand above the current levels.

- Currently, the wetland offers water purification ecosystem services worth $US 1.7 million, and if the Kigali City Wetland Master Plan is implemented, then the wetland would offer an improved water purification ecosystem services worth an annual incremental benefit of $US 8.9 million over and above the current wetland management and utilization

- The wetland currently offers sediment control ecosystem services worth $US 8 million annually. However, if the wetland master plan is implemented, then it will have an improvement and offer annual incremental net benefit of $ US 8 million over and above the current use of the wetland.

- Currently the wetland offers flood regulating services worth $US 1.5 million annually, and if the wetland master plan is implemented then the wetland would provide a more superior flood regulation worth an annual incremental value of $US 17 million over the current wetland management and use.

- The wetland currently contributes to the greening of the country with a carbon storage and sequestration potential worth $US 44 million. However, under the wetland master plan, the wetland would have an annual incremental benefit over the current management worth $US 113 million.

- The current economic value of habitat for biodiversity conservation is worth $US 2.8 million annually.

However, if Kigali City Wetland Master Plan is implemented, then the value will have an incremental benefit over the current practice worth $US 16.9million annually.

- Tourism and recreation currently have the potential to the stakeholders up to $US 83 thousand annually. However, if the wetland master plan is implemented, then it would result into an annual net benefit of over $US 800 thousand over the current business as usual scenario.

Conclusion

The Kigali City wetlands complex generates a number of ecosystem services that are of local, national and international importance. There are around four important provisioning ecosystem services that support local city dwellers with income and livelihoods, they include; crop framing, papyrus and papyrus products, grass harvesting, and bricks making which together generate a total economic value of slightly less than $US 22 million a year. The wetland also generates regulating and cultural services that have national, regional and international significance, these include climate change mitigation, habitat for biodiversity, sediment control, and water quality improvement at a value slightly worth more than $US of 51 million. If the status quo (business as usual) is maintained, then the Kigali City wetlands complex will accumulate net present value loss in terms of ecosystem services worth over $US 1.8 billion by 2050. While implementation of the Kigali City Wetland Master Plan would outperform the status quo by generating a net present value benefit of more than $US 1.9 billion by 2050. The wetland master plan would generate around an extra $US 155 million annually more than the status quo. For the wetland master plan, within its three management strategies of sustainable exploitation of the wetland, conservation, and tourism and recreation; conservation option offers the best value for money and highest net present economic benefits at $US 1.3 billion compared to the $US 536 million, and $US 35 million for sustainable exploitation and tourism and recreation respectively.

Recommendations

1. To keep track of the flow of the ecosystem services provision, there is need for investments in regular data collection

2. While investment and implementation of the Kigali City wetland master would lead to annual loss of slightly more than $US 10 million crop farming benefits, it will compensate this by generating several folds annual incremental benefits over the business-as-usual scenario annually, i.e., implementation of the wetland master plan will earn more than $US 155 million annually over the business-as-usual scenario and it is therefore a recommended plan. More specifically, investing in the master plan would results into annual incremental benefits over the BAU for the following ecosystem services.

    - Investment in wetland master plan implementation would result into an annual incremental benefit of flood control worth more than $US 17 million over the business-as-usual scenario.

    - Investment in wetland master plan implementation would result into an annual incremental benefit of tourism and recreation worth more than $US 800 thousand over the business-as-usual scenario.

    - Investment in wetland master plan implementation would result into water purification annual incremental benefit of $US 8.9 million over the current status quo management of the wetland

    - Investment in wetland master plan implementation would result into biodiversity conservation annual incremental benefit of $US 17 million over the current status quo management of the wetland

    - Investment in wetland master plan implementation would result into sediment control annual incremental benefit of $US 8 million over the current status quo management of the wetland

3. Stakeholders may also consider harnessing the prospects of climate change mitigation of the wetland through enhancing carbon storage and sequestration potential of the wetland

4. The study relied heavily on value transfer which has it's share of uncertainties, therefore more primary studies could still be conducted to enrich the appraisal of the policy and management options

1. INTRODUCTION

1.1. Background and Context

Wetland is a generic term for all the different wet habitats implying that it is land that is wet for some period of time, but not necessarily permanently wet (Tiner, 1996). According to the convention on wetlands of international importance, known as the Ramsar convention, a wetland "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 the depth of which at low tide does not exceed six meters." (Ramsar convention, 1971). Rwanda's wetlands consist of marshes, lakes and rivers and water, they represent about 14.9% of the national territory (GoR, 2003). At the global scale wetland ecosystems occupy only 6 % of the Earth's surface (Cherry, 2011).

Wetlands are highly productive ecosystems with a number of ecological functions that yields dozens of ecosystem services. They for instance offer surface water detention which yields flood protection services; stream flow maintenance that yields water supply services; nutrient transformation that yields water quality services; sediment and other particulate retention which is also associated with water quality service; provision of habitat for fish which is associated with subsistence and commercial fishing; provision of habitat for wildlife which is associated with recreation and tourism, and biodiversity protection and conservation; carbon storage and sequestration which is associated with climate stability among others (Tiner, 2003). The estimated global economic value of wetlands was placed at $US 15 trillion by Costanza et al (1997).

Despite wetlands having the ability to offer close to two dozen of ecosystem services, they are also one of the ecosystems that are being subjected to the greatest degradation globally (Millennium Ecosystem Assessment, 2005). There was a decline of about 35% of global wetlands between 1970 and 2015 (Ramsar Convention on Wetlands, 2018). The average annual rate of natural wetland loss estimated by the WET Index is -0.78% a year which is over three times faster than the average annual rate of loss of natural forests (-0.24% a year) between 1990 and 2015 (FAO 2016a).

The direct drivers or immediate causes driving wetland loss and degradation mainly include infrastructure development, over-use, land conversion, pollution, water withdrawal, climate change, eutrophication, pollution, and the introduction of invasive alien species (Millennium Ecosystem Assessment, 2005b; Camacho et al., 2020; Turner et al, 1998), while the underlying causes of the direct drivers (the indirect drivers) include price distortions, income distribution inequalities, absence of full cost accounting, policy failures, market failures (missing prices), lack of property rights, population growth and consequent and increasing economic development (Turner et al.,1998 Camacho et al., 2020). The main reason for the continued loss and degradation of wetlands throughout the world is because they (wetlands) have been traditionally considered to be of little or no value, or even at times to be of negative value (Turner et al.,1998). This lack of awareness of the value of conserved wetlands and their subsequent low prioritization by the decision-making process has resulted in the destruction or substantial modification of wetlands at an unrecognized social cost (Turner et al.,1998). This study therefore seeks to establish the exchange and utilitarian value of Kigali City wetlands complex so as to make them visible thereby making them comparable to other land uses. This, can aid in decision making regarding the appropriation of the wetlands complex.

1.2. Need for valuation and purpose of the study

Generally, valuation of ecosystem services can take one of the approaches which include: (1) an impact analysis if the main desire for valuation or the problem at hand is a specific external impact e.g., effluent polluting a wetland; (2) partial analysis, if the issue is about making one choice between a host of wetland use options such as conversion of a wetland to a residential land or diversion of upstream water for irrigation; and (3) a total valuation if the issue is a bit general such as determination of the worth of a wetland as a protected area, or seeking to incorporate the economic contribution of the wetland into national accounting or seeking to develop a conservation strategy (Barbier et al., 1997). From these three broad approaches to valuation, several reasons for conducting valuation studies can be made possible as shown in the table below.

Table 1: Some of the applications of valuation

Purpose	Possible assessment question	Example
Comparing alternative policies, programmes and projects	How do alternatives differ in terms of the gains and losses of ecosystem services (ESs) they are likely to produce or that are likely to arise from their implementation?	Assessing options for wetland protection for a range of grey and green infrastructures, including mixes of these
Identifying livelihood, development and investment opportunities	What new or improved economic opportunities can be developed based on the conservation and sustainable use of ESs?	Assessing the recreational value of wetland areas, to identify possible investment strategies to promote responsible tourism as a driver of local development
Designing environmental policy instruments, incentives, regulations and monitoring	What information on ESs will enable the design of effective, equitable and sustainable environmental policy instruments?	Assessing the value of carbon sequestration by wetland conservation project to access carbon markets and generate revenues that could support peatlands, and related co-benefits
Undertaking scoping and situation analyses	What is the state of ESs in a given context, and what values and stakeholders are associated with them?	Stakeholder consultation and ES assessment to identify the perceived importance of ESs among groups and to set priorities for wetland management (e.g., harvesting intensity and the frequency and size of set-asides)
Enhancing environmental awareness or advocating for a policy option	How can information on the provision and impacts of ESs be used to "make the case" for a given policy option?	Assessing the impact of a wetland restoration compared with those associated with other development to inform decisions making
Tackling environmental conflicts	How can a focus on ESs provide credible information on environmental change to help resolve conflicts?	Meetings with stakeholders and experts to manage human wildlife conflict
Assessing the impacts of policy changes, thus informing choices among competing uses	What are the impacts on competing resource uses of changes in existing policies?	Assessing the impacts of wetland policy changes in the conversion of wetland to agricultural land uses

Source: Adopted from: Masiero et al., (2019)

The main objective of this study was to carry out a total economic valuation of ecosystem services in the selected wetlands in Kigali City, and Rweru-Mugesera wetlands. The study will involve the development of a replicable methodology for ecosystem services assessment and total economic valuation and providing key and actionable recommendations for ecosystem mainstreaming in various sectors of development. It will involve collection, organization and the analysis of spatially explicit data to identify, assess and evaluate the key/priority ecosystem services in Kigali City and Rweru-Mugesera complexes. The results of this assessment will be the core input for a participatory process that aims to identify and prioritize management options and policy instruments to maintain and/or improve the flow of these key ecosystem services for the development processes in Rwanda. The expected outcome is an ecosystem-based decision-making guide for wetland management.

1.3. Scope of valuation

In the valuation study of ecosystem services, it imperative that the ecosystem whose ecosystem services are to be valued is identified, in this case then it is wetland ecosystems which included the Rweru-Mugesera complexes and two to three other wetlands within the Kigali City, however, in the case of Kigali, due to stakeholders interest, the study was expanded to cover the entire 37 wetlands using mostly secondary data. Establishing the scope of a valuation study entails identifying the wetland area under consideration, the time scale of the analysis and the geographic and analytical boundaries of the system (Barbier et al., 1997). Once the system and analytical boundaries are defined, then the basic characteristics of the wetland should be determined for valuation that is identification of ecosystem services. The scope of valuation can be considered to look at the kinds or categories of ecosystem services to be valued as is classified under the Millennium Assessment Report (MA, 2003).

1.4. Stakeholders of Wetlands and Wetland Ecosystem services

Wetlands attracts a number of stakeholders. It is also important to identify stakeholders to help in determining the main policy and management objectives, to identify the main relevant services and assess their value and to discuss the trade-offs involved in the wetland use. A stakeholder is a person, organization or group with interests in an issue or particular natural resource. Stakeholders are people with power to control the use of resources, and those with no influence but whose livelihoods are affected by changing the use of the resource. Stakeholders are typically classified or organized in terms of influence and importance to the study so that the relative levels of influence and importance determine whether a stakeholder is a primary, secondary, and tertiary.

Primary stakeholders are those who draw direct benefits from the use of the wetland such as those who directly harness the provisioning ecosystem services and or those who also benefit from the regulating, cultural, and supporting ecosystem services. Secondary stakeholders are those groups and organizations that have interest and influence in wetland management through government assigned mandates. While at the tertiary level are those organizations in the civil society movement whose interests are driven by passion to protect the environment or the wetland resources among others.

Table 2: Stakeholder analysis

Stakeholder Category	The stakeholders	Nature of interest	Level of interest and influence
Primary stakeholders	Brick makers	Making of bricks using wetland soil	They have high interest and sometimes high influence
	Crop farmers	Growing crops in the wetland such as rice, chewing cane, vegetables among others	High interest, but sometimes low influence
	Sugar companies	Growing of sugarcane for production sugar	High interest and high influence
	Papyrus harvesters	Harvesting of papyrus to make papyrus products such as mats	High interest but low influence
	Fish farmers	Harvesting of papyrus to make papyrus products such as mats	High interest but low influence
	Pasture harvesters	Harvesting of papyrus to make papyrus products such as mats	High interest but low influence

Secondary stakeholders	REMA	Overall authority for coordination and regulation of the protection, conservation & management of the environment	High interest, high influence
	MINAGRI	Develops, manages programmes of transformation & modernization of agriculture &	High interest, high influence
	MOE	Develops, disseminate, regulate, monitor, evaluate environment and natural resources policies	High interest, high influence
	City of Kigali	Implementation of Kigali City Wetland Master Plan	High interest, high influence
Tertiary stakeholders	Environmental Non-Governmental organizations	Protection of wetland biodiversity; maintenance of ecological, & hydrological integrity of the wetland	Low interest, low influence
	Property developers	Appropriation of the wetland for construction of settlements	high interest, high influence
	Association of manufacturers	appropriation of the wetland resource for the establishment of industries	High interest, high influence
	Development partners	Funding conservation and development projects	Low interest, low influence
	Research institutions	Education and research	Low interest, low influence

1.5. An overview of wetland valuation and valuation techniques

1.5.1. Value and value systems

Value refers to the contribution of an object or action to specific goals, objectives, or conditions (Costanza, 2004). Costanza further fronts that value of an object or action may be tightly coupled with an individual's value system because the latter determines the relative importance to the individual of an action or object relative to other actions or objects within the perceived world, where value systems refer to intrapsychic constellations of norms and precepts that guide human judgment and action (Farber et al., 2002). They refer to the normative and moral frameworks people use to assign importance and necessity to their beliefs and actions and are therefore internal to individuals but are the result of complex patterns of acculturation and may be externally manipulated through, e.g., awareness creation (Farber et al., 2002; Costanza, 2004)

People's perceptions are limited, they do not have perfect information, and they have limited capacity to process the information they do possess (Farber et al., 2002; Costanza, 2004). An object or activity may therefore contribute to meeting an individual's goals without the individual being fully (or even vaguely) aware of the connection (Farber et al., 2002; Costanza, 2004). The value of an object or action therefore needs to be assessed both from the subjective standpoint of individuals and their internal value systems and from the objective standpoint of what we may know from other sources about the connection (Farber et al., 2002; Costanza, 2004).

Reasoning on value of ecosystems runs between two approaches: (1) the anthropocentrism/utilitarian approach: Elements of Ecosystem Services are valuable insofar as they serve human beings; Valuable is what creates 'the greatest good for the greatest number'; and (2) eco- or biocentrism approach-rejects the 'dominant species' argument and replaces utility with intrinsic value: "value in and for itself, irrespective of its utility for someone else.

