Analysis of Change of the Marshland Value in Rwanda:

Case Study of Muvumba P8 irrigation scheme, Nyagatare District

By

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School of Science

Master of Science in Geo-Information for Environment and Sustainable Development.

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DECLARATION

I declare that this Dissertation contains my work except where specifically acknowledged.

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Signed………………………………………...

Date: June 20th, 2016

DEDICATION

This thesis is dedicated to

My late family

&

My lovely wife Uwera Noella and my first-born daughter RUTAGENGWA Iganje Tovah

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ABSTRACT

The Government of Rwanda considers marshland as a valuable resource for the intensification of agriculture, which is required to achieve the goals of food security and poverty reduction as targeted in the agricultural policy of May 2000. According to the National Poverty Reduction Programme, for Rwanda to achieve an overall GDP growth rate of 6.4%, agriculture should grow at 5.3%. It further estimates that reclaimed marshlands have the potential to contribute to this growth by 0.5%. Therefore, the GoR strongly supported marshland development with the aim of boosting agricultural production, revitalizing the rural economy and reducing poverty.

Since the 1980s, Rwanda has been unable to meet its domestic food needs from national production; especially important has been the growth of rice imports to satisfy the demand for food consumption. Since 2000, the government of Rwanda with the development partners created projects that quicken the development of marshlands to tackle with food security issues. Since then Rice has been given high priority to be cultivated in the reclaimed marshes, though it is resulting in a steep decline of ecosystem services. RAB reports that in 2015, rice was grown on about 18,000 ha, the production was 99,000 T of paddy.

In line with the support provided to organized farmers in the diversified value chain development, MINAGRI projects invested in the construction of economic infrastructures for developed marshlands. This is meant to facilitate organized farmers to collect their produce and more importantly enter the second stage of processing. This is the reason as to why the project constructs post –harvest infrastructures that complies with local priorities of farmers but more importantly reduce post-harvest losses. The essence in these investments is to facilitate organized farmers to be organized and benefits the infrastructure in place for collective storage and selling.

The aim of this research was to analyze the change of marshlands value in Rwanda, with a particular focus on discussing and visualizing land use/land cover change, socio-economic and environmental stakes before and after agriculture intensification program. The Muvumba perimeter 8 served as a research case study to represent other reclaimed marshlands. It is a marshland that was developed with the aim to extensively produce rice under valley irrigation.
A multi-method including field observation, focus group discussion, and imagery interpretation were followed to achieve the research objectives. Discussion with rice cooperative, agronomist, irrigation experts, district land and environmental officers and previous project reports were used to collect the information on the change of the marshland overtime and its impacts on the ecosystem services, particularly information that helped to evaluate economic values. Due to time constraint and data limitation to quantify environmental values, the enumeration of positive and negative impacts was preferred.

Study results show that the use changed and lead to a reduction in ecosystem services. Before 2008, farmland was the main type of land use, accounting for about 65.6% of the total area within the broadly-drawn Muvumba marshland. According to the satellite imagery of 2008, farmland, natural forest, and built-up areas (100%) were the main land-use types. Pasture and built-up area (66%) that was inside the marshland planned boundary were totally destroyed for the benefit of agriculture. From 2008 to 2015, the proportion of green land (farmland, forests, and grasslands covered areas) within Muvumba valley boundaries decreased 89%, but marshland water inflow increased from the deviation weir (dam) to peripheral, secondary and tertiary canals. Based on the satellite imagery of 2008 and 2015, the change of land use/land cover is remarkable in Muvumba where 89.5% of land use/land cover changed from natural vegetation, grasses, farmland and built-up to irrigation rice agriculture.

The analysis undertaken found out that economic value of ecosystem services provided by Muvumba's ecosystem decreased from 2008 to 2015, but the economic benefits from agriculture production increased considerably after reclamation from 2013 onward when comparing with the production that obtained from cow livestock. Conversion of farmland to agriculture uses was responsible for the largest reduction in the value of ecosystem services; reduction of water quality and increase polluted water supply resulting from the application of fertilizers (NPK) and reduction of wildlife habitat due to decreased natural vegetation. In 2008, the evaporation and infiltration were very minimum due to grass and forest land cover but increased after reclamation in 2015 to the maximum level of water infiltration and water pollution. The study findings show that the conversion of the marshland from farmlands to rice/maize agriculture has economically increased the farmers' livelihood due to the growth of production and commercialization of the produce, equal to 4 billion Rwandan francs (equivalent to 5.3 USD million) but disturbing the ecosystems services and environmental health.

Keywords: *Marshland, environmental value, economic value, ecosystem function/services, marshland reclamation.*

LIST OF ABBREVIATIONS AND ACRONYMS

AAA	Agro-Action-Allemande
EDPRS II	Economic Development and Poverty Reduction Strategy II
EPA	US Environmental Protection Agency
ERR	Economic Rate of Return
FAO	Food and Agriculture Organization
FGD	Focus Group Discussion
FRW	*Franc Rwandais* / Rwandan Francs
GDP	Gross Domestic Product
GIS	Geographic Information System
GoR	Government of Rwanda
GPS	Global Position system
IDA	International Development Association
KWAMP	Kirehe Watershed Management Project
LC/LU	Land Cover / Land Use
MA	Millennium Ecosystem Assessment
MINAGRI	Ministry of Agriculture and Animal Resources
MINIRENA	Ministry of Natural Resources
MINITERE	*Ministère des Terres*
Muvumba-P8	Muvumba Perimeter 8
NBI	Nile Bassin Initiative
NDVI	Normalized Difference Vegetation Index
NMDWI	Modified Normalized Difference Water Index
NPK	Azote-Phosphorus-Potassium (agro-fertilizer)
PADAB	Projet d'Appui au Dévelopement Agricole de Bugesera
PAPSTA	Strategic Plan for the Transformation of Agriculture
PASR	Project d'Appui au Secteur Rural

RAB	Rwanda Agriculture Board
REMA	Rwanda Environment Management Authority
RNRA	Rwanda Natural Resources Authority
RS	Remote Sensing
RSSP	Rural Sector Support Project
TEEB	The Economics of Ecosystems and Biodiversity
TF I&M	Task Force of Irrigation and Mechanization
UR	University of Rwanda
USEPA	United States Environmental Programme Agency
WUA	Water Users Association

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CHAPTER I: INTRODUCTION

1.1. BACKGROUND

In the world, marshlands are among the most productive ecosystems comparable to rainforests and rainfed hillsides. Not only numerous species of birds and mammals rely on marshlands for food, water, and shelter, especially while migrating and breeding but also marshlands are now an important source of food and water for human (EPA, 2012). Human activities in marshlands generate a wide range of products that are used locally or traded and are essential for the well-being of local community living near to the marshland.

In Africa, wetland and marshlands areas play a major role in the economy. This can include the direct production of food or other commodities or simply providing sound and sustainable incomes in both good and bad years for fairly large numbers of people (W. M. Adams, 1992). Indigenous irrigation is yet predominant in the most of the marshlands in Africa. A survey conducted by the Food and Agricultural Organization (FAO) in 1986 attempted to estimate the present extent of modern large-scale, small-scale and traditional irrigation in sub-Saharan Africa. It revealed that almost half the irrigated area in sub- Saharan Africa lies in the 'small-scale and traditional' sector (2.38 million hectares out of a total of 5.02 million hectares, 47 percent). It is in agriculture that indigenous use of marshland resources in Africa is most intricate (W. M. Adams, 1992).

Considering that 90% of the working population in Rwanda is employed in agriculture, the per capita availability of agricultural land has declined over the decades from 3 ha per household in the 1960's to less than 1 ha per household at present (Verdoodt and van Ranst, 2006). The increasing population pressure on available land and water resources has led to their degradation and resulted in the loss of productivity of arable lands and increased food insecurity (Bidogeza et al., 2009). The response of Rwanda's farmers to the pressure on land and associated decline in productivity has been to expand their agricultural activities into the fragile marshlands. In the past marshland in Rwanda have been used in many different ways and continue to play a great role in the national economy (Nsharwasi L, N, 2012). Understanding the value and change regarding the development of this valuable resource is vital to their long-term productivity and is the focus of this thesis.

These values arise from the change of the marshland from traditional use to modern cropping system. Marshlands were once considered useless, disease-ridden places (e.g., malaria and yellow fever) that were to be avoided. We now realize that wetlands being transformed to productive marshland and it can provide economic benefits to society – such as fish, natural water quality improvement, food, and income. Protecting and adequately developing marshlands can, in turn, protect our health and safety by reducing flood damage, hunger and preserving water quality.

In Rwanda, the Agriculture sector contributes 47 percent of the Gross National Product (GNP) and accounts for 71 percent of the country's export revenue. Only 52 percent of the land surface area is arable, of this land, the total area of marshlands in Rwanda is approximately 165,000 hectares (ha) of which 93,754ha (57%) has been cultivated (MINAGRI, 2010). Most of them support substantial communities of people, who depend on them for food, water and income but use traditional techniques. Agriculture (including flood cropping, notably of rice, flood recession cropping and various kinds of irrigation at different scales), fishing and pastoralism are important use of wetlands and marshlands (W. M. Adams, 1992). Since many years, the Rwandan marshlands were very useful for agriculture and livestock which were done in rudimentary ways for subsistence. The strongly seasonal flow patterns of many Rwandan rivers support marshlands of great ecological and economic significance. They comprise vital resources for human use along all agriculture seasons. They are also, for the same reason, major targets for the activities of development planners; they have also attracted development, particularly dams and irrigation schemes.