Some services of ecosystems, like fish or timber, are bought and sold in markets. Many ecosystem services, like wildlife viewing, are not traded in markets. Markets for most ecosystem services are missing but we still can measure their dollar values. We require a measure of how much one will give up to get the service of the ecosystem, or how much people would need to be paid in order to give it up. The value of an eco-system can be interpreted in many different ways e.g. (1) the value of the current flow of benefits provided by that ecosystem; (2) The value of future flows of benefits; (3) The value of conserving that ecosystem rather than converting it to some other use.

1.5.2. Valuation

This is the process of expressing a value for a particular action or object. Value is a measure of the maximum amount an individual is willing to pay (WTP) for goods and services, it entails financial value which is measured in prevailing market prices and economic value which is measured in economic or efficiency prices. The economic value prevails in a competitive market, free of any market imperfections (e.g., monopolies) or policy distortions (e.g., taxes or barriers to trade). It is a more accurate reflection of the contribution of a good or service to social welfare (Bishop, 1999).

In valuing ecosystem services we are interested in: (1) *Value of the total flow of benefits from ecosystems*: Contribution to economy by adjusting national account--We use total economic value; (2) *Net benefits of interventions that alter ecosystem conditions*: Arises in a project or policy context: We use marginal or net values; (3) *Examining distribution of costs and benefits of ecosystems:* This is to different stakeholder groups; (4) *Identifying potential financing sources for conservation* among others, see the purpose section above(Pagiola et al., 2004).

1.5.3. The concept of willingness to pay

In principle, economic valuation of ecosystem services is based on "people preference" and their choices. Therefore, it is quantified by the highest monetary value that a person is willing to pay in order to obtain the benefit of that particular service (Mehvar et al., 2018). The "willingness to pay" approach determines how much someone is willing to give up for a change in obtaining a certain ecosystem good or service (MEA, 2005). Thus, the key outcome of valuation studies is to illustrate the importance of a healthy ecosystem for socio-economic prosperity and to monetize the gains that one may achieve or lose due to a change in ecosystem services (Sukhdev et al., 2014).

1.5.4. Ways of measuring the value of ecosystem services

The value of ecosystem services can be measured in three different ways (Tinch and Mathieu, 2011): (1) Total economic value (TEV) that refers to the value of a particular ecosystem service over the entire area covered by an ecosystem during a defined time period; (2) average value of an ecosystem service per unit, which is often indicated for a unit of area or time; (3) marginal value which is the additional value gained or lost by an incremental change in a provision of a particular service.

Valuation starts from estimating a TEV of an ecosystem, which is in fact a sum of Consumer Surplus (CS) and Producer Surplus (PS). This is done by applying different valuation techniques. By definition, CS is the difference between the actual market price of the product and the maximum amount that people are willing to pay, while PS refers to the benefit that the producer earns when the market price is higher than the costs of production (also called net income). For example, in the case of tourism, PS is the direct or indirect benefit from the local ecosystems for the tourism sector by considering the revenue made from tourists minus the costs of providing these services to them (van Beukering et al., 2007). In addition, CS conveys the maximum amount that tourists are willing to pay for visiting the specific recreational area.

Value of nature depends on the perspective of various stakeholders such as local residents, visitors, policy makers, etc. The key factor of valuation studies is to show how a healthy ecosystem is important for socio-economic prosperity (Sukhdev et al., 2014).

1.5.5. Valuation techniques

There are four commonly used techniques for ecosystem valuation which can employ various methods. The four techniques are: market-based (which includes market price and productivity methods); revealed preference (which includes the avoided cost, replacement/substitution cost, travel cost, and hedonic pricing methods); stated preference (which includes contingent choice and conjoint analysis methods); and benefit transfer.

1.5.5.1. Market-Based

Market-based techniques for ecosystem valuation measure the "willingness-to-pay" (WTP) by consumers for benefits that contribute to the provision of marketed goods and services (U.S. EPA Scientific Advisory Board, 2009). Market-based techniques include the Market Price method and the Productivity Method.

Market Price Method

The Market Price Method is commonly used when the ecosystem good or service provided is a product that is bought and/or sold in commercial markets, e.g., commercial clams or lumber. This method calculates the changes in consumer or producer surplus of the product using market price and quantity data. The surplus is the amount that either the consumer enjoys above what he/she paid for the product (the difference between what they paid and what they are willing to pay) or that the producer enjoys beyond what he/she paid to produce the product (the difference between total revenue and total cost). This method is reliant on calculations of supply and demand. The primary objective is to measure the total economic surplus (consumer and producer) that would result due to the change in the quality or quantity of a final good or service. For example, the market price method can be used to evaluate the benefits of restoring a tidal flat area because market data is available for commercially sold clams that are harvested in the tidal flats. The increase in the healthy clam harvest resulting from the restoration would increase the net surplus (consumer and producer) and the value of that increased net surplus can be used to reflect the value of the restored tidal flat (for this singular activity).

Productivity Method

Productivity in economic terms is the ratio between the inputs and outputs of production and is therefore a measure of the efficiency of production. The Productivity Method can be used to estimate the economic value of ecosystem benefits that are used in the production chain (inputs) for commercially marketed goods (outputs). When natural resources are a component of production, then any changes in the quantity or quality of the resources will change production costs which, in turn, may affect the price and/or quantity of the final product. This method uses the value of the marginal changes to determine the value of the ecosystem good or service. For example, a consistent supply of groundwater is required for agricultural irrigation. The economic benefits of groundwater storage (provided by healthy wetlands) for a farming community struggling with drought can be estimated by the increased revenues from greater agricultural productivity which would result if they had a continual quantity of groundwater for irrigation.

1.5.5.2. Revealed Preference

Revealed preference techniques ask individuals to make choices based on real-world settings and individual responses are used to infer monetary value. This technique includes the following methods: avoided cost, replacement/substitution cost, travel cost, and hedonic pricing. Avoided Cost, Replacement Cost and Substitution Cost Methods. Replacement Cost and Substitution Cost Methods estimate the values of ecosystem benefits based on the dollar value of avoided damages, the cost of replacing ecosystem benefits or the cost of providing substitutes. These methods are not direct market valuation methods because they are not based on people's willingness to pay for a service or good. They are based on the costs people may incur to avoid damages or to replace or substitute ecosystem benefits that have been destroyed. Therefore, they are most useful in cases where damage avoidance investments, or replacement or substitution expenditures have already been or will be made.

Travel Cost

The Travel Cost Method is used to estimate the value of an ecosystem which offers recreational benefits to humans. The value is derived from the time and travel cost expenses that people incur to visit a site. Thus, the amount of money that people are willing to pay to visit the site (e.g., how much their time is worth; how much it will cost to travel to the site; how much it will cost to get in to the site) can be used to estimate its monetary value. This approach is very similar to the neoclassical economic principle of market value being based on peoples' willingness to pay for a marketed good (based on the quantity demanded at different prices). For example, the value of restoring a wetland could be estimated by surveying birdwatchers or hunters and asking them how far away they live from the wetland, what their travel costs would be to get to the wetland, how often they would use the site for recreation and/or how it compares to other possible substitute sites. This method can be challenging to employ, however, in a large area with no fixed point of entry. For example, a large restoration area with multiple points of access will make the travel costs variable depending on where the visitor is coming from and at what point they choose to enter the recreational site.

Hedonic Pricing Method

The Hedonic Pricing Method most commonly reflects variations in housing or land prices which reflect the value of local and/or nearby environmental attributes such as open space, water bodies, wildlife sanctuaries, hiking trails, etc. It can be used to estimate economic benefits or costs attributed to air pollution, water pollution, noise, views of or proximity to recreational areas. For example, if a house is placed somewhere desirable (such as a lot with a pleasant water view that offers recreational opportunities), the price that people are willing to pay for the exact same house in an undesirable location (such as next to a landfill or airport) will be significantly less even though it is the exact same house.

1.5.5.3. Stated Preference

Stated preference techniques ask individuals to respond to hypothetical situations and individual responses are used to infer monetary value based on demand. Stated preference techniques include: contingent valuation and conjoint analysis.

Contingent Valuation

The Contingent Valuation Method can be used to estimate use and non-use values for ecosystem benefits. Use value is the benefit people derive from using a service or good. Non-use value is the value people assign to goods and services that they never have or possibly never will use. Contingent valuation is the most commonly used method for estimating non-use values (such as preserving a scenic vista, saving whales, or preserving wilderness for the next generation) but is also a fairly controversial non-market-based valuation method. This method involves surveying people's willingness to pay for ecosystem benefits based on hypothetical situations, or, how much they would (hypothetically) want to be compensated to give up an ecosystem benefit. Since the method is based on asking people how much they would pay for a non-marketed ecosystem good or service (as opposed to observing their market behaviour), this method is subject to a significant amount of criticism.

Choice Modelling

Choice Modelling (also referred to as Contingent Choice Valuation) is similar to Contingent Valuation in that it presents people with a hypothetical situation, but it does not ask people to derive an explicit dollar value for an ecosystem benefit. Instead, people are asked to choose or rank various scenarios in terms of trade-offs which can often elicit monetary values for a whole suite of ecosystem benefits. Statistical models are then developed using multiple regression or Bayesian analysis techniques to reveal preferences and priorities. Choice modelling is "especially suited to policy decisions where a set of possible actions might result in different impacts on natural resources or environmental services." (King & Mazotta, 2000e) Therefore, it is particularly useful when deriving the value of potential improvements to ecosystems such as wetlands, given that several ecosystem benefits are often impacted simultaneously, e.g., flood water attenuation, wildlife habitat, clean water.

Value Transfer

Value Transfer is a widely used technique, particularly by organizations and agencies with limited time and budgets. However, like contingent valuation, it is fairly controversial and is often challenged in court. It involves finding research and studies already performed for similar projects in different locations (aka "study sites") and applying the economic values estimated from those previous studies for your particular situation (aka "policy site"). For example, if there is interest in eliciting the value for a particular wetland restoration proposal, but the cost of a primary valuation study is prohibitive, researchers can find a study from a similar project in a similar location with similar attributes and use those valuation results to estimate the value of wetland restoration for the current project. It is strongly recommended that study sites selected for benefit transfer are as similar to the policy site as possible. So, for example, if the current wetland area is isolated and about 10 ha in size and is located in a rural part of Michigan, it would be considered best practice to find a wetland project with similar attributes, of similar size, and which is located in another rural area of the Midwest such as Ohio (among other attributes to consider). It is also important to review the quality of the study site process and data to check that the results were properly vetted to ensure the highest accuracy of comparisons.

1.6. Institutional frameworks governing wetlands management

This section covers the policies, laws, regulations, strategies and plans that have been promulgated, enacted and designed for direct or indirect management of wetlands including Kigali City wetlands complex. It also covers the institutions or organisations that have direct and indirect mandates over the management of wetlands. However, to avoid redundancy, they have not been captured here since they are already covered under the stakeholder's section.

1.6.1. National Environment and Climate Change Policy

Adopted in 2019, this policy is a successor to the environment policy that was adopted in 2003. The 2003 environment policy had the policy goal of

The national environment policy and climate change has the goal of Rwanda being a nation that has a clean and healthy environment, resilient to climate variability and change that supports a high quality of life for its society.

The policy stipulates the following targets or actions that are specifically relevant to wetlands:

- Integrate Natural Capital Accounting and valuation of ecosystem services into national development planning frameworks
- Regularly conduct an inventory of degraded ecosystem and prepare restoration development plans
- Develop a master plan and implementation strategies for wetland management in Rwanda
- Develop guidelines for the use of wetlands
- Identify all polluted wetlands and develop a decontamination plan including the use of environmentally-sound technologies (Phytoremediation) for pollution prevention, control and remediation
- Promote and intensify wetland protection, and restoration and rehabilitation of degraded wetlands
- Strengthen collaborative and participatory management of wetland resources
- Strengthen existing wetland research and encourage conservation and restoration of ecosystems critically threatened by climate change
- Ensure the protection of wetlands, riverbanks, hilltops and slopes from unsustainable practices to prevent soil erosion and environmental degradation.
- Ensure that developmental activities within wetlands or in the buffer of wetlands conform with EIA process and procedures. Promote the use of alternative forms to biomass fuel (e.g., gas and electricity) in urban and rural areas

The policy will be implemented through ministerial and DDS, SSPs, annual Imihigo targets and action plans. The policy will also be implemented through the action plans of development partners, CSOs and the private sector who will translate the policy into action. Develop master plan and implementation strategies and sector specific detailed guidelines for wetland management in Rwanda (MOE, MINAGRI, REMA) between 2018 and 2024.

Identify all polluted wetlands, develop and implement their decontamination plan (REMA, MoE, MINAGRI, UR, CSO, DP) between 2019 and 2024.

1.6.2. Agricultural policy of 2017

Adopted in 2017, the policy is a successor to the agriculture policy of 2004. This policy has the mission of insuring food and nutrition security of Rwandans by using modern agribusiness technologies, professionalizing farmers in terms of production, commercialization of the outputs and then creating a competitive agriculture sector. The policy has identified four main strategic and enabling pillars upon which core policy guidance and actions have been based:

- ❖ Productivity and Commercialization for Food Security, Nutrition, and Incomes
- ❖ Resilience and Sustainable Intensification
- ❖ Inclusive Employment and Improved Agrofood Systems' Skills and Knowledge
- ❖ An Effective Enabling Environment and Responsive Institutions

MINAGRI is the key leading institution to deliver on the implementing of the policy. MINAGRI will closely collaborate in the policy implementation with a range of public institutions that influence the sector (MINALOC, MINICOFIN. RDB, MINEACOM, MINISANTE, MINIRENA, MIFOTRA, MINIFRA, MINEDUC, MYICT) through the creation of collaborative platforms.

More detailed policy guidance on a specific policy-area to be defined by subsidiary policies. Specific actions are and timelines are to be defined by subsidiary strategies.

1.6.3. Biodiversity Policy

Considers the rehabilitation of degraded ecosystems in Rwanda as an urgent and major task that requires the commitment of significant resources from both national budgets and other sources.

1.6.4. Energy Policy

recognizes the need to shift consumption from biomass-based energies to clean energies like electricity and Liquefied Petroleum Gas (LPG) to reduce pressure on forest resources. It also focuses on renewable energy infrastructure as one strategy to fight global warming through reductions in greenhouse gas emissions.