1.2. PROBLEM STATEMENT AND JUSTIFICATION

The traditional management of marshlands in Rwanda was based on the farmer's small financial capacity and local knowledge of hydrology, soils, and vegetation that has been gained over decades of working and observation. After that the Government of Rwanda (GoR) has invested and continues to invest in the advancement of the agriculture sector. Specifically, keen to see that the marshlands, considered to be islands of food production, continue to play a key role in agricultural development and has allocated a substantial share of resources to their development and reclamation (Nsharwasi L, N, 2012). One such investment is the development of marshlands into rice fields.

Launched in 2001, the Ministry of Agriculture (MINAGRI) released the National Rice Policy, which identified rice as a priority crop and set out to attain self-sufficiency in rice production (MINAGRI, 2010). Thus, the use of wetlands for agriculture intensification changed from approximately 400 ha of tea plantation, and rice cropping in 1960's to more than 11000 ha of swampland reclaimed for agriculture in 2011. In the framework of the implementation of the Vision 2020 and the Economic Development and Poverty Reduction Strategic Plan (EDPRS), the (GoR) has chosen to make rural development and agricultural transformation, to spearhead quick and sustainable development. The growth rate that is assigned to the agriculture sector is between 5 to 8% each year to reach its expected objectives by 2020 (Rwanda, 2004). Wetland conversion is one of the major foreseen activities of intensification and development of sustainable agricultural production systems. Following this policy, by the end of 2020, at least 40 000 ha of the wetland should be officially reclaimed (Malesu et al., 2010).

So far little is known about the spatial and temporal changes of marshlands value and use at small scale (adequate for Rwandan situation). Most spatiotemporal land cover assessments are on a large scale with limited level of details. Africover, is typical example of a coarse representation of land cover at continent and national level, apart from detailed land cover /use detection at small scale level for a given case study (Serneels, Linderman, & Lambin, 2007).

Agriculture development projects of MINAGRI have had serious implications for change of the marshland value in Rwanda, and continuous great care is needed to ensure that development projects cause real economic benefits. The present study is interested in analyzing the changes that derived from the reclaim of marshlands in Rwanda from subsistence use to market-oriented exploitation. Thus, using Earth observation imageries and geo-information, the change can be tracked. Benefits that marshlands provide and how that value has been changing in time can also be assessed through the changing use of the marshland from traditional use to modern cropping system. Protecting and adequately developing marshlands can, in turn, protect our health and safety by reducing flood damage, hunger and preserving water quality.

Among other Ecosystem Functions or values, this research was more limited to assess the economic/commercial function because it is the one which is the cause of the marshland value increase where the use was changed from rudimentary use with less income to more developed and organized use with high production. The undervaluing of wetland resources and functions is a major reason why wetland systems are misallocated, often to conversion or exploitation activities yielding immediate commercial gains and revenues.

This marshland of Muvumba 8 is one of the biggest marshlands which have been reclaimed from farmlands to commercialized agriculture by Rural Sector Support Project, a MINAGRI project co-funded by World Bank and GoR. Construction of irrigation infrastructure started in 2010 and completed in 2012. The first rice planting started in the season A 2013. Muvumba-P8 is representative for typical valorized marshlands of Rwanda as it represents contrasts in both environmental and socio-economic sides.

1.3. RESEARCH OBJECTIVES

General objective

The main objective of the present research is to analyze the change of marshlands value in Rwanda. It can be hypothesized that wetland conversion to sustainable agricultural use can increase human welfare in Rwanda.

Specific objectives

This study specifically

- Describes the use and characteristics of Muvumba marshland valorization/agriculture intensification program.
- Assesses the Muvumba wetland cover/use before and after agriculture intensification program.
- Compares the socio-economic and environmental stakes before and after agriculture intensification for the local community.

1.4. RESEARCH QUESTIONS

In relation to the specific objectives the following research questions are formulated:

i. **Objectives 1:** Wetland characteristics and use

   - What are the characteristics of Rwandan wetlands in general and Muvumba wetland in particular?
   - What are the ecosystem values of Muvumba-8?
   - How much and where are produced of Muvumba-8?

ii. **Objective 2**: Wetland value/use/characteristics changes in time and space

   - What was the status of Muvumba marshland before and after its reclamation for the intensified agriculture?
   - What are the changes in time and space?

iii. **Objective 3**: The comparison of advantages of benefits before and after land reclamation

- What is the comparative productivity in time and space?

1.5. RESEARCH HYPOTHESIS

The following research hypothesis guided the research:

- Muvumba Marshland (Perimeter 8) shows a notable increase in value since its development started in 2010. It is hypothesized that the reclaim of Muvumba marshland has resulted changes in the marshland use and value.
- The rehabilitation of irrigation system and commodity chain development is excellent tools to increase the commodity production while disturbing the environmental ecosystem.

TABLE 1: RESEARCH MATRIX

Specific objective	Research question	Methods/techniques for data analysis	Data required & source	Expected Results
1. Describe the use and characteristics of Muvumba marshland valorization/agriculture intensification program	What are the characteristics of Rwandan wetlands in general and Muvumba wetland in particular?	Literature review, field observation and group discussion/Land cover/use mapping and change detection	General Land cover/use from literature, imageries of 2008 and DEM from RNRA, imagery of 2015 from GoogleEarth	General context of marshlands and characteristics of Muvumba
	What are the ecosystem values?	Literature review, Group discussion/ Environmental values assessment	Wetland values from Literature	Wetland values and function
	How much and where are produced?	Field Observation, Group discussion, Economic/commercial benefits assessment	Importance and location of values from literature	Economic benefits values
2. Assess the Muvumba wetland cover/use before and after agriculture intensification program	What was the status of Muvumba marshland before and after its reclamation for the intensified agriculture?	Literature review, field observation and group discussion, Land cover/use mapping and change detection	Relief, climatic, hydrology, soils and use from literature and field data collection	Marshland land uses before and after
	What are the changes in time and space?	field observation and group discussion, Land cover/use mapping and change detection	Land cover/use, imageries of 2008 and from RNRA, imagery of 2015 from GoogleEarth	Land cover/Land use before and after
3. Compare the socio-economic and environmental benefits before and after agriculture intensification for local community	What is the comparative productivity in time and space?	Literature review, field observation and group discussion, Land cover/use mapping and change detection	Livestock and agriculture production from field data collection	Productivity before and after

1.6. RESEARCH ASSUMPTIONS AND LIMITATIONS

There are challenges encountered during the implementation of this research project and to try to achieve the most important decisions despite the following challenges:

- Time was limited to conduct this kind of investigation but especially for genuinely assessing wetland values, thus we managed to focus on the assumed to be most important and the central/ core value which is economic/commercial value.
- Unavailability of hyperspectral data that would be useful to track vegetation cover (NDVI) and water index (NMWDI) over both periods of assessment (2008 and 2015). In Available aerial photography of 2008 (25cm of resolution) and cloud free Google Earth imagery for after valorization (2015) was more useful in the land cover analysis.
- Some respondents were not giving clear answers to the asked questions during interview and discussion because of lack of memory on the subject, or even boredom.
- Availability of interviewees and discussants were difficult given that many people have their programs and as they recognize that the discussion was not for their benefit.
- Some data might be difficult to get from discussants and interviewees given that those data requires time and desk work for them to compile up.

1.7. THESIS STRUCTURE

The thesis is structured in five chapters;

Chapter 1 presents the background information on marshlands status and development over the time, the statement of the research problem for socio-economic impact, objectives and the hypothesis of the research study as well as the research significance.

Chapter 2 presents the literature review related to marshlands use and value across the world. The literature review gave an insight overview on the importance and value of marshlands for food security and economic benefit in parallel with provided ecosystem services.

Chapter 3 deals with the methodology used to conduct the study. The description of the study area with emphasis on elements that justify how the selected site was the right one to apply our objectives or to attest our hypothesis, data and material needed, their collection and analysis.

Chapter 4 presents, analyses and interprets findings for the change of the value of marshland development and put them in the general context of similar research findings in the discussion section.

Chapter 5 concludes, summarizes the main findings and formulates recommendations for further studies and practices.

CHAPTER II: LITERATURE REVIEW

The aim of this literature review is to show the readings and a good grasp of the main published work concerning the change of the marshland value. This work includes reports, books, and Journal papers relating to the subject.

2.1. CONCEPTS OF MARSHLANDS

Marshes can be classified as a type of wetlands which are periodically saturated, flooded, or ponded with water and characterized by herbaceous (non-woody) vegetation adapted to wet soil conditions (EPA, 2001). According to United Nations Integrated Water Task Force (2011), marshlands or wetlands deliver a wide range of services that are critical to the existence and well-being of a country, such as food, clean water and climate control. Marshlands produce a wealth of provisions, including wild and cultivated sources of food, freshwater and valuable biochemical and genetic materials. Local communities traditionally use the marshes and land to harvest food grains such as rice and maize, vegetables, etc., and to raise livestock.

Marshlands are amongst the Earth’s most productive ecosystems and are a valuable natural resource of considerable scientific value because they are associated with high biological diversity. Also, they provide important ecological functions and values, such as habitat for flora and fauna species, biodiversity (Mitsch and Gosselink 1993), ground water recharge, flood mitigation, and regulation of pollutants and water. Recently, marshlands have been under increasing pressure from anthropogenic activities, including conversion to intensive agricultural use and other industrial and residential uses. Detection and assessing changes in wetland vegetation over time is hence important for both natural resources management and agriculture monitoring (Zaman et al., 2011).

Marshlands cover 6% (seven to eight million km2) of the world's land surface (Erwin, 2009), and occur in every climate, from the tropics to the tundra, on every continent except Antarctica (Mitsch, 1994).

In Rwanda **"Marshland"** means all lowland and comprises all valley bottoms, both the well-drained and wet parts. It is often wet but may not be wet all year around. The primary functions of marshlands in Rwanda include agricultural production, livestock products, hydrological regulation, biodiversity reservoir, peat reserve, and mitigation of climate change (REMA, 2008). **Marshland reclamation** in Rwanda is the process of creating new agriculture land from marshes/wetlands, and it is often a major economic pursuit among rural communities since they provide suitable cultivation conditions for a range of crops such as rice, maize and various vegetables.

2.2. VALUE OF MARSHLANDS

If something has "value," then it is worthwhile, beneficial, or desirable. The value of a wetland lies in the benefits that it provides to the environment or to people, something that is not easily measured. Marshlands/wetlands can have ecological, social, or economic values. Once regarded as wastelands, wetlands are now recognized as important features of the landscape that provide numerous beneficial services for people and wildlife. The economic value of a wetland is an estimate of the importance, or worth, of one or more of its services to society.

Part of this **economic value** lies in the variety of commercial products they provide, such as food and energy sources. Rice can be grown in a wetland during part of the year, and the same area can serve as a wildlife habitat for the rest of the year. Some wetland plant species, such as wild rice and various reeds can be harvested for or used to produce specialty foods, medicines, cosmetics and decorative items (EPA, 2006).

The **environmental services** they provide can be divided into products and functions. Products are tangible outputs of a wetland and can be used directly or sold: agricultural commodities, fishes, wood and honey, handcraft material. Wetland components provide many goods of exceptional value, including: fish, Timber, fuelwood, tree products, Wildlife, Fertile land for agriculture, Water supply, Water transport and Peat.etc. Functions are what wetlands contribute to the wider environment and their value must be perceived in indirect ways: water filtering, water supply, flood control, ground water recharge, habitat for wild animals and birds, tourism and recreation (Heady, 1992).

As defined by US department of agriculture (USDA, 2000), **Ecosystem functions** refer to the physical, chemical, and biological processes or attributes that contribute to the self-maintenance of the ecosystem; in other words, what the ecosystem does. Some examples of ecosystem functions are wildlife habitat, carbon cycling, or trapping nutrients. **Ecosystem services** are the beneficial outcomes, for the natural environment, or for people, that result from ecosystem functions. Some examples of ecosystem services are support of the food chain, harvesting of animals or plants, clean water, or scenic views. For an ecosystem to provide services to humans, some interaction with, or at least some appreciation by, persons are required.

While it can be difficult to calculate the economic value provided by a single wetland, it is possible to evaluate the range of services provided by wetlands/marshlands. People may also just appreciate wetlands for their mere existence without directly using them. It is the use of these various characteristics that gives the wetlands high economic values and supports millions of people directly, while providing goods and services to the world outside the wetland/marshland. Wetland valuation means the quantification of the economic value of use of the wetland components, functions and attributes (Barbier E. B et al. 1997).

Wetlands are an obvious source of water for domestic, agricultural (irrigation, livestock) or industrial use. Particularly wetlands/marshlands play a role in the global cycling of carbon, nitrogen, and water. Wetlands help maintain and improve the water quality of our nation's streams, rivers, lakes, and marshes. Since wetlands are located between uplands and water resources, many can intercept runoff from the land before it reaches open water. As runoff and surface water pass through, wetlands remove or transform pollutants through physical, chemical, and biological processes. Scientists have estimated that wetlands may remove between 70% and 90% of entering nitrogen (Reilly 1991; Gilliam 1994 cited in Mitsch and Gosselink, 2000). Wetlands with high soil concentrations of aluminum may remove up to 80% of total phosphorus (Peterjohn and Correll 1984 cited in Mitsch and Gosselink, 2000). Wetlands remove between 20% and 100% of metals in the water, depending on the particular metal and the individual wetland (Taylor et al. 1990 cited in Mitsch and Gosselink, 2000). Wetland/marshland provides many functions such as flood control, storm protection, groundwater recharge, sediment/pollutant retention, nutrient retention, evaporation, and preservation.

Marshlands also serve as reservoir for watersheds and help to protect other downstream properties from flood damage. The value of flood control by wetlands increases with: (1) wetland area, (2) proximity of the wetland to flood waters, (3) location of the wetland (along a river, lake, or stream), (4) amount of flooding that would occur without the presence of the wetlands, and, (5) lack of other upstream storage areas such as ponds, lakes, and reservoirs (Mitsch and Gosselink 1993 cited in Mitsch and Gosselink 2000). The ability of wetlands to control erosion is so valuable. Wetland plants hold soil from upper lands and reduce the velocity of the water.

Diverse species of plants, insects, amphibians, reptiles, birds, fishes, and mammals depend on wetlands for food, habitat, or temporary shelter. Wetlands also have archeological, historical, cultural, recreational, and scientific values.

In addition, we can define economic and social assessment as the attempt to assign qualitative values to the goods and services provided by environmental resources. Why then value environmental resources? The answer to this question is that although we know intuitively that such resources may be important, this may not be enough if we are to ensure their wise use before and after marshland conversion into rice fields. Many environmental resources are complex and multifunctional, and it is not obvious how the myriad goods and services provided by these resources affect human welfare. In some cases, it may be worthwhile to deplete or degrade environmental resources while developing agriculture; in others, it may be necessary to 'hold on' to these resources. Assessment of the importance of wetland values (before and after conversion) provides us with a tool to assist with the difficult decisions involved (Barbier et al, 1997).

The following wetland values and function will be assessed before and after implementation of rice agriculture development.

TABLE 2: CLASSIFICATION OF TOTAL ECONOMIC VALUE FOR WETLANDS

USE VALUES			NON-
Direct Use	**Indirect Use**	**Option and**	**Existence**
• Livestock • Agriculture • Wood, charcoal… • Recreation • Wildlife harvesting	• Nutrient retention • Flood control • Groundwater recharge • External ecosystem support • Micro-climatic	• Potential future uses (as per direct and indirect uses) • future value of information	• Biodiversity • Culture, heritage

Source: Adapted from Barbier, 1997

Wetland resources are particularly susceptible to mis-allocation decisions because of the nature of the values associated with them. Wetlands are multi-functional resources par excellence. Not only do they supply us with some significant resource outputs (e.g., wood, wildlife, water, energy, livestock, food, money, recreation, etc.), but they also perform an unusually large number of ecological functions which support economic activity. Many of these last services are not marketed; that is, they are not bought and sold because the support they provide to economic activity is indirect and therefore largely goes unrecognized. In the case of Rwandan wetlands, many of the subsistence uses of wetland resources are also not marketed and are thus often ignored in development decisions.

Some of the ecological services, biological resources and amenity values provided by wetlands have the qualities of what economists call a public good so that it would be virtually impossible to market the service, even if this were desired. For example, if a wetland supports valuable biodiversity, all individuals potentially benefit from this service, and no one person can be excluded from the service. Such situations make it tough to collect payment for the service, since whether you pay or not, you may still reap the benefit. In such circumstances, wetland services are liable to be undervalued.

According to Aylward (1992), a public good exists where one individual may benefit from the existence of some environmental service or attribute, and this does not reduce the benefit another person can receive for that same service or attribute. This situation contrasts with that of a private good, where two individuals cannot jointly consume the good. Another way of clarifying these concepts is to refer to their degree of exclusiveness (whether some people can be refused access to the resource) or rivals (whether the use of the resource by one individual reduces its possible use by another). Many wetland resource users are non-exclusive but rival, that is, they are open to all but diminish as use increases. Some users are non-rival and non-exclusive – this is the characteristic of 'pure' public good, such as biodiversity and non-use values.

Some of the difficulty arising from the public good qualities of wetland values would be unimportant if all wetland benefits could be enjoyed simultaneously, without any conflict among the various uses. Aggregating all possible use values together in such an unfettered multiple-use situation would be more likely to lead to recognition of the importance of conserving a wetland in its natural or a semi-natural state. However, amongst many wetlands uses there are inherent conflicts or tradeoffs, even when the wetland is maintained in a more-or-less natural state (Turner, 1991). For instance, it may not be possible to manage a wetland for recreation or commercial fishing while at the same time using it for wastewater treatment. Even if the latter use is more valuable, its non-market and public good properties mean that its value is unlikely to be reflected in market decisions automatically. If public policy is to allow individuals responding to market signals to determine the allocation of wetland uses – the so-called 'free market' solution – then it is unlikely that the wetland will be used for wastewater treatment. Thus, the resulting 'undervaluing' of a key ecological service may once again lead to inappropriate wetland uses (Barbier et al., 1997).

Undervaluing of wetlands can be a serious problem when outright conversion of the wetland area is at stake. As noted in previous sections, development or conversion of the wetland tends to produce marketable outputs, while maintaining the wetland in a natural or managed state usually leads to the preservation of non-market goods and services. Such a dichotomy often results in the development option – i.e., conversion to agriculture, fish ponds, and commercial or residential property – being widely regarded as the most valuable wetland use. As such activities also generate additional government revenue; it is not surprising that decision-makers also support the conversion of wetlands to ‘commercial’ uses.

Even where revenues may not be the primary objective of wetland exploitation and conversion, agriculture, value chain development and other conversion activities are considered important for economic development and national growth. They are seen as having significant ‘linkages’ to other sectors, especially processing and industries, and can provide many jobs.