1.6.5. Organic Law (No. 04/2005 of 08/04/2005) Determining the Modalities of Protection, Conservation and Promotion of the Environment in Rwanda

Article 87 of the law prohibit to construct houses in wetlands (rivers, lakes, big or small swamps), in urban or rural areas, to build markets there, a sewage plant, a cemetery and any other buildings that may damage such a place in various ways. All buildings shall be constructed in a distance of at least twenty (20) metres away from the bank of the swamp. If it is considered necessary, construction of buildings intended for the promotion of tourism may be authorized by the Minister having environment in his or her attributions. It is also prohibited to carry out any activities, except those related to research and science, in reserved swamps. The order of the Minister having environment in his or her attributions determines the list of plains in which construction is not permitted and the swamps that are reserved according to assessments of the experts.

1.6.6. National irrigation master plan

This plan was developed in the year 2010 with the aim of development and management of water resources to promote intensive and sustainable irrigated agriculture and to improve food security (GoR, 2010). The potential of the country for irrigation as captured in the plan is estimated at 600,000 hectares, from this, the potential for wetland use for irrigation is estimated at 219 793 hectares (GoR,2010).

The estimated total area of marshes in the country is 275 689 ha, of which 55 896 ha are fully protected, 204 198 ha are non-protected but with limitations while 15 595 ha are non-protected without limitations. It is these latter two categories that have been summed up to carry the irrigation potential for the marshlands (GoR, 2010).

By the end of 2006, almost 11 000 ha of swampland had been reclaimed and used for rice production, and it was projected that by the end of 2020, 40 000 ha of swampland should have been reclaimed, and a plan for irrigating 1000 ha in Bugesera was prepared and implemented (GoR,2010).

1.6.7. Crop intensification programme

The Crop Intensification Program (CIP) is a cornerstone program for staples food activities within MINAGRI and the GOR. Launched in 2007, the CIP is the main policy adopted by the Rwandan government to bring about agricultural modernisation. The CIP aims for the prioritisation of six food crops (maize, wheat, cassava, beans, Irish potatoes, and rice), and at a uniformity in farming practices across the country. The programme focuses on four axes: (1) land use consolidation; (2) the distribution of fertilisers (namely DAP – diammonium phosphate – and urea) and improved seeds; (3) the provision of proximity extension services; and (4) the improvement of post-harvesting handling and storage. Since its implementation, the CIP has led to encouraging results in terms of productivity. Production of maize, wheat and cassava tripled between 2007 and 2010, bean production doubled, and rice and Irish potato production increased by 30% over the same time span (MINAGRI 2011).

2. APPROACH AND METHODOLOGY

2.1. Overview of the study approach and methodology

We adopted and modified the methods described in Troy & Wilson (2006) to develop the research methods which entailed; delineation of study area, typology development, data collection strategy, mapping, and data analysis (estimation of current economic values, and scenario analysis i.e. projections of future ecosystem services values based on feasible alternative options for the management and governance of the wetland) as discussed in the next paragraphs.

2.2. Study area delineation

The economic values of ecosystem services are typically expressed as per household, per individual, or per hectare values (Barton et al., 2019; He et al. 2015; Bateman et al.,2010; Siikamaki et al., 2015). This is an important step to factor in and take care of since even small boundary adjustments can have significant impacts on the final ecosystem service value estimates. Spatial boundary needs to correspond to the bio-geophysical boundaries, such as being consistent with the characteristics of wetland ecosystem biophysical features such as presence of hydrophytic vegetation associated with wetland such as phragmites (papyrus), soil type (mainly hydric soils), and areas of inundation (hydrographic boundary) as well (Covington et al., 2003).

2.2.1. The hydrology of Kigali City wetlands complex

The Kigali City wetlands complex is a mosaic of some 37 wetlands. The wetlands complex is located within the Lower Nyabarongo catchment. Lower Nyabarongo catchment is further divided into two catchments (c0mmonly known as catchment level 2) namely NNYL_1 (also called Nyabugogo catchment) and NNYL_2 (also known as Mambu/Base sub catchment). The thirty-seven (37) wetlands complex of Kigali City which are the subject of economic valuation in this study are all found in the Nyabugogo catchment (level 2 catchment). Nyabugogo level two catchment is comprised of Nyagugogo river which collects all the waters from the 37 wetlands and associated rivers and streams and hand over the waters to Nyabarongo river towards the south-western part of the city of Kigali.

Kigali City is drained by streams and rivers and the area can be delineated into twenty-five watersheds. Lake Muhazi lies along the northern border of the City of Kigali northeast of Gasabo District. The lake is the main source of water to the Nyabugogo River. The Nyabugogo River traverses the City of Kigali and has many tributaries such as the Mwange River, Rusine River and Marenge River on its upstream portion. It is later fed by other rivers from the urbanised part of Kigali such as the Rwanzekuma River, the Ruganwa River, the Mpazi River and the

Yanze River. (Nhapi et al., 2011). The main river (Nyabugogo) flows into the Nyabarongo River to the west of the city. The Nyabarongo River borders Nyarugenge and Kicukiro Districts along the south western edge of the City of Kigali and most of the rivers draining the City of Kigali flow into this river. The Nyabarongo River flows near Lake Rweru and is part of the Nile River Basin.

2.2.2. The ecology of the wetlands complex

The wetlands complex of the City of Kigali is a home to diverse flora and fauna, who have complex ecological interactions. Wetlands (such as Nyandungu-part of Gikono, Inyange, Ruliba, Kajevuba, Rubilizi and Gahanga) that have some natural areas have vegetation dominated by *Polygonum senegalense*, *Cyperus papyrus*, *Cyperus latifolius*, and *Typha domingensis*. These plant species are exploited for making mats, and also making ropes (i.e., from *Cyperus denudatus*). Some exotic and invasive plant species such as *Lantana camara*, *Mimosa pudica*, *Mimosa pigra*, *Centella asiatica*, and *Eichhornia crassipes* are also found in many of the wetlands and, in particular areas that have suffered from human disturbance.

Fourteen species of anuran (Amphibians) in six families have been recorded in wetlands in the City of Kigali. It is worth noting that they (Amphibians) are also ecological indicators of the health of a wetland, since most of them require clean water to lay their eggs and for the tadpoles to hatch. Nine (9) species reptiles have also been recorded in the city of Kigali wetlands, including *Crocodylus niloticus* (Nile crocodile) that is internationally protected by CITES. For birds, 82 species have been recorded in a cross section of the wetlands in the city of Kigali. The highest species diversity of the birds has been recorded at Nyandungu Wetland with 15.9% of the total birds recorded followed by Bumbogo, Gikondo Carlos and Kimihurura-Nyabugogo–Gitikinyoni Wetlands with 10.4%. Rwampara and Rugende-Kabuga wetlands have recorded the lowest bird count, respectively with just 6.7% and 5.5% respectively of all the birds recorded. Two important wetlands, Nyandungu and Bumbogo, are colonized by an endangered bird species, the grey-crowned crane (*Balearica regulorum*), while the wetland from Inyange factory towards Kiradiha and Kitaguzirwa Wetlands and onto the Nyabarongo River harbours a globally threatened species, Laniarius mufumbiri (*Papyrus gonolek),* which appeared on the CITES protected list.

In a study conducted by SMEC (2019), few mammals were recorded alive, however, there presence was inferred by the observation of their faecal pellets. Mammals play a vital role in ecosystems as herbivores, predators and prey. They provide ecological services as seed dispersers. About one hundred and ten invertebrate species belonging to 39 families were also recorded from fourteen wetlands in the same study.

2.2.3. The socio-economy of the Kigali City wetlands complex

The Kigali City wetlands complex is located in the city of Kigali. The city has an area of 730 and a human population 0f 1.3 million and a population growth of 4% per year as at 2012. Sixty-three per cent of the land within Kigali is used to grow food, and the Government of Rwanda recognizes the need to allow this food production to occur and the Urban Planning Code permits gardening and tree nurseries within residential areas. Kigali is Rwanda's major financial, economic, cultural and transport hub and contributes 50% of the country's GDP. The city's largest employment sectors are all water related activities, such as agriculture, fishing, and forestry, construction, mining, and quarrying operations are also significant components of the economy with manufacturing activities including brickmaking, textiles, paint, tanneries, iron, and sugar (REMA 2009), minerals are mined as well (REMA,2009). Economic drivers that have strong links with water resources are the tourism, fishing, water supply and irrigation from, in and around Lake Muhazi, as well as agriculture and the City of Kigali. The number of people living within the catchment has been estimated at 1,355,222, with 46.1% urban and 53.1% rural. 49% of the population are male and 51% female, 38% of the population is < 15 years and 48% of the population is below 20 years (EICV4).

2.3. Typology development

Typology has to do with the determination of land use and land cover types that exist in the delineated area of study or ecosystem of study. In this study, this was conducted through a review of existing literature on the Kigali

City wetland ecosystem or other wetlands of similar nature, and through GIS and remote sensing. The land use land cover determined are as shown in the table 5 below.

Table 3: Land use, land cover identified in the Kigali City wetlands complex

Land use, land cover	Area in ha (2018)
Papyrus (Phragmites)	408.1
Cropland	7,273.1
Fallow land (grass & crops	40
Built-up areas (commercial buildings, public facilities and residences)	1050
Green spaces (parks and river)	388.8
Total	9,160

Source: Adopted from REMA, 2012; MoE, 2019

This was followed by a review of economic studies to determine whether ecosystem service value coefficients have been documented for these cover types in a similar context.

2.4. Data collection strategy

2.4.1. Data Needs, sources and types

The table below shows the various data needs that are necessary in order to for the study objectives to be achieved. The information needed is presented for the potential ecosystem services that are likely to be valued in this study, the nature of the data, the potential sources of the data, and the preferred valuation method

Table 4: Data Needs, and Sources

Potential Product/ services	Valuation Method	Data needs	Potential Sources of data
Agricultural crops	Market prices	Production volume, local units and conversion, cost of production, and Market prices	Local market prices and quantity supplied, Rwanda Bureau of Statistics, District level responsible offices, literature and annual reports
Domestic water supply	Market price	Number of households whose water source is from the wetland Average water use per household Water use price	Rwanda Bureau of Statistics, state and national level reports
Communal grazing	Market price	Number of cattle which graze from the wetland	Review of existing literature, national and state level reports
Livestock watering	Market price	Number of cattle which drink water from the wetland, average amount of water consumed per head per day	Local market price, national and state level reports
Fish	Market price	Amount of fish extracted per annum, cost of fish extraction, price of fish	Local market prices, literature, reports at federal & state levels, Rwanda Bureau of Statistics

Fodder	Surrogate, Market prices	Quantity in kg, sacks and other local measures to be converted to kg, estimated cost of production	Household surveys, Local market prices, literature, reports at federal & state levels, Rwanda Bureau of Statistics
Carbon sequestration	Market prices	Above ground Biomass (AGB), Below ground biomass) (BGB, Soil biomass), international voluntary carbon market, total area under vegetation, IPCC carbon default values	Existing literature on estimated CO_2 sequestration at local or regional level, IPCC reports Reports on National and/or regional and/or local level carbon sequestration levels
Flood control	Market price and/ or avoided cost	Number of Households around the wetland, estimated cost that would have been incurred for flood control	Available literature, global and TEEB database
Water purfication	Market price and/ or avoided cost	Total number of households that uses wetland as a major source of water, cost that would be incurred for water purification	Exciting literature, national and regional level report
Soil protection (prevented soil erosion)	Avoided cost	-cost of 1 ton of sediment removal -ratio of sediment entering rivers or reservoirs to total soil lost -Soil erosivity for restored and non-restored forest (tons/ha)	Literature, reports from Ministry of Water Resources & Irrigation, Rwanda National Lands Commission, and State Lands Commissions, National and/or regional and/or local level soil maps
Education & research	Averted cost Revealed price Value Transfer	Cost learning institutions would incur to visit other wetlands of similar nature	Annual reports from learning institutions/ market information, existing literature
		Funds spent by researchers	Records from research clearing institutions, and research institutions
Habitat for biodiversity	Revealed price and/or value transfer	Expenditures (budget allocated) for biodiversity conservation by national and international actors (agents)	National budget allocation, budget set by international actors and NGOs, annual reports and literature

2.4.2. Sampling procedures and strategy

Purposive sampling will be used for qualitative data collection methods such as key informant interviews, and focus group discussions. Data collection through purposive sampling become adequate and reliable once saturation is reached, i.e., a point in which any new respondent interviewed or more focus group discussion adds no new information, Guest et al., (2006) proposed that for Key Informant Interviews, saturation is reached at the 12th respondent for a homogenous group/population. In this proposed study, three kinds of target population have been proposed. They include government agents with interest and mandates on wetland resources, civil society groups with interest in wetland resources, and local community user groups. Therefore, to achieve the minimum requirements for saturation, a total of 36 respondents, 12 for each of the three stakeholder groups will be conducted. For focused group discussions, Guest et al., (2017) advice that a study objective can be sufficiently addressed by between three and six focus group discussions for homogenous groups. Therefore three (3) focus group discussions will be held for each study site, totalling to nine (9) focus group discussions.

2.4.3. Data collection

Both primary and secondary data were collected and analysed. Wetland related policies in particular and environmental related policies, strategies, and plans in general are briefly reviewed and incorporated to understand the enabling policy and strategy environment to implement wetland conservation activities and to support integrated development decisions.

Primary data were collected through Key Informant Interviews (KII) and Focus Group Discussions (FGDs). KIIs and FGDs provided us with vital information that were helpful in understanding the local contexts, and to develop possible scenarios for wetland conservation options and to value the wetlands ecosystem services.

Given that value transfer approach was the main plausible option considering the circumstances of the study; much of the information has been extracted from available secondary sources and literatures. The existing TEEB database and reports and valuation studies and the global Ecosystem service valuation database for data and knowledge sharing at Ecosystem Service Partnership (ESP) were good assets for this purpose. Population data of the wetland site and national level, activities performed in and around the wetlands, benefits obtained from the wetland areas, challenges of the wetlands and related information were generated from secondary sources. Statistical bulletins, published and unpublished materials about these issues were also consulted as well.

2.4.3.1. *Key Informant Interviews (KIIs)*

KIIs planned to be carried out with selected experts at different levels of the administrative and institutional hierarchy to solicit information related to the wetlands using a checklist that wa prepared as a guide for interviewing[1] and consultation process. In addition, information about the existing situation of the wetlands, stakeholders impacted by the wetlands, wetland conservation options given the local circumstances, viability of the different wetland conservation options, socioeconomics and biophysical characteristics of the wetland area, current estimates of costs and benefits from alternative wetland conservation options (if any), expert outlooks of the state of the wetlands and other information are outlined and obtained from the KIIs workout. The Key informant checklists and potential stakeholders is developed and annexed.