These are compelling arguments for planners and decision-makers in many countries for supporting wetland conversion at the expense of other wetland values. In contrast, non-marketed ecological functions and amenity values generated by natural or managed wetlands may create little in the way of spinoff benefits, and instead, may even substitute for employment-generating activities (e.g., water treatment and flood control) or require additional investments of scarce public resources (e.g. roads for recreational uses). Some wetlands may also generate negative external effects in the form of support for disease vectors such as malaria-carrying mosquitoes which may be recognized while other indirect support functions are ignored.

In sum, the undervaluing of wetland resources and functions is a major reason why wetland systems are misallocated, often to conversion or exploitation activities yielding immediate commercial gains and revenues. Value evaluation may provide decision- makers with vital information on the importance and benefits of alternative wetland use options that would otherwise not be taken into account in development decisions.

2.3. USE OF GIS AND REMOTE SENSING FOR MARSHLAND VALUE STUDIES

GIS techniques have been applied to estimate the contemporary extent of important wetlands (peatlands) in Ireland from soil and land cover maps dating from the 1970s, 1980s, and 1990s (Connolly et al., 2007). Now, Remote Sensing (RS) integrated with the Geographic Information System (GIS) are providing new tools for advanced ecosystem management, at local, regional and global scales over time (Zubair, 2006). Remote sensing technology and GIS are considered useful tools in analyzing complex ecosystem problems.

High-resolution remote sensing Landsat (TM) images and GIS have been used to determine the real extent of the cover and rate of change in wetland in Kuala Terengganu in Malaysia (Ibrahim and Jusoff, 2009). A project mapping ecosystem decline along the Niger River Basin integrated Landsat (TM and ETM+) satellite imagery with GIS facilities (Twumasi and Merem, 2007).

In South Carolina, the United States, satellite images (medium resolution Landsat) and aerial photographs combined with GIS have been used to obtain spatial information and assess temporal changes affecting the function and structure of wetlands over large geographic areas (Mironga, 2004).

This technique of using medium resolution remote sensing data in combination with GIS is common. It has been applied to describe the condition of wetlands along the coastline of Sri Lanka about trends in land use arising from changes in agriculture and sedimentation (Rebelo et al., 2009). Identical techniques have been applied to classify and map the plant communities of wetlands in the Prairie Pothole Region of Central North Dakota (Mita et al., 2007). Medium resolution remote sensing and GIS tools have been used for habitat and species mapping, land change detection and monitoring of conservation areas (De Roeck et al., 2008).For example, to acquire data on land cover/use changes, and to determine the main environmental factors affecting these changes in Lake Cheimaditida, located in Northern Greece (Papastergiadou et al., 2008).

2.4. RWANDA'S MARSHLANDS

2.4.1. Marshlands Exploitation in Rwanda

Rwanda is experiencing fast socio, demographic and economic transformation since 2000. It has been recording on average of 8% GDP annual growth during that period, mainly driven by agriculture and services (NISR, 2015). This gives this sector a predominant role in the economy of Rwanda. The cultivable surface area is estimated at 1 385 000 ha. The cultivated area is about 825 000 ha, that is 31.3% of the total surface area of the country and 59.5% of the cultivable surface (REMA, 2010). According to the same source, hillside slopes (about 660 000 ha) are not exploited in the dry season and marshlands (about 165,000 ha) are partially used in the rainy seasons depending on their degree of flooding.

The high demographic growth rate resulted in intense land pressure on the available uplands. It also caused a modification of the fundamental land structure. The land available for a household for agricultural exploitation is below 1 ha. Consequently, the demographic growth cannot be sustained by farming on hill slopes alone. The development of marshlands and valleys remains one of the sustainable alternatives in response to population pressure on the fragile soils of hillsides. Marshlands contain large water reserves; have lower erosion risks, a natural fertility and offer possibilities to populations to work together in these marshlands, which are considered to be a factor that can contribute to national reconciliation. About 94 000 ha of marshlands are currently exploited, the remaining being large marshlands made up of peat or organic soils covered by papyrus, are not cultivated (MINIRENA, 2011).

The potential of a soil for agriculture is determined by inherent soil properties which may be limiting to production within an environment and for a given crop. For the wetlands soils of Rwanda, this potential varies from marshland to marshland. The large pedo-agronomic variability of marshlands renders the type of crop cultivated as well as the yields very variable. The high diversification of areas, depending upon the altitude and the climate, results in the existence of a wide variety of crops, like tubers, legumes, and cereals. One salient point to note is, however, the predominance of sweet potatoes in many marshlands especially in the dry season. Many reasons can explain this phenomenon. Sweet potato is resistant to drought, requires very little inputs and has a vegetative cycle of 4 to 6 months (Acland, 1981). As soil degradation and poor water regimes characterize many marshlands, farmers prefer to grow the sweet potatoes, which at least guarantee them a harvest, however, meager it may be.

According to the Water Resources Management Sub-Sector Strategic Plan (2011 – 2015), wetlands are among the most productive aquatic ecosystems in Rwanda, performing valuable ecological, social and economic functions. They serve as reservoirs and purifiers of fresh water. They attenuate peak flows, storing water and releasing it back gradually and allowing for year-round stream flow. They act as flood buffers and sink for sediments (including clay soluble inorganic nutrients); regulate climate, and contain large deposits of peat valued for its energy potential. Most importantly, wetlands help to maintain the quality of surface and ground water and regulate micro-climatic conditions through moisture recirculation, and cooling of surrounding areas. In extreme drought conditions, wetlands have supported food security, and large tracts of wetlands are under flood plain production of cereals, vegetables, and other crops.

Wetlands provide unique habitats to biodiversity especially for rare or threatened species, and are the only remaining biodiversity hotspots outside the three national parks and protected natural forests. They act as spawning and feeding grounds for fish and support artisanal fisheries. They have become an important source of raw materials for the fast growing *Agaseke* (basket) sub-sector. Rwanda has a total of 860 wetlands covering a total area of 165,000 Ha i.e. 7% of the total surface area (REMA, 2010).

In Rwanda, the abundance of water resources is reflected by the existence of a network of wetlands in various parts of the country. Wetlands and aquatic lands are generally represented by lakes, rivers and marshes associated with these lakes and rivers (MINITERE, 2005). The water resources are mainly influenced by rainfall and evaporation and hence climate information and preparedness are essential in the management of water resources (NBI, 2005).

Marshlands are owned and managed by government and farmers are only given leases for a certain period, after accepting to fulfill the conditions in the agreement such as crops to be grown, methods of production and maintenance of the marshlands and hitting the target yield. The targets are based on the productivity of marshlands depending on crop types, the fertility of the soil, temperature, rain, among others.

Marshland valorization is part of government efforts to increase agricultural productivity and ensure food security which is important in poverty reduction and the socio-economic development of the country as it has the monetary value attached to it.

Rice crop in Rwanda is grown in developed flood valleys or in the marshland development partners for rice are the following:

- Rural Sector Support Project for (RSSP) for marshland development,
- Projet d’Appui au Développement Agricole de Bugesera (PADAB),
- Strategic Plan for the Transformation of Agriculture in Rwanda (PAPSTA)
- Welthungerhelfe (WHH) – former Agro-Action-Allemande (AAA) Project
- Task Force for Irrigation and Mechanization (GFI)
- Kirehe Watershed Management Project (KWAMP)
- Land Husbandry, Water harvesting, Hillside irrigation (LWH)
- Rural Community Support Project (RCSP)

A lot has been achieved under this component to promote especially rice. Marshlands (like Rwagitima-Ntende (Gatsibo), Rusuli-Rwamuginga-Cyarubare (Huye), Kanyonyomba (Gatsibo), Kibaya-Cyunuzi (Ngoma-Kirehe), Rwabikwano-Kiruhura-Nyaburiba-Ruvubu (Bugesera), Agasasa (Nyanza), Rugeramigozi (Muhanga), Nyarubogo (Nyanza), Muvumba P2,3,4,5&8 (Nyagatare), Kagitumba (Nyagatare), Kinnyogo (Kirehe), Gisaya (Ngoma), Mukunguri (Ruhango-Kamonyi), Runukangoma (Huye), Rwasave-Migina (Huye), Busoro/Kinyegenyege (Ruhango-Nyanza), Base (Ruhango), Bugarama (Rusizi), Kirimbi & Kamiranzovu (Nyamasheke), Cyiri (Gisagara), Gacaca (Kayonza), Rwinkwavu (Kayonza), Cyunuzi and Rwabutazi (Kirehe), Mwogo (Huye), Rutenderi (Ruhango), Kiryango (Ruhango), Nyakagezi (Gatsibo), Kagondo-Rwuya-Mwogo (Nyanza), Rwangingo-Karangazi (Gatsibo-Nyagatare), Nyirabidili (Rwamagana), Cyizange (Kayonza), Ruziganbogo&Kajevuba (Gatsibo) and Ruterana (Muhanga) amongst others were reclaimed, valorized and managed to sustain their operations.

TABLE 3: CHANGES AMONG MARSHLANDS OF RWANDA (IN HECTARES)

District name	2008	2009	2010	2011	2012	2013	2014	2015
Nyarugenge	0	0	0	0	0	0	0	0
Gasabo	0	264	333.3	342.7	271.5	348	363.5	371
Kicukiro	0	0	0	0	0	0	0	0
Nyanza	350	506	271	460	470	611	372	489
Gisagara	1350	2175	2029	2165	1930.5	1983	1085.2	1993
Nyaruguru	0	0	0	0	0	0	0	0
Huye	300	665	1190	304	1231	1787.2	1107.8	1381.8
Nyamagabe	0	0	0	0	0	0	0	0
Ruhango	620	594.45	716.5	533	1003	1066.5	609	970.5
Muhanga	0	37.2	164.2	556.6	265.8	305.28	247.06	372
Kamonyi	236	293.45	323	273	343	407	368.2	443.5
Karongi	10	10	10	10	10	10	10	10
Rutsiro	0	0	0	0	0	0	0	0
Rubavu	0	0	0	0	0	0	0	0
Nyabihu	0	0	0	0	0	0	0	0
Ngororero	45	45	45	30	50	0	0	0
Rusizi	2348	1388	2097.8	3032.4	2972	3253	3034	2818
Nyamasheke	368	457	368	233	560	501.75	490.25	390.5
Rulindo	24	24	48	24	24	45	46.5	48
Gakenke	10	10	10	10	94	0	0	0
Musanze	0	0	0	0	0	0	0	0
Burera	0	0	0	0	0	0	0	0
Gicumbi	0	0	0	0	0	0	0	0
Rwamagana	421	264.6	275	325	375	408.6	410.8	525.6
Nyagatare	**1070**	**1155**	**1175**	**1390**	**1350**	**1936**	**2564**	**3823**
Gatsibo	604	605	700	1050	1304	1694	2099	1477
Kayonza	184	143	97	110	134	270	133	394.88
Kirehe	916	748	1219.2	1361	1720.5	1607	821.1	1064.3
Ngoma	735	905	830	950	1013	1165.5	845	938
Bugesera	638	572.5	187	596.5	642	807.5	856	1282.19
Total	**10,229**	**10,862**	**12,089**	**13,756**	**15,763**	**18,206.3**	**15,462.4**	**18,792**

Source: RAB, 2016

As shown by the table above, the country focused on sustained efforts to reduce poverty through the development of marshlands rice schemes (from 10,229Ha cultivated with rice in 2008 to about 18,792Ha in 2016). On the other hand irrigation activities provided marshlands with water for farmers to use all the time including in the dry periods. That is achieved by highly financial and technical demanding constructions/ installations, done by government organizations and development donors. The irrigation scheme rehabilitation or establishment mainly deal with hydraulic structures, dykes and dams, feeders roads around or inside the marshlands, erosions control system in the catchment area, drying bays for rice, storage facility, etc.

FIGURE 1: MARSHLANDS WITH RICE IN RWANDA

Source: MINAGRI, Rwanda, 2010

2.4.2. MANAGEMENT OF RECLAIMED LAND OF MUVUMBA-8

Reclaimed marshlands are those with potentials to irrigating rice or vegetables and which are economically viable once are developed with the dam, drainage, and irrigation networks. Their farmers are organized in cooperatives and water users' associations.

For the case of the perimeter 8 of Muvumba, after being reclaimed and developed with irrigation infrastructures, it is divided into three categories of land leasing. The categories are described as:

- *Category 1:* People being allocated land on a 49-year lease on free hold basis like in other marshlands. This category includes people who originally owned land titles in the marshland and smallholder farmers whose at least 60 % of land was taken for infrastructure construction, or people who were using the marshland as the only source of income. This category of farmers was allocated blocks of 0.5 to 5 ha for a total 350 ha of the marshland.

- *Category 2:* Commercial plots of 1-5 ha for a 49-year lease. These were leased to local private investors interested in rice farming with priority given to Nyagatare residents who initially used land in the marshland, on a first come first serve basis. A total of 700 ha were allocated to this category.
- *Category 3:* Commercial block of 700 ha was leased to a large-scale investor for 49 years, SRI BHAGYALAKSHMI GROUP (currently named Nyagatare Agroventure Ltd.)

Conditions governing land allocation are:

- According to the original plan, the area has been developed to be primarily used for rice cultivation or another rotational crop agreed-upon by MINAGRI
- Every person who will be allocated land has to belong to a cooperative (category 1 & 2)
- All farmers are obliged to pay a determined water fee annually to a Water Users Association.
- Payment of land lease fee of 200 $ US per ha for both category 2 and 3. The private operator will invest in rice milling, storage facilities, and energy production.
- The investor has been selected on the basis of established interest and historical guaranteed capacity that will enable him to lead on modern agriculture farming, including mechanization, value addition and storage (category 3).
- The investor will partner with other rice growers in the marshland through contract farming (category 3).
- Transfer of ownership of allocated plots for category 1 and 2 is forbidden without prior approval from MINAGRI. No form of land subdivision, either for inheritance or sale will be allowed in this marshland as it interferes with water distribution and mechanization of plots.

MINAGRI through the RSSP project established organizational structures for better use of Muvumba marshland. These structures are based on farmers holding irrigated plots in the well-laid marshes after the redistribution of land. Thus, the committees of the water users' association and cooperatives with farmers' perimeter Muvumba have put in place proper water management and irrigation infrastructure and the cooperative for rice farming practice.

These committees have the following mandates:

- Management of farmers and promoting rice
- Supply of agricultural inputs,
- Equitable management of irrigation water,
- Identification, management and allocation of royalties,
- Search for outlets for farm products.

MINAGRI then developed a model of marshland lease agreement with the Mayor as a signatory representing the State and the president of the cooperative committee representing farmers. This contract is accompanied by a textual convention between the two parties (the State and the Committee) that defines the obligations of each signatory party.

Apart from the different farmer groups, there is the Water Users Association (WUA) which is responsible for maintenance of irrigation infrastructure. The committee members of this association have had different capacity building activities such as training and study tours to create awareness on infrastructure maintenance.

The market linkage is done at the beginning of the harvesting season; a supply contract is signed between the marshland committee representing farmers and a local rice mill in Nyagatare. This Miller not only provides a market for their rice but also supplies them with inputs, mainly fertilizers at the planting time. To ease payment to the farmers, the marshland committee has hired an accountant who works with the marketing committee and the marshland committee president to ensure accountability and professionalism in their endeavors.

Marshland valorization is necessary to allow the respiratory process in crops like maize and rice. On the other hand, for rice to grow well in marshlands that sometimes are water-logged due to flooding, drainage has to be done to allow the free flow of water as the crop grows poorly when water is stagnant underground.

2.4.3. Policy, institutional and legal framework affecting marshland development in Rwanda

The necessity to develop legislation on marshlands was perceived very early by the Government, due to the acuteness of land shortage which characterizes the country. That situation makes marshlands the only alternative to alleviate pressure on the fragile slopes as well as increase production to ensure food security for the population.

In 1988, the GoR began to work out legislation for the exploitation of marshlands with assistance from the FAO. Within the framework of this support, legal documents were prepared but they have not yet been submitted to the Government. In those legal texts, are defined: the status and definition of marshlands, their delimitation, classification, rules of exploitation, institutions in charge, modalities of management, maintenance, and production, contracts of the utilization of the marshlands, etc. These legal texts, which date back to the pre-war period, now have to be updated following the preparation of a new land law currently under study. We can, however, say that in Rwanda marshlands belong to the State and can be given to associations or private people according to defined modalities.

The performance of the economy and the development of agricultural sector are closely linked. Therefore, the strategic interventions and policies governing the marshland agriculture sector in the country should be consistent with its national and regional framework of strategies.

According to the Vision 2020, the GoR intends to become middle income-economy (with a per capita income of 900 USD), decrease the poverty to 30%, and increase the average life expectancy to 55 years by the year 2020. The government seeks to accomplish this vision by transforming agriculture into a productive, high value, market oriented sector, with forward linkages to other sectors. The government recognizes the need to devise ways and means to promote the development of industrial scale agro-processing industries by developing an efficient private sector that is driven by the spirits of competitiveness and entrepreneurship. Therefore, the initiatives on increasing production and quality of rice, maize and horticulture are in consistence with the overarching goals set by the nation. With EDPRS II, water resources utilization for growth is expected to increase, as more land will be put under irrigation; more hydro-power generation potential will be exploited.

According to article 18 of the environmental law, the management of water resources should in no way reckless use operating methods which can be the cause of certain disasters, such as floods or droughts.

About the human environment, Articles 32 and 33 are accurate regarding construction of public works such as roads and dams. The law states that no public or private work in the scope to which a plan cannot be realized if it is compatible with the latter, and if it takes into consideration the environmental provisions, provided by the texts in force.

In connection with marshes, wetlands, the law reminds environmental issues and clarifies Article 90 & 91 that agricultural activities are permitted beyond the depth of 10m from the shore of rivers and beyond 50 m from the shore of the lakes. No farming business is allowed below those limits. That pastoral activity must respect the margin of 10 m from the banks of rivers and of 50 m from the edges of the lakes. The construction of cattle stables is strictly prohibited on the bands adjacent to the 150 m 10 m bank for watercourses and lakes for 50 m.

Rice has become a major food crop in Rwanda. In the past 10 years, the total rice production has increased by 6-fold from 11,949 tons in 2000 to 72,000 tons in 2009. This increase is mainly due to a parallel increase in rice area under cultivation. Due to rising incomes and changing lifestyles of the growing population, however, the demand for rice consumption has outstripped the local production (MINAGRI, 2010).

According to Rwanda rice policy report, the rice sub-sector in Rwanda faces two challenges – insufficiency (volume) and inappropriateness (value). Self-sufficiency in rice production shall be achieved by (a) raising the productivity of existing lands and (b) by further expanding the area under rice cultivation.