2.4.3.2. *Focused Group Discussions (FGDs)*[2]

Again, more qualitative information expected be solicited and explored through the focused group discussions. The FGDs participants will further communicated for avail information and consultations. The lists of guiding questions that will be used during focus group discussions with potential stakeholders is developed and annexed.

2.5. Mapping

Map creation involves GIS overlay analysis and geoprocessing to combine input layers from diverse sources to derive the land use/ cover map. In this study, the land use cover in Kigali City was analysed and it revealed that the existing land uses include; water body, phragmites, crop land (within the wetland & buffer zones) grassland, these maps are facilitators for the analysis and modelling of the stocks and flows of wetland ecosystem services using various valuation techniques including value transfers as shown in table 8 with the acreage extent for each land use, and land cover.

1 Leading or guiding KII questions and checklist are annexed
2 Leading or guiding key FGD questions are annexed

2.6. Baseline economic values

Once each mapping unit is assigned a cover type, it can then be assigned a value multiplier from the economic literature, allowing ecosystem service values to be summed and cross-tabulated by service and land cover type.

The total ecosystem service value flow of a given land use/cover type is then calculated by adding up the individual, non-substitutable ecosystem service values associated with that land use/ cover type and multiplying by area as given by the general equation below.

$$AEV(ES_i) = \sum_{k=1}^{n} A(LU_i) * AEV(ES_{ki}) \quad (1)$$

Where:
$AEV(ES_i)$ = annual economic value per unit area for ecosystem service type k generated by land use or cover type i,
$A(LU_i)$= area of land use or cover type i

The economic value of individual ecosystem services is initially estimated using various techniques and models as indicated in the table 7 below

Table 5: Models for estimation of the baseline economic values of ecosystem services

Ecosystem service	Valuation technique	Model	Model Explanation
Domestic Water supply	Market price	V_w=l*m*n*365 day	l= Households dependent on wetlands for water supply
			m=Average use of water per household
			n= Market price per m³ (US$)
			V_w= Gross annual value of water for domestic consumption (US$)
Water for Irrigation	Production function	1. Agronomic model	Y= Yield in tons; i= location; c= crop type; LD= Land size; W= Irrigation water; LA= labour; S= seed
		$lnY_{ic} = \ln a + blnLD + clnW + dlnLA + elnS + f\ln CH + glnI + hlnCA$	CH= chemicals; I= implements; CA= capital; a= is the specific total factor productivity which explains effects in total output (CV) not caused by inputs; b to g = are the output elasticities of the input variable
		2. Economic model	MP_W = Marginal product of irrigation water
		$MP_W = \frac{\partial lnY}{\partial lnW} \cdot \frac{Y}{W}$	P_{shadow} = Shadow price of irrigation water
		$P_{shadow} = P_{output} \cdot MP_W$	P_{output}= Output price of irrigation water

Water for Livestock	Market price	Vl_w=p*q*r*365 Adopted from (Kakuru et al., 2013)	Vl_w= value of livestock grazing p= Number of cattle obtaining water from wetlands q= Amount of water consumed per day per head of cattle r= Cost of water per 20 liters (US$)
Crop farming in the wetland	Market prices	$T_v = (Q_i * P_i) - C_i)$	T_v is the economic value of the product/output, Q_i is the quantity of good/product; P_i is farm gate price of the product, C_i is the cost of production. The value of costs and benefits will be calculated per hectare to develop the enterprise budget
Livestock grazing in the wetland	Market price	Vg=o*p*365 Adopted from (Kakuru et al., 2013)	Vg= value of grazing o= Number of cattle raised in wetlands p= Average value of pasture consumed per day per animal (US$)
Grass harvesting	Surrogate, Market prices	$T_v = (Q_i * P_i) - C_i)$	Where, T_v is the economic value of the product/output, Q_i is the quantity of good/product; P_i is farm gate price of the product, C_i is the cost of production,
Capture fisheries	Market price	$V_f = (Q_f * P_f) - C_f$	V_f= Value of fish Q_f= Quantity of fish harvested P_f= Price of fish, say, per tonne C_f = cost of extracting fish, say, per tonne
Products from Papyrus & other related grasses	Market price	$T_v = (Q_i * P_i) - C_i)$	Where, T_v is the economic value of the product/output, Q_i is the quantity of good/product; P_i is farm gate price of the product, C_i is the cost of production,
Fuelwood	Market price	$T_v = (Q_i * P_i) - C_i)$	Where, T_v is the economic value of the product/output, Q_i is the quantity of good/product; P_i is farm gate price of the product, C_i is the cost of production,
Natural medicine	Market price	$T_m = (Q_m * Pm))$	T_m- the economic value of medication Q_m – number of people treated by natural medication

			P_m- estimated price of medication
Pottery	Market price	$T_v = (Q_i * P_i) - C_i)$	Where, T_v is the economic value of the product/output, Q_i is the quantity of good/product; P_i is farm gate price of the product, C_i is the cost of production.
Carbon sequestration & storage	Market prices	- $V_R = (Q_r * P_c * S_r) - (Q_d * P_c * S_d)$ This is adapted from InVEST model	V_R=the carbon sequestration value of conservation transition; Q_r=carbon sequestration (CO_2) in restored area; P_c=the international carbon sequestration price; S_r = the area restored (ha); Q_d is the carbon sequestration (CO_2) in degraded area; S_d is the area degraded (ha)
*Water purification	Market price and/or avoided cost	Vp=A*B Adapted from (Verma and Negandhi, 2011)	V_p is the economic value of water purification A= total purification cost per household in the absence of the wetland B= total number of households who uses the wetland as a source of water
Sediment control	Avoided cost	$V_k = K * G \sum_{i=1}^{n} S_i * (d_i - d_0)$	Where V_k is the economic value of soil-erosion regulation; -K is the cost of a ton of sediment removal; -S_i is the area of forest-vegetation types in hectares; -G is the ratio of sediment entering rivers or reservoirs to total soil lost; -d_i is the erosivity of non-restored land (tons/ha); and d_o is the erosivity of restored land (tons/ha).
Flood control	Market price and/or avoided cost	V_w= A*B Adapted from (Merriaman, 2016)	V_w - value of water attenuation A- Total household likely damaged by disaster without wetland ecosystem B- Estimated cost per household

		Adapted from (Merriaman, 2016)	A- Total household likely damaged by disaster without wetland ecosystem B- Estimated cost per household for flood control or storm surge protection or wave attenuation
Education & research	Averted cost of travel	$V_e = A*B$	V_e =Value of wetland for education A= Total trips made likely to be made by schools for wetland educational tours in a year B= Estimated cost per trip to the nearest wetland of similar nature
	Research expenditures	$\sum_{i=1}^{n} RE_i$	RE= research expenditures
Habitat for biodiversity	Conservation budget expenditures	$\sum_{i=1}^{n} CE_i$	CE= Conservation expenditure
Nearly all Ecosystem Services	Value transfer	$In(y) = a + X_s b_s + X_p b_p + X_e b_e + u$	where a is the usual constant term, u a vector of residuals (assuming well behaved underlying errors), and the vectors $b.$ contain the estimated coefficients on the respective explanatory variables.

2.7. Scenario Analysis

2.7.1. Overview

In this section we assess how the baseline economic values will change based on the decision that could be taken towards managing of the wetlands. Following a review of the literature and discussions with stakeholders, two possible scenarios of wetlands management have been considered in this study as discussed in the next paragraphs.

2.7.2. Status quo (also the business-as-usual) scenario

This scenario is largely driven by the CIP (Crop Intensification Programme) and SSP (Strategic Plan for Agricultural Transformation). Rwanda's agricultural sector covers plant production, animal husbandry, fisheries and productive forests and contributes approximately 30% to the country's GDP, constitutes 50% of export and absorbs 70% of the labour force. Agriculture is directly linked to water, the environment and other sectors in complex relationships and is the backbone for achieving food security, improved livelihoods, and socio-economic development. Goals for 2024 include: Doubling irrigation in marshlands and on hillsides to 102,284 ha; Putting wetlands under irrigation; Quadrupling fish production (a near-non-consumptive use of water; Doubling fertiliser inputs per hectare (which may lead to higher pollution levels in waterbodies);

Rolling out support packages such as agroecology, integrated pest management, climate smart agriculture (CSA) and IWRM in irrigation to protect the environment and water quality while building climate resilience (MoE, 2018.).This scenario is regarded as the status quo given that more than 70% of the Kigali wetlands complex is already under crop framing. We however, argue that there will be no more reclamation of the remaining less than 30% of the wetlands for agricultural production.

2.7.3. The implementation of Kigali City Wetlands Master Plan

In 2019, the Ministry of Environment in liaison with other stakeholders, developed a master plan for the management of the Kigali wetlands complex known as the "Kigali Urban Wetlands Master Plan". The master plan is elaborated with proposed strategies and targets for its protection. Proposed strategies are: (1) Conservation and restoration of encroached wetlands and waterbodies; (2) Resettlement of settlements encroaching or endangering wetlands or those subject to flooding risk; (3) Reducing wetlands informal and non-sustainable cultivation and mineral extraction; (4) Restoring natural drainage network; (5) Use wetlands for recreation activities; and (6) Promotion of green economy activities and jobs (sustainable farming, horticulture, fishing and clay extraction) (MoE, 2019).

The wetlands master plan proposes three management strategies for the wetlands in Kigali City, and five zones which include:

2.7.3.1. Buffer Zone

Buffer zones are established by Law and are set to establish a minimum distance between developed areas and protected sites. In the case of wetlands, the buffer zone is set at 20 m. While all areas included within the official wetlands boundary are automatically considered Public Domain, buffer zones can also be under private property. Although privately owned plots may be zoned by the Kigali Master Plan with different uses (commercial, residential), wetlands buffer zones supersede any other regulations. Plots that are partially affected by the buffer zone will be able to transfer Development Rights on that specific portion to the remaining developable part of the plot as prescribed by the City of Kigali Master Plan (MoE, 2019).

2.7.3.2. Rehabilitation Zone

Areas showing signs of a diverse wetlands ecosystem that previously existed but are now under different uses, have been studied and their boundaries have been delineated as a Rehabilitation Zone. Planning intent behind creation of such zones is to re-establish a wetlands ecosystem (MoE, 2019).

2.7.3.3. Sustainable Exploitation Zone

There are certain wetlands which are to be rehabilitated and their ecosystem improved, while retaining their existing economic/utilitarian/recreational value. It is recommended to follow sustainable practices while deploying resources offered by the wetlands. Such zones are delineated as sustainable exploitation zone (MoE, 2019).

2.7.3.4. Conservation Zone

The wetlands which are still supporting significant areas of natural vegetation, where water is permanently present and that represent a valuable ecosystem, have been delineated as a Conservation Zone. Wetlands with these existing natural values are to be fully conserved (MoE, 2019).

2.7.3.5. Recreational Zone

Wetlands which offer potential to be developed as recreational spaces due to their proximity to strategic areas in the Kigali Master Plan have been identified as a Recreational Zone. There are certain wetlands which are currently under other uses that can be transformed with a focus on public open spaces, passive and active recreational uses and these are also delineated as recreational zone(MoE, 2019).

Based on the Kigali City Wetlands Master Plan, the wetlands that have been assigned into either of the three strategic management goals are shown in table 7 below.

Table 6: Wetlands Land use, land cover change proposed by the Kigali City Master Plan

Management goals under scenario 2	Wetlands assigned	Total area (ha)
Conservation	Ruhosha-Ayabaraya; Kanyetabi; Rwintare; Nyabarongo-Aval; Nyabuhoro-Kiruhura; Nyabarongo-Amont;	3888
Sustainable exploitation	Kitagiziwa; Degi-Nyarufunzi; Rugende-Isumo; Rufigiza-Akagogo; Kururuma; Rwamageni; Kamusenyi; Nyabugogo-Kabuye; Byabagabo; Gikono; Kajevuba; Misare; Kaziramuboro; Nyacyonga-Mulindi; Yanze; Nyabuhoro; Mugasagara; Kibobo; Nyagasozi-Kigozi; Kiradha; Mulindi-Kanombe; Rwabashamana	3851
Recreation and tourism	Mwanana-Mulindi-Kanombe; Nyabugogo; Rwenzangoro; Rwampara; Rugenge	1421
Total		**9,160**

3. RESULTS AND DISCUSSIONS

3.1. Kigali City wetlands complex land use land cover characteristics

3.1.1. Papyrus (Phragmites)

Phragmites are the main vegetation types found in wetlands. About 408.1 hectares of undisturbed wetlands in the delineated wetlands area in Kigali City have abundance of phragmites. Mapping study showed that papyrus dominated land use among the Kigali wetlands occupied a land area of 5221 hectares in 2012, and by 2018, this reduced to 408.1. indicating a decline by 4580.08 and if we assume a curvilinear rate of change of quadratic type then the annual rate of change in papyrus land cover is on the decline by 34% per year. In this study though, we argue that in either of the two scenarios being explored, there will be no more loss of the papyrus landcover.

3.1.2. Cropland

Cropland land use and landcover represent growing of crop within the wetlands. The main crops grown within the wetlands of Kigali include rice, sugar cane, maize, Irish potato among others. Mapping of the land use landcover by crop land type showed that in 2012, cropland occupied a total of 3600 hectares of the Kigali City wetlands, and in 2018, the proportion of the wetlands that was under crop farming was 7273.1 hectares, a positive change of 3494ha signifying an increase in wetlands use for crop farming (MoE, 2019). Again, if we assume a curvilinear trajectory of quadratic form, then the annual rate of adoption of wetlands for crop farming is 11.24%

3.1.3. Fallow land (Grass and crops)

Fallow land represent cropland that has been left unfarmed. They represent areas within the wetlands delineated areas that have been used in the past for crop farming but are no longer farmed. While there was no evidence of such fallow land within the wetlands, the 2018 mapping of the wetlands showed that around 40 hectares of land within the wetlands was lying fallow. This has been taken to mean that there was an increase of 40hecatres of the six-year period considered. In this study such fallow land has been considered to represent grassland.

3.1.4. Built-up areas

Built-up areas representing commercial buildings, public facilities and residences are also another type of land uses found in the wetlands, in a 2012 mapping study of the Kigali City wetlands, the built-up areas represented 247.4 hectares and by 2018 mapping exercise, built-up occupied a total of 1050ha representing an annual increase of about 27.45% (MoE, 2019).

3.1.5. Green spaces

Green spaces represent parks and rivers and these occupied 91.6 hectares in 2012, and increased up to 388.8 hectares in 2018 representing an annual increase of 27.25%. For purposes of our analysis, we make two assumptions under this land use category. One, is that the water bodies component of the green spaces comprises rivers, streams, ponds, and lake (Majorly Lake Muhazi component found on the Kigali City), and this we assume to measure 215.4 hectares; the second component of the green spaces is assumed to largely comprise of grass covered areas and this measures 173.4 hectares attributed to Mwanana Mulindi-Kanombe wetlands.