Rice is almost exclusively grown in marshlands in Rwanda. Owing to a considerable demographic pressure, it is largely cultivated in smallholder farms of about 5 acres where the scope for raising productivity is often limited. The government shall prevent further defragmentation of rice farms and promote consolidation of land holdings wherein cooperative farming shall be envisioned. The individual farmers shall become shareholders and employees of a larger farm. The country shall produce more rice by diversifying the rice ecosystem whereby upland rice and rain-fed rice can be grown on gentle slopes and valleys where water is scarce (MINAGRI, 2010).

In recent years, the Government's investment efforts have been directed towards the reclamation of vast areas of inland valleys swamps (marshlands), construction of several small dams in the valleys, organization of farmers' cooperatives, privatization of rice mills, farm mechanization and facilitation of the supply of inputs such as seeds, fertilizers, and pesticides. As a result, the total area under rice cultivation increased dramatically from 3,549 Ha in 2000 to 13,000 Ha in 2009. In parallel, the total milled rice production had also increased by 6-fold from 5,975 tons in 2000 to an estimated 36,000 tons in 2009.

CHAPTER III: RESEARCH MATERIALS, METHODS AND PROCEDURES

3.1. OVERVIEW

This part gives in details materials, methods and tools used to analyze the change of marshlands value in Rwanda. The location, physical and socio-economic conditions of the study area have been presented. Literature review, field observation, focus group discussion were applied for data collection and analysis of land use/land cover change detection was assessed thanks to the use of ArcGIS software.

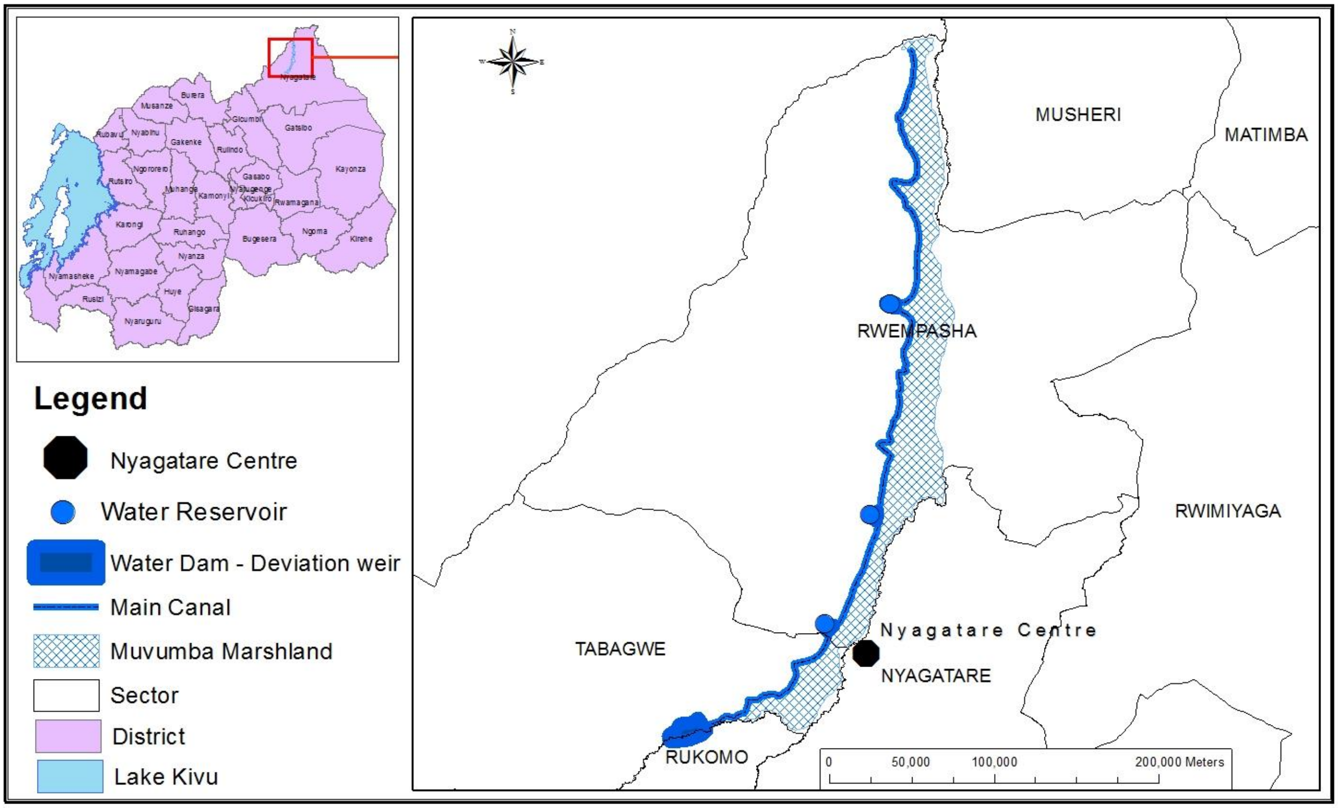
3.2. STUDY AREA

This part will describe the location and characteristics of the study area such as climate conditions, topography, hydrology system and soil conditions.

3.2.1. STUDY AREA LOCATION

Muvumba Marshland P8 is located in Nyagatare district, near Nyagatare urban Centre, as floodplain of Muvumba river. Nyagatare District borders Uganda in the North, Tanzania in the East, Gatsibo District of the (Eastern Province) in the South, and Gicumbi District of the Northern Province in the West. The total gross area of the marshland is 2,236 Ha, and the productive surface area of Muvumba P8 is 1600Ha.

FIGURE 2: LOCATION OF MUVUMBA MARSHLAND P8.

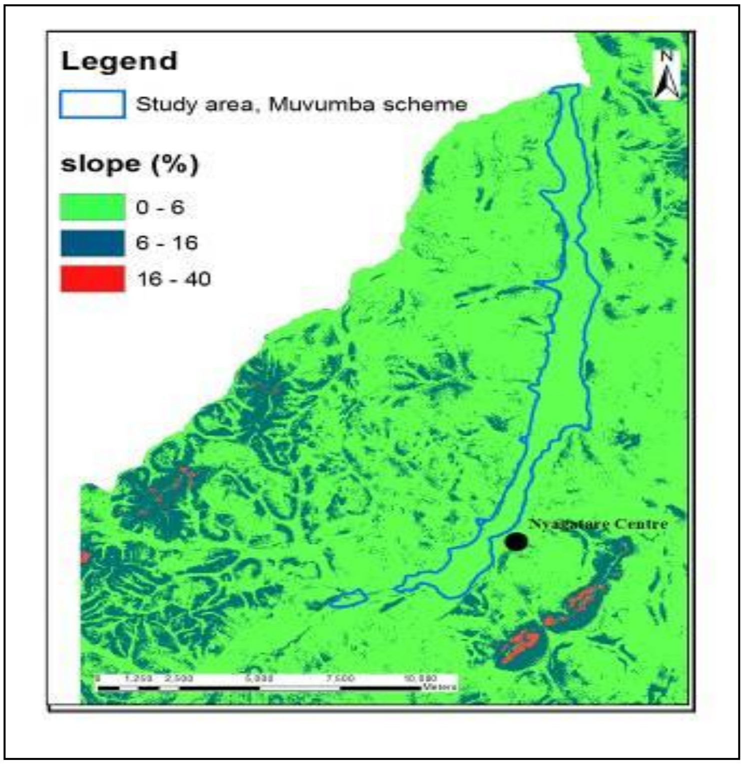


3.2.2. PHYSICAL CONDITIONS

Muvumba marshland P8 located in Eastern Province, Nyagatare District, in Tabagwe and Rwempasha sectors. It lies in an area of grassy plains, and low hills, with excellent views in all directions, including the mountains of southern Uganda. Lowly inclined hills are separated by dry vallies for a long period of the year (June–October). The marshland is located in the granite low valley whose altitude is around 1270m.

This kind of topographical layout constitutes an important potentiality for modern and mechanized agriculture. The area is flat (see the slope map below).

FIGURE 3: SLOPE IN MUVUMBA MARSHLAND AND ITS SURROUNDINGS.



The hydrographic network is very limited in Nyagatare district. Muvumba-P8 is usually the great swamp of low altitudes or collector marshes. They are concentrated along the primary river system. Muvumba also receives lower precipitations. The land was not farmed as extensively as other areas of the country, and there was a lot of cattle.

The area had a higher average daytime temperature than the Rwandan average, and lower precipitation, which come sometimes lead to droughts. Annual rainfalls are both very weak (827 mm/an) and very unpredictable to satisfy the needs in agriculture and livestock. The monthly distribution of the rains varies from one year to another. Muvumba River, which crosses the district, is a result of the reunion of two rivers: Ngoma and Karungeli. They have an important buffer function (rainy season floods and maintains a high flow during the dry season). The river is the main water reserve for the people and the cattle in the vast dry land. Few of the rivers found there such as Nyiragahaya, Kayihenda, Karuruma, Nayagasharara and Kaborogota are erratic and intermittent. The weak river network constitutes a serious handicap to responding to the needs of water for people and animals (PASR, 2008).

The soil of this area is characterized by the tightness of the humifere layer of the soil brought about by the grassy savanna and by the vertisoils that are rich in nutrients mineral elements for lush growth of grasses of the genus *Hyparrhenia* (*Hyparrhenia filipendula*) much coveted by livestock but lacking organic substances. These types of soils may be exploited with the help of modern agricultural techniques and form sorts of artificial pastures camps for livestock.

3.2.3. SOCIO-ECONOMIC CONDITIONS

FIGURE 4: COWS IN MUVUMBA MARSHLAND BEFORE RECLAMATION

FIGURE 5: RICE GROWN AFTER RECLAMATION

Referring to the figure 4 & 5, cattle livestock was more developed in the marshland because of a well-developed herbaceous cover and making a meadow. Rice is grown in its large valley since 2012 onward; the developed marshland irrigation scheme covers a gross area of 2,236 hectares but it was designed to allow the cultivation of rice in two seasons of 1,625 ha net. Rice cultivation will be secured by the construction of a diversion dam development head. The double rice crop is expected as many as the area allows the configuration of the marsh. In terms of soil science, all the land of marshes consists of soils that are well suited to rice growing as evidenced by the gradual colonization of the valley Muvumba by this culture.

3.3. MATERIALS AND TOOLS APPLIED IN DATA COLLECTION

The aim of this research is the assessment of how the marshland changed value over time due to the adoption of production and improved farming technologies. Remote Sensing (RS) and Geographic Information System (GIS) approaches, combined with ground truthing, were applied. They provide new tools for advanced ecosystem management, by providing the ability to monitor change over time.

3.3.1. LITERATURE REVIEW

Cooperative documents, video, photo taken over times, existing maps of the scheme and available reports were used to document this research. The MINAGRI rural sector support project (RSSP) was the source of major documentation. Papers, thesis, reports and other publications related to wetland values, wetland valuation, marshland land use change, etc. were consulted to document this research.

3.3.2. FIELD DATA COLLECTION

To assess the dynamics of marshland change, field observation and group discussion with farmers and their leaders were conducted.

3.3.2.1. FIELD OBSERVATION

A field data collection in Muvumba marshland was performed between August 2014 and September 2015, to collect data related to existing land uses and recording historical background of the marshland and how it changed in time. The field observations were recorded as text, photographs, and their geographical coordinates were captured using GPS receivers. As well as group discussion with farmers' organization and agronomist of the marshland was conducted. Observations have been discussed later in the results.

FIGURE 6: FIELD OBSERVATION IN MUVUMBA P8 MARSHLAND

3.3.2.2. GROUP FOCUS DISCUSSION

Group discussion provided the complex textual descriptions of how farmers experience the change of the value of the marshland especially identification of intangible factors for socioeconomic change. The discussion with farmers' cooperative committee, famous old inhabitant near the valley, the marshland agronomist, the District land officer were about the following issues:

- Land use that was in place before conversion
- Functions and characteristics of the marshland before conversion (livestock)
- Incomes from cattle (before) and agriculture (after)
- Benefits from wetland environmental values (water quality, water supply, erosion control and flood protection, wildlife habitat, recreation/aesthetics/culture/science and commercial benefits). As well, positive and negative impacts due to the change of the function collected from group point of views.
- Economic benefits from irrigation developed in the marshland
- Comparison of land use/cover before and after marshland reclamation

3.3.3. Data Analysis

3.3.3.1. Land cover/use mapping and change detection

3.3.3.1.1. Needed/Used data: RS data Imagery; GIS data & Ground truth data

The change of land use between 2008 and 2015 was assessed through the analysis of aerial photography (orthophoto 2008/2009) produced by Rwanda Natural Resources Authority (RNRA). They were the basis for collecting land cover of before conversion from cattle livestock to irrigation agriculture. The Google Earth Imagery of Rwanda/Muvumba was used to capture information on the current land cover. The ortho-photo, Google Earth 2015 imagery, field observation together with farmers' discussion were the basis for collecting and analyzing land uses. The GPS was used to capture different land use identification points such as the location of rice plots, roads, canals, water reservoirs, forest, Nyagatare Centre, etc.

Ancillary Datasets Utilized are from the rural sector support project (RSSP) of Ministry of Agriculture and Animal Resources (MINAGRI) such as ground survey data and other available datasets like datasets on wetlands, hydrology, roads, country administrative boundaries, etc.

3.3.3.1.2. Image interpretation to get Land cover/use maps of 2008 and 2015

The remote sensing data analysis using appropriate software with command based on local knowledge of user and ground truth data are commonly used for mapping vegetation types (Adam et al., 2010).

In our case, we used the Google Earth images of 2015 and aerial photographs of 2008/9, to generate the land cover /use maps of the period of 2008 and 2015.

The primary analysis was conducted by interpreting vegetation cover from aerial photographs, using GIS combined with ground truth data. Unsupervised and supervised classifications with the same technique for aerial photography interpretation were used to interpret the vegetation cover.

3.3.3.1.3. Visualization of produced maps

An important step in geographical analysis is choosing the way to represent results on the map. The results of image interpretation delineated the following cover/use types or classes similarly for both periods: water reservoirs; forest, livestock; Rice cropped area; Rice 1-38 blocks. GIS is an essential tool for mapping existing wetlands and for identifying areas for wetland restoration or creation. GIS, such as ArcGIS, comprises spatial databases that store data as coordinates or vectors, or as grid-cells in a raster matrix (Harris, 2007). The use of GIS allows the analysis of multiple datasets, and a visual representation of mapped areas that may be suitable for wetland monitoring.

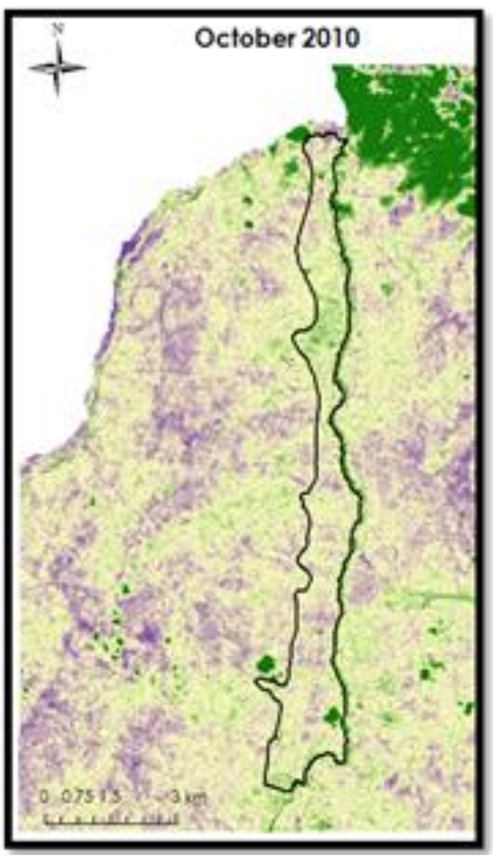


FIGURE 7: PASTURES IN 2010 BEFORE VALORIZATION INTO AGRICULTURE FIELDS

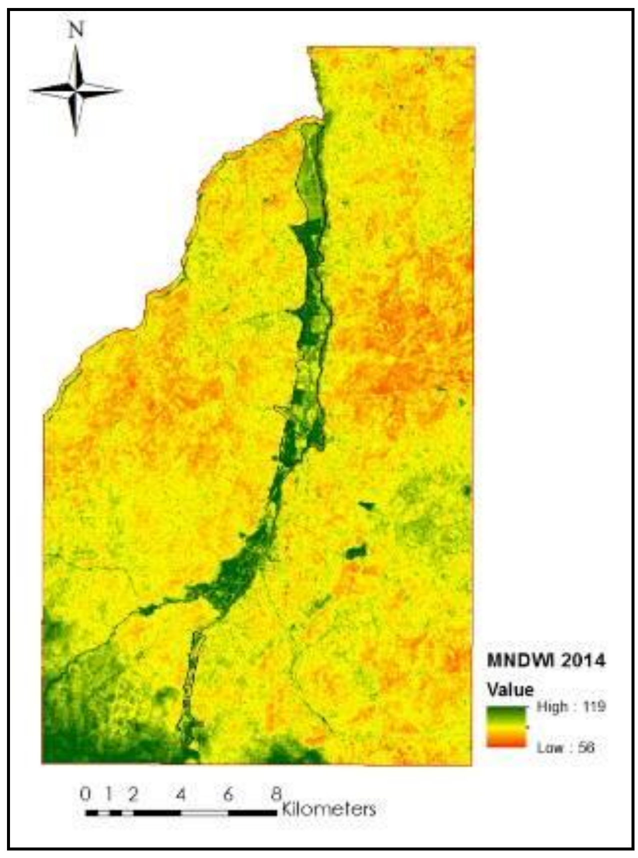


FIGURE 8: RICE FIELDS IN NORTH EASTERN RWANDA DERIVED FROM LANDSAT 8 IMAGERY (FEBRUARY 2014).

THE LIGHTER GREEN AREA ADJACENT TO THE DARKER AREA SHOWS THE RICE FIELDS BEING PREPARED

FIGURE 9: SATELLITE IMAGERY FOR A PORTION OF MUVUMBA, 2016

FIGURE 10: SATELLITE IMAGERY SHOWING STAGNATE WATER DUE LEVELING ISSUES, 2016

3.3.3.1.4. Change detection

LC/U map of 2008 was overlapped with LC/U map of 2015 and using spatial analyst tools of ArcGIS we have statistically and spatially quantified the changes from livestock to Rice.

3.3.4. MUVUMBA WETLAND VALUES ASSESSMENT

In this section of the methodology, we emphases on the establishment of the methods to evaluate Muvumba wetland values which are namely:

- Water Quality,
- Water Supply,
- Flood Protection and Erosion Control,
- Wildlife Habitat,
- Recreation /Culture/Science, and
- Commercial Benefits

The analysis categorized the above-mentioned values in two groups and was analyzed differently. The environmental values were water quality, water supply, Flood protection and erosion control; Wildlife habitat and Recreation/culture/ science value and the commercial value or economic value.

By comparing the various benefits of Muvumba marshland, economic and social assessment can be a powerful tool to aid and improve wise use and management of Rwandan marshland resources and basing on it to make a comparative assessment of the value of before and after marshland agriculture development.