3.1.6. Summary of land use change (2012 and 2018)

Based on the synthesis presented in above sub sections of section 3.1, table 8 below presents a summary of the synthesis. While the table has a column on annual changes that took place between 2012 and 2018, we do not imply that such trends are trends alive going into the future.

Table 7: Projected land use, land cover change

Land use, land cover	Area (ha) (2012)	Area ha (2018)	Share from or within the change	Change in terms of area	Annual rate of change
Marshland	5221	408.1	-49.99	4580.08	-34.00%
Cropland	3600	7273.1	+38.15	3494	+11.24%
Fallow land (grass & crops	-	40	+0.41	40	+85.95%
Built-up areas (commercial buildings, public facilities and residences)	247.4	1050	+8.33	763.02	+27.45%
Green spaces (parks and river)	91.6	388.8	+3.08	282.12	27.25%
Total	**9160**	**9160**	**0**	**9160**	-

3.2. Baseline Economic Values of the Ecosystem Services

3.2.1. Crop production

Wetlands mapping for 2018 revealed that crop land occupied 7273.1 hectares of the wetlands complex (i. e. 79% of the total wetlands). The kinds of crops reported to be grown in the wetlands, including plot sizes, yields, and average values as computed by the SMEC technical study towards development of the Kigali City Wetlands Master Plan are presented in table 8. The total gross economic value of crop production within the wetlands is **US$US 20,357,035** per year, while the total variable production cost was $US **4,769,497,** and the net economic value was **$US 15,587,538.** The main crops grown in the wetlands include; Bananas, Flowers, Irish potatoes, Rice, Soybeans, Sweet potatoes, sugarcane, Tomatoes, Egg plants, Cabbages, Pigweed, Cassava, Maize, and Beans.

Table 8:Value of crop production Kigali wetlands complex

Crop type	Total area (ha)	Estimated yield (kg/ha)	Price ($US/kg)	Gross value	Total Variable Cost ($US)	Net Economic Value
Bananas	1744	30,000	0.12	6,278,400	502,359	5,776,041

Flowers	203	250,000	0.025	1,268,750	889,085	379,665
Irish potatoes	174	18,000	0.3	939,600	610,268	329,332
Rice	327	4,000	0.25	327,000	85,126	241,874
Soybeans	131	3,200	0.2	83,840	23,469	6,0371
Sweet potatoes	1512	16,000	0.2	4,838,400	532,128	430,6272
sugarcane	1039	50,000	0.015	779,250	163,592	615,658
Tomatoes	615	19,000	0.2	2,337,000	818,354	1,518,646
Egg plants	462	18,000	0.25	2,079,000	623,376	1,455,624
Cabbages	308	25,000	0.1	770,000	385,270	384,730
Pigweed	155	950	0.1	14,725	1,469	13,256
Cassava	242	17,500	0.08	338,800	60,885	277,915
Maize	181	4,800	0.15	130,320	31,215	99,105
Beans	181	3,800	0.25	171,950	42,902	129,048
Total	7273			**20,357,035**	**4,769,497**	15,587,538

Source: Adopted from MoE,2019

Figure 1: Crop farming in Ayabaraya wetlands in Kigali

3.2.2. Pasture for livestock production

Wetlands mapping shows that by 2018, there were over 40 hectares of fallow land in the entire wetlands complex that could serve as a source of grass for the livestock keepers, and hay makers. While there was a trend in wetlands change between 2012 and 2018. Here we assume that the change has been halted in favour of papyrus regeneration so that there is no loss of papyrus land and also other wetlands uses are retained so that the grassland area remains at 40ha even in our baseline year of 2020. Drawing from the findings conducted in Rweru-Mugesera wetlands complex, a study that is a sister to this study, a hectare of grassland yields a gross value for grass harvesting of $US 4416. The gross economic value of the grass for pasture for the Kigali City wetlands complex was $**US 176,640**. The average cost of harnessing grass per hectare based on the findings from the

Rweru-Mugesera was $US 3487.67, therefore borrowing these values, then the average cost of grass harvests from the Kigali City wetlands complex is $US 139,507.

3.2.3. Bricks and clay making

Bricks making, is also one economic activity that typically take place in a wetlands, even though the practice involve degradation of wetlands quality unless accompanied with elaborate restoration and rehabilitation plans. The economic value estimation of this service entailed value transfer from studies conducted in Rwanda, and else within the East African region. A study conducted in Rwanda towards the development of the Rwanda Master Plan by SMEC (2019) showed that brick making occurs in the Byabagabo, Kamusenyi, Kanyetabi, Nyabuhoro and Rugende-Isumo Wetlands. Based on the findings, 1ha of wetlands produces a total 3 million blocks of bricks and a block of brick was sold at an equivalence of $US 0.1. Total gross value of bricks per hectare is there $USD 300,000. It was also reported in the same study that a total of 5 hectares of wetlands is harnessed for bricks making, and sixty percent of the revenues represent production cost. Therefore, the total wetlands value for bricks making is a gross value of $US **1,500,000** with total cost production cost of **$US 900,000.**

3.2.4. Papyrus harvesting

The wetlands area occupied by papyrus in 2018 was 408.1 hectares, under the assumption that loss of papyrus area is halted, the size of papyrus holding land in 2020 was assumed to be 408.1 hectares. Papyrus is harnessed by for mulching, mat making and sometimes they are used for rope making. Based on a review of a number of studies including Rweru-Mugesera wetlands sister study, the average economic value of one hectare of papyrus is $US 318, therefore the gross total economic value of the Kigali City wetlands is **$US 129,776**, the average cost of harnessing papyrus products was established at $US 57 , therefore the total cost of production of papyrus production was $**US 23,261.7.**

Figure 2: Reeds harvested from Nyabarongo wetlands

3.2.5. Sediment control

There are a number of irrigation dams projects and future ones downstream of the Kigali City wetlands in both Rwamagana and Bugesera districts that could be affected by sediments since there usually exists concerns about loss of dam capacity due to sedimentation. It is estimated that more than 0.5 percent of the total reservoir storage volume in the world is lost annually as a result of sedimentation (Palmieri et al., 2003). Adeogun et al (2018) notes that for a multipurpose dams' typical costs that sediment pose on dams include; dredging costs, avoided damage to turbines, and avoided loss of power production if the dams also serve as source of power generation. The City of Kigali lies within an area with medium to high-risk soil erosion and soil present on slopes greater than 5% slope are susceptible to heavy erosion. About 17% of the City of Kigali is on land with slopes of more than 30%. Inappropriate developments including unplanned settlements on steep slopes has caused extensive soil erosion in some areas. This results in heavy sediment loads in streams and rivers and high rates of sedimentation within wetlands.

Wetlands capture sediments before they are swept downstream helping to among others retain top soil, decrease turbidity of water, and decrease sediment accumulation downstream which would be useful for the ongoing works of construction of the Nyabarongo II multi-purpose dam that is earmarked for generation of hydropower and water for use by the local community, and especially relevant to this study location would be irrigation dams that are directly downstream of the Kigali City wetlands complex. The utility or exchange value of such roles that wetlands play in capturing the sediments thereby saving the stakeholders dredging costs can be estimated using number of valuation methods such as damage cost avoided, replacement cost method among others. Typical data needed for such an estimation may include; cost of 1 ton of sediment removal, ratio of sediment entering rivers or reservoirs to total soil lost, Soil erosivity for restored and non-restored wetlands (tons/ha). In this study though, such data were not accessed, therefore alternative method of value transfer was adopted. Borrowing from Adeogun et al., (2018), the total value of avoided costs related to sediment export to hydropower dams is equivalent to $US 23.28 per ton of sediments (covering dredging costs, avoided damage to turbines, and avoided loss of power production). Given that a hectare of wetlands retains around 78.4 tons of soil per year (REMA, 2019), and that the total papyrus and grassland, green spaces (excluding water bodies assumed to be 188.8 ha from the total of 388.8) is 648.1ha, the total economic value of sediment control role of wetlands for hydro-power generation is therefore estimated at **$US1,182,881** per year. However, for irrigation dams, then the focus is only on dredging and this would cost around $US 1.72 per ha, being the adjusted (2020) average value from three studies namely; $ US 0.66 per ton $^{-1}$for a study conducted in India by Verma et al., (2015); $US 4.011 for a study conducted in Nigeria by Adeogun et al., (2018); and $US 1.98 for a study conducted in Kenya by Langat (2015). Based on this value function transfer and the relevant spatial area, the total economic value of $**US87,375.**

Figure 3: Settlements on hilly areas around Nyabarongo wetlands exposing land for sediment transport

3.2.6. Water purification

When loads of nutrients, sediments and pathogens entering rivers and water supply reservoirs are elevated due to anthropogenic activities in catchment areas, these can lead to loss of reservoir capacity, deterioration in raw water quality in reservoirs, and impacts on downstream ecosystems and their capacity to supply ecosystem services. Natural areas, especially wetlands and the vegetation alongside rivers, may remove some of these anthropogenic inputs before they enter drainage systems, thus ameliorating these damages. The wetlands of Kigali City, therefore have a role in the purification of waste water from the city that find their way into the Nyabarongo river and with the potential to pollute downstream communities, especially at the Nyabarongo multi-purpose dam that will also supply communities with water for agricultural and even domestic use.

The exchange and utility value of water purification role of a wetlands can be estimated using among others, damage cost avoided method, replacement cost, production function method, among others. Using these approaches typically require estimation through cost of replacing an ecosystem services with artificial or man-made products, infrastructure or technologies, in terms of expenditures saved (Emerton, 2009). When applying infrastructure or technologies, the method assesses the cost of replacing wetlands's role in water purification and waste assimilation services with artificial waste treatment plants or water supply system. Data needed include: bill of quantities for the construction, operation and maintenance, and decommissioning of a sewerage treatment facility; or bill of quantity for cost of construction, operation, maintenance, and decommissioning of a water supply system, level of pollution of water at the start of the wetlands ecosystem, level of water pollution at the lower reaches of the wetlands. Useful parameters include; Nutrients such as nitrates, phosphates and others, turbidity among others.

In this study, however, such data were not accessed, therefore value transfer method was adopted. The meta-analysis of the water purification role of wetlands is valued at $US 2043 per hectare of a marshland, being representative of the cost of water purification by a man-made water filtration facility that is equivalent to what a hectare of marshland would purify. If apply this to the wetlands of Kigali City wetlands area of 836.7 hectares (papyrus, grassland, and green spaces), then the total value of water purification role currently played by the wetlands is equivalent to $**US 1,709,378** per year

Figure 4: Nyabarongo river near Kigali City

3.2.7. Flood control for disaster mitigation

Wetlands are known to regulate the impacts of floods. Some of the documented impacts of flooding in Rwanda include; loss of lives, the displacement of affected population as well as damage to infrastructures (roads, bridges, houses, schools, and other properties), crops and a serious environmental degradation. Floods and landslides usually originate from heavy rainfall, which causes rapid and unpredictable surges in the flow of rivers downstream mainly in rain season (from March to June) and from (October to December). The two predominant types of floods are: localized floods caused by exceptionally heavy rains and run-offs ii. widespread floods caused by overflowing rivers and their tributaries. They also cause physical damage by washing away structures, crops, animals and submerging human settlements.

Typical economic valuation methods commonly applied in the valuation of flood control role of wetlands include; mitigative/avertive expenditure, production function, damage cost avoided, replacement cost method, among others. While the classical data needs for such an exercise may include; amount of maximum water storage capacity of the wetlands, discharge rate of the wetlands, retention period of the wetlands, man-made flood control measures that would mitigate or avert the wetlands loss and costs of its construction and operation. However, such information was not accessed. Therefore, a meta-analysis data on tropical freshwater wetlands role in flood water regulation found in ESP database show that 1 hectare of a marshland (Phragmites) has economic value of $US 3638 which is the amount money that required to establish man made infrastructures that regulate an equivalent of what a hectare of marshland does, with a marshland area pf 408.1 ha, the wetlands of Kigali City currently have an economic value of **$US 1,490,789**.

Figure 5: Flood water held by Nyabarongo river near Kigali City

3.2.8. Carbon sequestration for climate change mitigation

Freshwater water tropical wetlands largely comprising of marshlands and reclaimed wetlands also provide climate regulation ecosystem services (Wong et al.,2017). These wetlands play an important role of carbon sequestration and storage. Freshwater marshlands are known to sequester and store carbon thereby contributing to climate change mitigation (MEA, 2005).

The amount of carbon storage and sequestration benefit is estimated by adopting the formula used by Murray et al (2017) as shown in equation 8

$$GHG\ Benefit\ Flux_{it} = CS_{it} + AvCO2_{it} - M_{it} \quad (8)$$

where is the habitat type, and is time expressed in years; is the annual carbon sequestration rate, taken as 1.29 metric tons of carbon per hectare per year (Mitsch., 2021), which continues as the habitat is retained; is the emissions avoided from the habitat's conversion; and represents the annual methane emissions that continue to be emitted as the habitat remains intact (Murray et al.2011). Similarly, in computing and adjusting the carbon biophysical values to the reference year relative to the years in which site studies were conducted, one main assumption that was made is that methane gas emissions from the naturally occurring wetlands is subtracted from creditable avoided emissions, and is assumed to be 1.85 tons of carbon dioxide equivalents per hectare (Murray et al.2011).

Table 11 shows carbon storage and sequestration across various wetlands land uses and the carbon pools.

Land use	**Area in ha**	**A G tCO2e / ha**	**B G tCO2e / ha**	**SC tCO2e /ha**	**D M tCO2e**	**Sequestration**	**Total tCO2e / ha**	**Total tCO2e**
Phragmites	408.1	84.41	159.65	2506.61	20.92	4.73	2776.32	1,133,016
*Grassland	213.4	5.51	95.42	397.83	1.10	-	499.86	106,670
Cropland	7273.1	6.97	3.30	436	0.37	-	446.64	3,248,457
**Water bodies	215.4	-	-	-	-	-	-	-
Built up areas	1050	-	-	-	-	-	-	-
Total	9,160						3722.82	4,488,143

*For purpose of carbon accounting, grassland is considered as comprising the land use for fallow land (40ha), and vegetation component of the green spaces land use (assumed to be 173.4ha, being the size of Mwanana-Mulindi-Kanombe

**Water body which is part of green spaces is assumed to cover 215.4 being the portion left after subtracting the Mwanana-Mulindi-Kanombe wetlands.

Where AG= Aboveground Carbon; BG= Belowground Carbon; SC= Soil Carbon, DM=Dead matter carbon

Source: Adopted from BIOFIN et al (2019)

Wetlands are also known to have natural emissions for greenhouse gases, largely methane gas, in cases where paddy rice is grown using inorganic fertilizers then the problem of greenhouse emissions gets compounded due emissions related to these fertilizers. In this study we assume that there are natural methane gas emissions associated with the papyrus occupied areas of the wetlands. The natural methane gas emissions figure is adopted from Murray et al (2011) report which is 1.85 tons of carbon dioxide equivalence.

Table 9: Natural greenhouse gas emissions from the wetlands

Land use	**Land use area (ha)**	**Emissions from methane (t CO2e/ha)**	**Total (tCO2e)**
Papyrus (Phragmites	408.1	1.85	754.99
Grassland	213.4	1.85	394.79
Cropland	7273.1	1.85	13,455.24
Water bodies	215.4	>=0	0
Built-up areas	1050	>=0	0
Total	9,160		14,605.02

Source: adopted from (REMA, 2012; MOE, 2019)

We subtract this figure from the total of tons of carbon dioxide equivalence and then we obtain 4,473,538 tons of carbon dioxide equivalence mitigation potential. If we consider a carbon price of $US 10 per ton of carbon dioxide equivalence, then the current economic value of carbon is **$US 44, 735,380**

Figure 6: Phragmites and cropland land use at Ayabaraya wetlands in Kigali

3.2.9. Tourism and recreation

There is an ongoing work on for establishing an urban wetlands recreation park in Nyandungu wetlands by the Rwanda Environment Management Authority (REMA) as documented by the SMEC (2019) technical study report towards the development of the wetlands master plan. According to the documentation, the project will provide social and economic benefits to the communities and support innovative approaches in restoring wetlands ecosystems. The project is expected to cost around $US 2.41 million. It is projected (based on the documentation by SMEC) that the project would make **$US 1 million** profits in the first 12 years of operation, this translates into an annual benefit of $**US 83, 333.**

3.2.10. Habitat for biodiversity conservation

Wetlands provide conducive environment for a host of animals to thrive in. They act as nurseries and breeding grounds for some fish and other aquatic animals, and also offer protection to some species from predators. Kigali City wetlands complex is also a home to more than diverse flora and fauna such as *Polygonum senegalense*, *Cyperus papyrus*, *Cyperus latifolius*, and *Typha domingensis*, *Cyperus denudatus* plant species. Some 14 species of amphibians are found in the wetlands among other types of animals. The primary economic valuation approach preferred for habitat for biodiversity included revealed price method, followed by value transfer in the absence of adequate data. The revealed price method favoured is based on the funds allocated by national government agencies, local governments, and non-governmental organizations and spent for the conservation of the wetlands complex in the year 2020. However, there was inadequate information on such expenditures, therefore value transfer approach was used, in adopting value transfer approach, a meta-analysis of biodiversity conservation value studies synthesized and archived in ESP database showed that the economic value of a hectare of a tropical freshwater wetlands was $US 3,427. Working with this value for the Kigali City wetlands complex for papyrus land area, green spaces, and grassland all of which measure 836.9 ha gives a total economic value of $US **2,868,056.**

3.2.11. Summary of the baseline economic values of the wetlands ecosystem services

Table 11 shows the computed total economic value of the Kigali City wetlands complex which is an annual (2020) of slightly less $US 190 million. Economic valuation conducted for three other wetlands of priority importance in the country included; economic valuation of Nyungwe National Park in 2014 which had a total economic value of $US 4.8 billion; total monetary value of Rugezi wetlands was $US 374.32 million in 2014; while the total economic value of the Akagera Wetlands Complex includes a stock value (carbon storage) of 1.1 billion USD, and an annual flow value of 11.9 million USD[1].

Table 10: Summary of baseline economic values of Kigali City wetlands ecosystem services

Ecosystem service	**Land use area involved in hectares**	**Total economic value**
Crop farming	7273.1	20,357,035
Papyrus products	408.1	129,776
Bricks making	5	1,500,000
Grass harvesting	40	176,640
Flood control	408.1	1,490,789
Sediment control	648.1	1,182,881
Water purification	836.9	1,709,378
Habitat for biodiversity	836.9	2,868,056
Tourism and recreation	388.8	83,333
Carbon storage & sequestration	7894.6	44,735,380
Total Baseline value	**9,160**	**74,233,268**

3.3. Cost Benefit Analysis of the scenarios for wetlands management

This section focuses on the benefits and costs associated with how the baseline economic values of the ecosystem services under each of the two scenarios identified in section 2.7 will perform in the next 30 years with 2020 as the baseline year at constant prices, and at 10% discount rate.

3.3.1. Assessment of the future economic of values under business-as-usual scenario

Under the business-as-usual scenario, we make an assumption that there will be no more loss of papyrus (phragmites) land use to either of the other land uses, neither will there be land use losses to any other land use category. Instead, the current existing land use practices will be maintained. Table 11 shows the projected land uses over the next 30 years.

3 https://www.worldagroforestry.org/file-download/download/public/23133

Table 11: Projected land use, land cover change under BAU up to 2050

Land use, land cover	2020 size (ha)	2050 size (ha)	Change in size (ha)
Papyrus (Phragmites)	408.1	408.1	<=0
Cropland	7273.1	7273.1	>=0
Grassland (Fallow land)	40	40	<=0
Green spaces	388.8	388.8	>=0
Built up areas	1050	1050	>=0
Total	9,160	9,160	>=0

Table 13 also shows the computed economic values of the ecosystem system services based on the spatial and temporal dimensions of the wetlands under the BAU indicating the economic value of the ecosystem services for the baseline year (2020), 2050, the aggregate values for the next 30 years, and the present value of the total benefits over the next 30 years.

Table 12: Present values of the benefits of wetlands ecosystem services 2020-2050(2020 USD)

Ecosystem services	Baseline ecosystem value ($US)	2050 economic value ($US)	Total economic value by 2050	Present Value of total benefits
Crop farming	20,357,035	20,357,035	610,722,207	191,907,534
Grass harvesting	176,640	176,640	5,299,200	1,665,170
Papyrus products	129,776	129,776	3,893,274	1,223,385
Bricks making	1,500,000	1,500,000	45,000,000	14,140,372
Tourism and recreation	83,333	1,034,208	20,566,615	3,573,399
Water purification	1,709,378	1,709,378	51,293,601	16,118,013
Sediment control	1,182,881	1,182,881	35,486,430	11,150,918
Flood control	1,490,789	1,490,789	44,540,034	13,995,836
Carbon storage & sequestration	44,233,268	44,233,268	1,342,061,400	421,716,601
Habitat for biodiversity	2,868,056	2,868,056	86,041,689	27,036,921
Total Value	**74,233,268**	**74,682,031**	**2,244,904,450**	**702,528,149**

3.3.2. Costs associated with business-as-usual scenario

Costs associated with status quo (business as usual) considered in this study include: **opportunity costs** which are the economic value of the forgone alternative use of the wetlands resource (considered for crop farming land use only), and this was taken as biodiversity conservation and the connected co-benefits as shown in table 14 since the wetlands complex is more than 70% reclaimed for other land uses other than the more natural papyrus vegetation. The other cost considered is the **production cost**, mainly for the provisioning ecosystem services. Due to paucity of information and data, **management and implementation cost** of the BAU have not been considered. Other costs not considered are the degradation costs (over abstraction of wetlands resources beyond the regeneration capacity such as excess of over-fishing as an example). Externalities e.g., the effect of fertilizer use on climate regulation have also not been considered.

Table 13: Present value of costs under the BAU 2020 -2050 (USD 2020)

Items	Baseline value of costs	2050 value of costs	Total economic value of costs by 2050	Present value of total costs

Production costs				
Crop farming	4,771,154	4,771,154	143,134,608	44,977,257
Bricks making	900,000	900,000	27,000,000	8,484,223
Grass harvesting	79,818	79,818	2,394,540	752,437
Papyrus products	23,262	23,262	697,851	219,286
Opportunity costs				
Biodiversity conservation	24,924,571	24,924,571	747,737,130	234,961,799
Flood regulation	26,459,174	26,459,174	793,775,220	249,428,370
Sediment control	13,273,225	13,273,225	398,196,750	125,125,557
Water purification	14,858,739	14,858,739	445,762,170	140,072,062
Carbon storage & sequestration	201,787,516	201,787,516	6,053,625,475	1,718,790,456
Total Value	287,077,459	287,077,459	8,612,323,744	2,522,811,447

3.3.3. The Net Present Values of the Business-as-Usual Scenario

Net present value is the difference between present value of benefits, and present value of costs over the entire project period. A positive present value shows economic efficiency of the management option or policy option, while a negative net present value shows that the management option or policy is not economically efficient and therefore not desirable. Table 15 shows the net present value of the business-as-usual scenario.

Table 14: Net Present values of wetlands ecosystem services under the BAU

Ecosystem services	Present Value of total benefits
Crop farming	191,907,534
Grass harvesting	1,665,170
Papyrus products	1,223,385
Bricks making	14,140,372
Tourism and recreation	9,749,390
Water purification	16,118,013
Sediment control	11,150,918
Flood control	13,995,836
Carbon storage & sequestration	421,716,601
Habitat for biodiversity	27,036,921
Sub total	702,528,149
Production costs	
Crop farming	44,977,257
Bricks making	8,484,223
Grass harvesting	752,437
Papyrus products	219,286
Opportunity costs	
Biodiversity conservation	234,961,799
Flood control	249,428,370
Sediment control	125,125,557

Water purification	140,072,062
Carbon storage & sequestration	1,718,790,456
Sub total	2,522,811,447
Net Benefit Net Present Value) (Present Value Benefits- Present Value Costs)	-1,820,283,298
Benefit –cost ratio (Present Value Benefits/ Present Value Costs)	0.28

3.3.4. Assessment of the future economic values under Kigali City Wetlands Master Plan

3.3.4.1. Projected economic benefits and under Kigali City Wetlands Master Plan

Under the Kigali City Wetlands Master Plan, there are three broad objectives of allocation of some wetlands (3888 ha) for conservation, some other 3851 ha of wetlands for sustainable use, and the remaining 1421 hectares of wetlands for tourism and recreation.

a. ***Economic benefits and costs of Tourism and Recreation***

An investment plan for one of the tourism and recreation wetlands measuring 244 ha show that it will bring returns of up to $US 1 million by the 12th year which we assume here to be 2032 and also cost $US 2.41 million within that period, so for the tourism and recreation, we make an assumption that works on the other remaining 1,177 ha will commence in the next 5 years (2025) and be complete by 2037, and yield a proportionate revenues while also incurring similar costs over the same period, that then translates into a gross revenues of slightly more than $US 4.8 million for the other wetlands by 2037 and a cost of slightly more than $US 11.6million over the same period. After these two episodes of maturation, we assume that the average estimates of economic benefits of wetlands of $US 2660 per ha/year as documented in ESP database shall apply. We make an assumption that operation and maintenance costs of the parks will constitute 30% of the revenues collected. Other ecosystem services co-benefits that will accompany establishment of recreational parks will include; habitat for biodiversity, which we assume be supplied by 50% of the wetlands area, carbon storage and sequestration assumed at 70% of the land area and majorly grassland area. Table 16 shows the computed total and present values of the ecosystem services associated with assigning and setting up of some of the wetlands for tourism and recreation, over the next 30 years and at 10% annual discount rate.

Table 15: Present value of economic benefits of tourism and recreation land use management objective

Ecosystem Service	**Baseline Value (2020)**	**2050 value of benefits**	**Total value of benefits by 2050**	**Present value of total benefits**
Tourism and recreation	83,333	20,120,240	220,006,966	24,668,955
Carbon storage and sequestration	853,761	4,972,107	128,571,490	31,259,858
Biodiversity value	418,094	2,434,884	62,962,558	15,308,220
Total	**1,355,188**	**27,527,231**	**411,541,014**	**71,237,033**

Similarly, table 17 shows the computed costs associated with assigning and setting up some of the wetlands as tourism and recreational sites over the next 30 years and at 10% annual discount rate.

Table 16: Present value of costs of tourism and recreation management objective

Ecosystem Service	Baseline Value (2020)	2050 value of costs	Total value of costs by 2050	Present value of total cost
Implementation, operation & maintenance	200,833	1,133,958	29,750,286	7,295,872
Opportunity cost (Crop farming in 1421 ha)	3,045,203	3,045,203	91,356,090	28,706,868
Total	**3,246,036**	**4,179,161**	**121,106,376**	**36,002,740**

And finally, table 18 shows the computed net present values (over the next 30 years and at 10% discount rate) of assigning and setting up some of the wetlands as tourism and recreational sites

Table 17: Net Present Value of Tourism and Recreation

ITEM	Present Values ($US)
Benefits	
Tourism and recreation	24,668,955
Carbon storage and sequestration	31,259,858
Biodiversity value	15,308,220
Costs	
Implementation, operation & maintenance	7,295,872
Opportunity cost (Crop farming in 1421 ha)	28,706,868
Net Present Value (Benefits-Costs)	35,234,293
Benefit- Cost Ratio	1.99

b. ***Economic benefits and costs of conservation strategic objective***

A total of six (6) wetlands have been designated as conservation wetlands, and they both have a cumulative land area of 3888.4 hectares. They include; Ruhosha-Ayabaraya, Kanyetabi, Rwintare, Nyabarongo, Nyabuhuro-Kiruhuma, and Nyabarongo Amont. The ecosystem services associated with conservation include; biodiversity value, flood control, sediment regulation, water quality purification, Carbon storage and sequestration. Table 18 shows the estimated present value of the benefits of these ecosystem services based on the spatial a temporal dimensions of wetlands land area allocated for conservation. The temporal dimension is based on a 30-year period and a 10% discount. Data on management costs are not available and value transfer figures have been explored. There are no degradation costs or externalities considered. However, opportunity cost has been considered and this is for crop farming which is the prevalent land use in the wetlands.

Table 18: Net present value of conservation strategic objective of the Kigali City Master Plan on Wetlands

Ecosystem Service	Baseline Value (2020)	2050 value	Total value by 2050	Present value
	Baseline value for benefits	*2050 value of benefits*	*Total value by 2050*	*Present value of benefits*
Biodiversity value	13,325,547	13,325,547	399,766,404	125,618,790

Carbon storage & sequestration	108,066,413	108,066,413	3,241,992,384	1,018,732,830
Flood control	14,145,999	14,145,999	424,379,976	133,353,125
Sediment control	7,011,563	7,011,563	210,346,886	66,097,404
Water purification	7,944,001	7,944,001	238,320,036	74,887,420
Total	150,493,523	150,493,523	4,514,805,686	1,418,689,569
	Baseline value for costs	2050 value of costs	Total value of costs by 2050	Present value of costs
Opportunity cost (Crop farming in 3888.4ha)	8,332,841	8,332,841	249,985,236	78,552,981
Net Present value (Benefits-costs)				1,336,136,588
Benefit- cost ratio				18

c. Economic benefits and costs of sustainable exploitation conservation strategic objective

The concept of sustainability has three dimensions, we have the dimension of environmental sustainability which seek to ensure that regeneration or assimilation limits of the natural resources, or environmental are stretched beyond elastic limits. Economic sustainability, which mainly focuses on efficiency in costs or revenues. Social sustainability focuses on the acceptability of an ecosystem services by the local or affected/impacted population. The vast majority of the wetlands have been assigned to belong to the sustainable exploitation strategic objective. We assume that up to one third (1283 ha) of the wetland area allocated for sustainable exploitation (3851ha) will be allocated for Papyrus habitation, other land uses that we have considered based on the 2012 land use situation include; crop farming (2431.4ha), grassland(40ha), Bricks making(5ha), and 91.6ha for green spaces. The benefits associated with ecosystem services per land uses is considered in table 20 below.

Table 19: Ecosystem services and the associated land uses under the sustainable exploitation objective

Ecosystem service	Papyrus area (1283 ha)	Crop land area (2431.4)	Grassland area (40ha)	Bricks making (5ha)	Green spaces (91.6)
Crop farming	-	√	-	-	-
Grass harvests	-	-	√	-	-
Papyrus products	√	-	-	-	-
Bricks making	-	-	-	√	-
Biodiversity	√	-	√	-	√

Carbon storage & sequestration	√	√	√	-	
Flood control	√	-	√	-	-
Sediment control	√	-	√	-	-
Water purification	√	-	√	-	-

Table 21 shows the net present value of the benefits and costs associated with sustainable exploitation objective under the City of Kigali Master Plan. The costs considered include production costs for provisioning ecosystem services, and opportunity cost for crop farming.

Image 7: Wetland Ecosystem Services: Community Fetching Water from the wetland

Table 20: Net present value of sustainable exploitation management objective

Ecosystem Service	Baseline Value (2020)	2050 value	Total value by 2050	Present value
	Baseline value for benefits	*2050 value of benefits*	*Total value by 2050*	*Present value of benefits*
Papyrus products	334,863	334,863	10,045,890	3,156,725
Crop farming	5,211,025	5,211,025	156,330,753	49,123,888
Grass harvesting	37,134	37,134	1,114,032	350,063
Bricks making	600,000	600,000	18,000,000	5,656,149
Biodiversity value	4,847,834	4,847,834	145,435,026	45,700,118
Carbon storage & sequestration	46,716,685	46,716,685	1,401,500,549	440,394,193
Flood control	4,813,074	4,813,074	144,392,220	45,372,437
Sediment control	2,385,634	2,385,634	71,569,008	22,489,164
Water purification	2,702,889	2,702,889	81,086,670	25,479,903
Total	**67,649,138**	**67,649,138**	**2,029,474,148**	**637,722,640**
	Baseline value for costs	2050 value of costs	*Total value of costs by 2050*	*Present value of costs*
Opportunity cost (Crop farming in 3851ha)	10,778,949	10,778,949	323,368,470	101,612,230
Net Present value (Benefits-costs)				**536,110,410**
Benefit- cost ratio				**6.27**

3.3.5. Summary of benefits and costs under the Kigali City Wetland Master Plan

While all the three management objectives as proposed under the Kigali City Wetland Master Plan have positive net present values and benefit-cost ratio of more than 3, conservation has the greatest net present benefit and benefit cost-ratio, an indication that it has the highest economic benefit and also the best value for money. It is followed by sustainable exploitation of the wetland resource and last in the list is tourism and recreation.

Table 21: Summary of benefits and costs of the Kigali City Master Plan

Management objective	Land use area (ha)	Present value of benefits	Present value of costs	Net Present value	Benefit- Cost ratio
Tourism and Recreation	1,421	71,237,033	36,002,740	35,234,293	1.99
Conservation	3,888	1,418,689,569	78,552,981	1,336,136,588	18
Sustainable exploitation	3,851	637,722,640	101,612,230	536,110,410	6.27
Total	9,160	2,127,649,242	216,167,951	1,907,481,291	9.84

3.3.6. Comparison of the BAU and the Kigali City Wetland Master Plan

Placing the Kigali City wetland complex under the Kigali City Wetland Master Plan implementation would yield a net present benefit of over $US 1.9 billion over the next 30 years, while under the current business as usual, the wetland would yield a net present cost of $US 1.8 billion over the next 30 years.

Table 22: Comparison of the BAU and the Kigali City Wetland Master Plan

Management objective	Present value of benefits	Present value of costs	Net Present value	Benefit- Cost ratio
Business as usual scenario	702,528,149	2,522,811,447	-1,820,283,298	0.20
Kigali City Wetland Master Plan	2,127,649,242	216,167,951	1,907,481,291	9.84
Evaluation	Kigali City Wetland Master plan has larger NPV hence more economically efficient than the current BAU, the master plan also has bigger B-C ratio indicating a better value for money than the BAU The negative NPV of the business-as-usual scenario means that it is an option that is not economically desirable and the less than zero benefit to cost ratio means that it is an option that has power value for manufacture			

3.3.7. Comparison of individual ecosystem services under the alternative management options

Out of the four provisioning ecosystem services valued for the Kigali City wetland complex, it is only in crop farming that BAU performs better than a management regime based on the implementation of the Kigali Wetland Management Plan. Given the assumptions set under each of the two scenarios, bricks making will retain the 5 ha currently in use and so are the grassland land use hence brick making and grass harvesting will yield similar economic values in both scenarios. The wetland master plan out performs the business-as-usual scenario for all the regulating ecosystem services.

Table 23: Comparison of individual ecosystem services under BAU and wetland master plan

Ecosystem services	Baseline value under BAU	Baseline value under wetland master plan	Total value by 2050 under BAU	Total value by 2050 under wetland master plan
Papyrus products	129,776	407,994	3,893,274	12,239,820
Crop farming	20,357,035	6,805,489	610,722,207	204,164,658
Grass harvesting	176,640	176,640	5,299,200	5,299,200
Bricks making	1,500,000	1,500,000	45,000,000	45,000,000
Biodiversity value	2,868,056	18,591,475	86,041,689	608,163,988
Flood control	1,490,789	18,959,073	44,540,034	568,772,196
Water purification	1,709,378	10,646,890	51,293,601	319,406,706
Sediment control	1,182,881	9,497,197	35,486,430	281,915,894
Tourism & recreation	83,333	83,333	20,566,615	45,524,430
Carbon storage & sequestration	44,233,268	155,636,859	1,342,061,400	4,772,064,423
Total	**74,233,268**	**222,304,950**	**2,244,904,450**	**6,862,551,315**

3.3.8. Incremental benefits or costs of Kigali city wetland master plan

This section evaluates the incremental benefits of Kigali City wetland master plan over the status quo (the current practice, also known as the business- as usual) scenario. That is, the net present value of the wetland master plan less the net present value of the current practice (BAU). This will enable us quantify the additional benefit or cost of the recently formulated wetland master plan over or against the current practice also known as the business as usual or status quo scenario. The evaluation is also conducted using the annualized net present values, i.e., the annual net benefit expressed in each period as an even flow of the undiscounted net benefits and it is the same in each period as shown in table 25 below.

Table 24: Ecosystem services incremental benefits of the wetland master plan over BAU (2020 $US)

Ecosystem services	NPV of the BAU	NPV of the wetland master plan	Incremental benefit of the wetland master plan	Annualized net NPV
Papyrus products	1,004,099	3,156,725	2,152,626	228,349
Crop farming	146,926,767	49,123,888	-97,802,879	-10,374,856
Grass harvesting	350,063	350,063	0	0
Bricks making	5,656,149	5,656,149	0	0
Biodiversity value	27,036,921	186,627,128	159,590,207	16,929,209
Flood control	13,995,836	178,725,562	164,729,726	17,474,405
Water purification	16,118,013	100,367,323	84,249,310	8,937,103
Sediment control	11,150,918	88,586,568	77,435,650	8,214,316
Tourism & recreation	9,749,390	17,373,083	7,623,693	808,716

Carbon storage & sequestration	421,716,601	1,490,385,881	1,068,669,280	113,363,634
Total	**653,704,757**	**2,120,352,370**	**1,466,647,613**	**155,580,876**

4. POLICY IMPLICATIONS, CONCLUSION, AND RECOMMENDATIONS

4.1. Policy Implications

A number of policy and management issues can be established for each ecosystem services and the findings of this study can help in clarification of the potential policy and management issues of the ecosystem services, as highlighted in the next paragraphs.

4.1.1. Crop farming

One of the potential policy and or management issues that could be evaluated in this study is whether more reclamation of the remaining natural vegetation, shifting of other existing land uses to crop farming, or if retaining the existing crop farm lands, the most economically efficient way to harness the Kigali City wetland complex? From the findings in SMEC study (2019), crop farming offers more than 14 thousand households opportunity for income and nutrition, they would stand as losers if another management alternative that does away with crop is implemented and still some of them would lose out if a portion of the wetland is harnessed for another land use other than crop farming. Under the BAU, crop farming will produce the second greatest economic benefit of all the ecosystem services after carbon storage and sequestration due to the presence of carbon on various carbon pools, moving away from the status quo would lead to an annualized loss of benefits of over $US 10 million. Overall, the opportunity cost of crop farming under the wetland master plan includes conservation, and tourism and recreation, both of which would give economic value of $US 1.37 billion over the 30 years period.

4.1.2. Bricks making

As both population growth and quality of life increases, demand for building and construction materials such as bricks will increase. Commercialized bricks making yield one of the highest per unit benefits of the wetland resource harnessing.

4.1.3. Grass harvesting

The wetland currently offers a cross section of the city dwellers the opportunity to harvest grass for livestock feeding, this earns an annual value of $US 12,720, and could potentially benefit xxxx households. Based on the assumptions made of no land use movement /change regarding grassland landcover across the two management scenarios, there are no incremental benefits or costs associated with a shift to either of the two options considered.

4.1.4. Products from Papyrus & other related grasses

The wetland's natural vegetation, mainly phragmites offers the local community opportunities for mulching, making handicrafts among others that are worth around $ US 130 thousand, and if the wetland master plan is implemented then it there will be an annual incremental benefit of papyrus economic benefits worth $US 228 thousand above the current levels.

4.1.5. Purification of water for use by downstream community

Currently, the wetland offers water purification ecosystem services worth $US 1.7 million, and if the Kigali city wetland master plan is implemented, then the wetland would offer an improved water purification ecosystem services worth an annual incremental benefit of $US 8.9 million over and above the current wetland management and utilization

4.1.6. Sediment control

The wetland currently offers sediment control ecosystem services worth $US 8 million annually. However, if the wetland master plan is implemented, then it will have an improvement and offer annual incremental net benefit of $ US 8 million over and above the current use of the wetland.

4.1.7. Flood control for disaster mitigation

Currently the wetland offers flood regulating services worth $US 1.5 million annually, and if the wetland master plan is implemented then the wetland would provide a more superior flood regulation worth an annual incremental value of $US 17 million over the current wetland management and use.

4.1.8. Carbon storage and sequestration for climate change mitigation

The wetland currently contributes to the greening of the country with a carbon storage and sequestration potential worth $US 44 million. However, under the wetland master plan, the wetland would have an annual incremental benefit over the current management worth $US 113 million.

4.1.9. Habitat for biodiversity conservation

The current economic value of habitat for biodiversity conservation is worth $US 2.8 million annually. However, if Kigali city wetland master plan is implemented, then the value will have an incremental benefit over the current practice worth $US 16.9million annually.

4.1.10. Tourism and recreation

Tourism and recreation currently have the potential to the stakeholders up to $US 83 thousand annually. However, if the wetland master plan is implemented, then it would result into an annual net benefit of over $US 800 thousand over the current business as usual scenario.

4.2. Conclusion

The Kigali city wetland complex generates a number of ecosystem services that are of local, national and international importance. There are around four important provisioning ecosystem services that support local city dwellers with income and livelihoods, they include; crop framing, papyrus and papyrus products, grass harvesting, and bricks making which together generate a total economic value of slightly less than $US 22 million a year. The wetland also generates regulating and cultural services that have national, regional and international significance, these include climate change mitigation, habitat for biodiversity, sediment control, and water quality improvement at a value slightly worth more than $US of 51 million. If the status quo (business as usual) is maintained, then the Kigali city wetland complex will accumulate net present value loss in terms of ecosystem services worth over $US 1.8 billion by 2050. While implementation of the Kigali city wetland master plan would outperform the status quo by generating a net present value benefit of more than $US 1.9 billion by 2050. The wetland master plan would generate around an extra $US 155 million annually more than the status quo. For the wetland master plan, within its three management strategies of sustainable exploitation of the wetland, conservation, and tourism and recreation; conservation option offers the best value for money and highest net present economic benefits at $US 1.3 billion compared to the $US 536 million, and $US 35 million for sustainable exploitation and tourism and recreation respectively.

4.3. Recommendations

From the findings of this study, several recommendations have been proposed for potential consideration by the relevant stakeholders.

1. To keep track of the flow of the ecosystem services provision, there is need for investments in regular data collection
2. While investment and implementation of the Kigali City wetland master would lead to annual loss of slightly

more than $US 10 million crop farming benefits, it will compensate this by generating several folds annual incremental benefits over the business-as-usual scenario annually, i.e., implementation of the wetland master plan will earn more than $US 155 million annually over the business-as-usual scenario and it is therefore a recommended plan. More specifically, investing in the master plan would results into annual incremental benefits over the BAU for the following ecosystem services.

- Investment in wetland master plan implementation would result into an annual incremental benefit of flood control worth more than $US 17 million over the business-as-usual scenario.
- Investment in wetland master plan implementation would result into an annual incremental benefit of tourism and recreation worth more than $US 800 thousand over the business-as-usual scenario.
- Investment in wetland master plan implementation would result into water purification annual incremental benefit of $US 8.9 million over the current status quo management of the wetland
- Investment in wetland master plan implementation would result into biodiversity conservation annual incremental benefit of $US 17 million over the current status quo management of the wetland
- Investment in wetland master plan implementation would result into sediment control annual incremental benefit of $US 8 million over the current status quo management of the wetland

3. Stakeholders may also consider harnessing the prospects of climate change mitigation of the wetland through enhancing carbon storage and sequestration potential of the wetland
4. The study relied heavily on value transfer which has it's share of uncertainties, therefore more primary studies could still be conducted to enrich the appraisal of the policy and management options

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Annexes

Data Collection Instruments

ECONOMIC VALUATION OF WETLANDS ECOSYSTEM SERVICES

Benefits obtained from the Wetland

Do you get the following services from the wetland?

Benefit	Yes	No
1. Water Supply (Domestic use)		
2. Capture Fisheries		
3. Herbal Medicine		
4. Papyrus and other grasses		
5. Cutting grass as fodder		
6. Firewood from papyrus and reeds		
7. Crop Farming		
8. Livestock Grazing		
9. Aqua Culture		
10. Sand Harvesting		
11. Brick Making		
12. Bee keeping		
13. Making pots		

WATER SUPPLY

Do you obtain any water from the wetland?

☐Yes ☐No

If Yes, What is the purpose of the water?

☐Domestic ☐Selling

If Domestic, Ho many litres do you fetch in a day ……………………

If selling how many litres do sell in a month……………………

If selling, how much do you pay (in a month) those who you hire help you in the business of selling water……

If selling, how much do you incur a month as other costs…………………..

How many minutes does it take you to bring water home per trip …………..

Which of the following modes of transport do you use to fetch water…………

Mode of transport	Yes	No
On foot		
Use donkey		
Bicycle		
Motorbike		
Wheelbarrow		
Cart(mkokoteni)		

If you don't fetch water from the wetland for your domestic use, which of the following are your main sources of domestic water.

Source of water	Yes	No
Piped water		
Water kiosk		
borehole		
Shallow well		
Water vendors		

CAPTURE FISHERIES

Do you catch fish from the lake/ wetlands?

Yes No

If Yes, which type of fish do you catch?

………
………
……………..

If yes which of the following fishing gears and equipment, do you use

Equipment/gear	Yes	No
1. Canoe		
2. Nets		
3. Hooks		

If you catch fish from the lake/wetland, are you a member of the cooperative association of fishermen?

Yes

No

If you are not a member of the cooperative association, could you share with us the reason as to why you are not a member

………
…

If you are not a member of the cooperative association of fishermen, how many days do you go fishing in a month.

PRODUCTS FROM PAPYRUS AND OTHER GRASSES

Do you use any papyrus reeds from the wetland for Mat making or other products?

Yes……………

No………………

If No, why don't you use papyrus to make mats and other products…………..

If Yes, how many mats do you make in a year?.............................

How much do you sell one mat for………………..

Do you hire people to help you in mat making Yes …….. No…….

If Yes, How much do you pay them per month ……………or in a year ………………..

What is the cost for transporting the mats to the market …………..

How much do you pay the county government / municipal council as tax in the market per month………..

Why don't you make mats in some months …………………………………………………

HERBAL MEDICINE

Do you use any plants from the wetlands to make herbal medicine?

Yes No

If Yes, what are the plants that you use ………………………………………

What are they types of diseases that you treat people for …………………………..

How much do you charge per patient ……………………………………………….

How many patients did you treat last year ………………………………………..

Do you spend any money when treating a patient

Yes No

If yes, which costs do you incur when treating a patient ……………………….

How much ……………………………………………

In your opinion, what is the trend of availability of the plants you use from the wetlands to treat patients

Abundant Increasing in Population Stable Population Decline in Population

AQUACULTURE

Do you have any fish ponds within the wetlands?

Yes No

If Yes, which fish species do you farm

Tilapia Catfish others

If Others, Please Specify ………………………………………

How many Kgs of fish do you harvest in 1 year ………………………

What is the price of 1kg of fish ………………………..

What is the size of 1 pond in square metres ……………………………

How many ponds do you have ………………………………………………………..

How much do you pay people who work for you in the fish ponds per month …………………..

How much do you spend on feeds per month ……………………………..

How much do you spend on stocking fingerlings per year ………………………….

How many years does a fish pond last before it is abandoned ……………………………

How much do you spend in a year to maintain the fish ponds ……………………………..

How much do you spend on permits per year ………………………..

How much do you spend on tax ……………………………..

How much do you spend on transporting the fish to the market ……………………

Which tools do you use in the whole of your aquaculture enterprise…………………

GRASS HARVESTING

Do you harvest any grass from the wetland?

Yes No

If yes,

What do you use the grass for?

Domestic Selling

If Domestic,

What do you use the grass domestically for?

Thatching houses Livestock feeding Direct Selling

If Thatching,

How many bundles do you use ………..

How long does the roof last ………………………..

When was the roof last done ………………

How much did you spend on labor ………………………

If livestock feeding

How many cows do you feed from the homestead …………….

How many bundles of grass do you feed them in a week ……………..

If selling, what do you use the grass for?

Broom making Basket weaving

If Broom making,

How many brooms do you make in one month ………………..

How much do you sell one broom for ………………………….

How much do you pay the people who help you in making the brooms per month …………

How much do you spend on tax per month …………………..

If basket Weaving,

How many baskets do you make in one month ……………..

How much do you sell one basket for …………………….

How much do you spend on labor per month………………………

How much do you spend on transport to the market per month …………………

How much do you spend on tax per month …………………..

If Direct Selling the Grass,

How many bundles do you sell in one month …………………

How much do you sell one bundle for …………………………..

How much do you spend on labor per month ……………..

How much do you spend on transport to the market per month …………………..

How much do you spend on tax per month …………………..

LIVESTOCK GRAZING

Do you take your livestock to graze in the wetland?

Yes No

If Yes,

How many cows do you graze in the wetland ……………………………

How many times do you take your cows to graze in a week during the dry season ……………….

How many times do you take your cows to graze in a week during the wet season ……………….

How much do you pay a herds boy per month …………………………..

How much do you spend on treatment of cows for grazing in the wetland in one month ………..

HUNTING

Do you conduct any hunting activities in the wetland?

Yes No

If Yes,

Which animal do you hunt …………………

How many times do you hunt in a month during the dry season …………………

How many times do you hunt in a month during the wet season …………………..

Why do you hunt?

For food For Fun Controlling wildlife

SAND HARVESTING

Do you harvest any sand from wetland?

Yes No

If Yes,

How many trips of sand do you produce in one month during the dry season ………………

How many trips of sand do you produce in one month during the wet season ………………..

How much do you sell one trip of sand for ………….

How much do you pay people who help you in harvesting the sand per trip …………………..

How much do you pay for loaders per trip ……………………

Where do you harvest the sand?

Riverbed River Bank Farms within the swamp

In which village do you harvest the sand ……………………………………………

BRICK MAKING

Do you conduct any brick making activities in the wetland?

Yes No

If Yes,

How much do you earn from brick making in one year ……………

Which village do you carry your brick making business in ……………….

How many times in a year do you make the bricks ……………………………

CROP FARMING

Do you conduct any farming activities in the wetland?

Yes No

Which Types of crops do you farm?

Vegetables Maize Yams Rice Sugarcane Beans

If Vegetables,

How many sacs did you harvest last year …………..

What was the maximum price of one sac …………………..

What is the size of the farm you use (In acres) …………………..

How much did you spend on hired labor last year ……………………..

How much did you spend on fertilizers last year ……………………

How much did you spend on pesticides last year ………………………

How much did you spend on seeds last year …………………

How much did you spend on transportation to the market last year …………………

How much did you pay for licenses and permits last year ……………

How much did you spend on tax at the market last year ……………

If Maize

How many sacs did you harvest last year …………..

What was the maximum price of one sac …………………..

What is the size of the farm you use (In acres) …………………..

How much did you spend on hired labor last year ……………………..

How much did you spend on fertilizers last year ……………………

How much did you spend on pesticides last year ………………………

How much did you spend on seeds last year …………………

How much did you spend on transportation to the market last year …………………

How much did you pay for licenses and permits last year ……………

How much did you spend on tax at the market last year ……………

If Yams

How many sacs did you harvest last year …………..

What was the maximum price of one sac …………………..

What is the size of the farm you use (In acres) …………………..

How much did you spend on hired labor last year ……………………..

How much did you spend on fertilizers last year ……………………

How much did you spend on pesticides last year ………………………

How much did you spend on seeds last year …………………

How much did you spend on transportation to the market last year …………………

How much did you pay for licenses and permits last year ……………

How much did you spend on tax at the market last year ……………

If Rice,

How many sacs did you harvest last year …………..

What was the maximum price of one sac …………………..

What is the size of the farm you use (In acres) …………………..

How much did you spend on hired labor last year ……………………..

How much did you spend on fertilizers last year ……………………

How much did you spend on pesticides last year ………………………

How much did you spend on seeds last year …………………

How much did you spend on transportation to the market last year …………………

How much did you pay for licenses and permits last year ……………

How much did you spend on tax at the market last year ……………

If Sugarcane,

How many sacs did you harvest last year …………..

What was the maximum price of one sac …………………..

What is the size of the farm you use (In acres) …………………..

How much did you spend on hired labor last year ……………………..

How much did you spend on fertilizers last year ……………………

How much did you spend on pesticides last year ………………………

How much did you spend on seeds last year …………………

How much did you spend on transportation to the market last year …………………

How much did you pay for licenses and permits last year ……………

How much did you spend on tax at the market last year ……………

If Beans,

How many sacs did you harvest last year …………..

What was the maximum price of one sac …………………..

What is the size of the farm you use (In mugende) …………………..

How much did you spend on hired labor last year ……………………..

How much did you spend on fertilizers last year ……………………

How much did you spend on pesticides last year ………………………

How much did you spend on seeds last year …………………

How much did you spend on transportation to the market last year …………………

Which equipment do you use for farming?

Sprayers Jembe Tractor Ox plough Bull Irrigation kits Panga Wheelbarrow

If Sprayers,

How many people did you employ for your farming activities last year ....

IRRIGATION

Do you use any water from the wetland to irrigate crops grown outside the wetland?

Yes No

If Yes, which crops ....

What is the size of the farm that you irrigate (immugende) ....

Which equipment do you use for irrigation ....?

How much do you buy the equipment for ....

How much do you incur as costs in a year out of your irrigation farming................

How many days do you spend working on the irrigation farm in a year.................

FIREWOOD

How many bundles of firewood do you get from the wetland in a year ....

How many bundles do you sell per month during season? ....

How many bundles do you sell during wet season? ....

How much do you sell a bundle of firewood per month during dry season? ....

How much do you sell a bundle of firewood per month during wet season? ....

How long does a trip to collect fuelwood from the wetland take you or a member of your ....?

How much do you pay (per bundle) people who collect for you firewood during dry season ....

How much do you pay (per bundle) people who collect for you firewood during wet season ....

FLOODS

Have you ever experienced flood destructions in your home or farm?

Yes No

If Yes, what size of your farm was destroyed (in acres) ....

Which is the latest year that you experienced the floods ....

BIODIVERSITY MAINTENANCE

Think about the status of the wetland. Which box do you think best describes the condition of the wetland in terms of degradation? (Please tick one box)

01. Heavily degraded

02. Somewhat degraded

03. Good State

04. Excellent state

In a scale of 1 to 5, do you agree that diversity of plants and animals in the wetland provide the following services to the people?

The wetland acts a nursery and breeding ground for fish and other wildlife

Fully disagree

Disagree

Somewhat agree

Agree

Fully agree

No idea

The wetland helps in recharge and discharge underground water

Fully disagree

Disagree

Somewhat agree

Agree

Fully agree

No idea

The wetlands plants abundance helps control flooding

Fully disagree

Disagree

Somewhat agree

Agree

Fully agree

No idea

The wetlands plants abundance helps in purification of the river

Fully disagree

Disagree

Somewhat agree

Agree

Fully agree

No idea

The wetland is home to some of the globally threatened plants and animals

Fully disagree

Disagree

Somewhat agree

Agree

Fully agree

No idea

The wetland attracts tourists and people seeking recreation

Fully disagree

Disagree

Somewhat agree

Agree

Fully agree

No idea

The wetland offers education and research opportunities for researchers and

Fully disagree

Disagree

Somewhat agree

Agree

Fully agree

No idea

Each member of the plants and or animal species plays an important role in that ecosystem

Fully disagree

Disagree

Somewhat agree

Agree

Fully agree

No idea

Do you think conservation of the wetland is important?

Yes No

The wetland consists of papyrus, reeds, open water channels, grasslands and trees, and wild animals, does it matter to you whether these plants and wild animal communities in the wetland exist in their natural state.

Yes No

How much of these plant and animal communities should be conserved in a natural state?

- All of them
- Most of them
- Half of them
- Little of them
- None of them

In your opinion, which management strategy for the wetland do you prefer?

1. Full conservation of the entire wetland
2. Conservation of a considerable section of the wetland
3. Conservation of only a small section of the wetland
4. Full reclamation of the wetland for agriculture
5. Full reclamation of the wetland for fish farming
6. Full reclamation of the wetland for settlements
7. Full reclamation of the wetland for industrial packs

The wetland is one of the places in Rwanda which is considered to be an environmentally significant place since they play a host of rich diversity of plants and animals; it is also a habitat for rare and threatened birds and animals, the abundance of reeds and papyrus helps in flood control, and many other benefits. Suppose you are asked to make some contribution to promote the conservation of the wetland so that the richness and abundance of the various plants and animals are enhanced would you be will to make such a contribution.

Yes……………………………….

No………………………………

If yes, which type of contribution would you be willing to make? (Tick one only)

Volunteer time for conservation of the wetland…………………………

Contribution of commodities as such maize………………………………

Cash contribution…………………………………………..

Hint: please consider your household financial needs and your monthly earnings and only propose that amount which you are willing to contribute out of this your monthly earnings

How much of your contribution would you be will to make? (Use only one method of contribution)

Contribution	Monthly	Twice a year	Once a year
Volunteer labour in hours			
Maize in tins or sacks			
Amount of Cash			

If you are not willing to make any contribution towards the conservation of the wetland's biodiversity, please kindly share with us some of the reasons that has informed your choice

……………………………………………………………………………………………..

HOUSEHOLD CHARACTERISTICS

What is your age in years?

……………………………………….

What is your gender?

01. Male

02. Female

How many people live in your household, including yourself? (Please count separately the number of adults and children)

01. Adults

02. Children (below 18 years)

What is the highest level of education you have obtained (until now)?

01. Never went to school , Years….0

02. Primary, Years…….

03. Secondary, Years…….

04. Certificate, Years ………

05. Diploma, Years……….

06. University degree, Years………..

07. Post-graduate degree, Years ………..

Do you belong to any environmental or social group?