3.3.4.1. Environmental values assessment

In this research thesis, we provided a general appraisal framework for Muvumba environmental values, including any analysis of distributional impacts that assists in assessing the benefits of alternative wetland use options. However, given that data and time limitations often constrain the ability to conduct economic valuation of the wetland, it was necessary only to limit the research to general appraisal framework of the marshland environmental values. A selection of priority areas for value assessment using appraisal framework of all ecosystem functions was not possible due lack of appropriate local level spatial and time series data. Thus, the decision to be limited to the economic/business value of the marshland was taken.

3.3.4.2. Economic/Commercial benefits assessment

Economic/Commercial benefits function of Muvumba Perimeter-8 has been assessed, and a certain appraisal of its value has been conducted through: (i) focus group discussions; and (ii) transect walk and (iii) knowledge of the valley before and after transformation iv) reading district and project report.

FIGURE 11: RICE PRODUCTION AFTER RECLAMATION

The research appraises the situation of the environment before and after reclamation which brought benefits and losses from the development done. The population made that comparison through the discussion we held and simulate advantages and disadvantages caused by the valorization. As it is hard to quantify every benefit and loss, the enumeration of them was preferred. These include qualitative benefits related to the standard of living caused by the project through increased revenues (as illustrated by figure 12) and the implementation of environmental safety.

Environmental protection practices have been done such as access to safe drinking water through the installation of modern wells, value increase by agriculture products, trees and grasses planted at the buffer zone of the developed scheme. For example, grasses and trees have been planted along the main irrigation canal to control floods and pollution of river water. No more reduction of natural vegetation that used by population in traditional arts and medicine, birds, pastoral and family resettlements disturbed, etc

Using observation and discussion with different stakeholders, some environmental values was enforced and other disturbed by the reclamation. To illustrate that, the letter of "***V***" was used where the presence of environmental value is still playing a big role to servicing the local population and the letter of ***"X"*** was used where the environmental value has been disturbed considerably by marshland reclamation.

CHAPTER 4: RESULTS AND DISCUSSION

This section presents the results and detailed discussion of the research findings. It starts off with marshland characteristics before and after reclamation, detailing land Cover/Use change detection 2008 – 2015 as well as comparing socio-economic and environmental benefits of farmers for both periods.

4.1. THE FUNCTION AND CHARACTERISTICS OF THE MARSHLAND

4.1.1. PHYSICAL CHARACTERISTICS

Muvumba marshland has an important buffer function (rainy season floods and maintains a high flow during the dry season). It was not exploited from the agricultural point of view but more from livestock covered with well-developed grass and making it a meadow.

FIGURE 12: AERIAL IMAGERY OF MUVUMBA-8 IN 2008/2009

Source: Imagery of 2008 & field picture

Figure 13: Picture of farms before irrigation scheme (2008)

Source: Imagery of 2008 & field picture

According to the discussion with local farmers, the big part of the valley of Muvumba (Perimeter 8) was owned by local breeders and used as pastoral land before 2008. Livestock farmers were evicted from the marshland, following the government's decision to extend the marshland for the purpose of rice farming.

FIGURE 14: LIFTING THE IMPROVED BREED OF COWS IN THE STUDY AREA

Cows, pastures, planted grasses and natural vegetation as well as small built up area characterized the valley before reclamation (as shown in Figure 13&14) and were replaced mainly by the rice, irrigation infrastructures, and post-harvest facilities. It is a real change of land use and function that characterized the marshland for the advantage of marshland irrigation;

4.1.2. FAUNE AND FLORA

According to the study report, hippopotamuses, and Nile crocodiles were lived in Umuvumba River (CIMA International, 2008). During flooding, these animals could get close to populated areas with dangerous consequences. The natural vegetation also accommodated a huge variety of birds such as birds of prey, guinea fowl, partridges, herons, etc. Hares, wild boar, monkeys and other rodents are occasionally found in the wooded savanna.

The flora in Muvumba marshland was made in general by afforested savanna vegetation and gallery forest along the river. The predominant species are *Acacia Senegal*, *A. hockii*, *A. sieberana*, *Lannea stuhlmannii*, *Ozoroa reticulata*, *Entada abyssinica* and *Solanum* species tree (Fisher, 1992 cited in CIMA International, 2008). The gallery forest of Muvumba required a rational exploitation because its removal could cause significant environmental risks from flooding to the loss of water quality (CIMA International, 2008).

FIGURE 15: LIVESTOCK TYPE ANKOLE CATTLE WATERING IN MUVUMBA

SOURCE: CIMA INTERNATIONAL, 2008

The district's economy is primarily agricultural and more livestock. A cattle breeding was dominant throughout the project area The *Ankole* race was the most dominant (as shown in the figure 15). The artificial insemination advances that the livestock had already produced 5% of improved breeds. Food crops were maize, beans, sorghum, rice, banana and cassava (CIMA International, 2008).

4.1.3. LAND COVER/USE CHANGE DETECTION 2008 – 2015

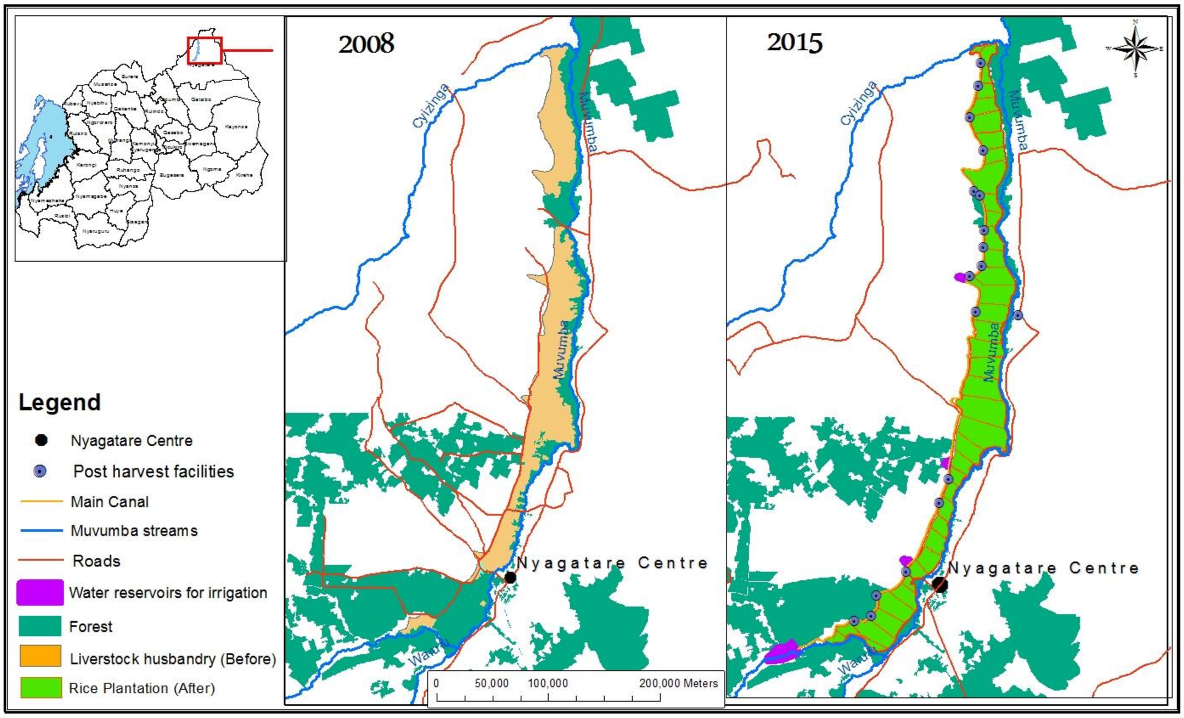


FIGURE 16: LAND COVER/LAND USE MAP FOR 2008 AND 2015

Detection change based on satellite imageries of 2008 and 2015 reveals that Muvumba was a marshland of 2,236 hectares that was covered mainly by pastures, savannah, natural vegetation and a built up area. It has been transformed to a rice scheme connected with irrigation canals and access roads. The pasture and savannah that covered 1,467 ha (65.6%) and 10Ha of houses (0.4%) in 2008 were located within the marshland boundaries and were converted into agriculture lands with irrigated and access roads infrastructures. In 2008, The natural vegetation was covering 759 ha (33.9%) and had been reduced in 2015 from 759ha to 233.3 ha. This means that only 30.7% of natural vegetation remain within the boundaries of the planned marshland with 525.7 ha (69.3%) of the forest was lost, which was converted to agriculture.

The analysis of both time series imageries showed that farmlands and natural vegetation were more predominant in the area which explains how local population was more attached to cow livestock and also it reveals how natural ecosystem and Community settlement has been disturbed for the development of agriculture. As collected from the district, about 300 families have been relocated from the Valley. It is evident that most evicted Cattle farmers and inhabitant from the valley were met difficulties to find other areas to settle.

4.2. COMPARISON OF THE SOCIO-ECONOMIC BENEFITS OF FARMERS FOR BOTH SITUATION /SCENARIO

The GoR has undertaken a comprehensive program for Poverty Reduction. Thus, he launched through MINAGRI, the Project for the Rural Sector (RSSP), which aims to revitalize the rural economy and improve the quality of life of the rural poor through increased transfer of technology and financial resources for sustainable rural development.

It receives funding from the International Development Association (IDA) via a credit to the GoR to finance the following sectors of marshland development;

i. the development of marshes and arable land of hills,
ii. the promotion of commercial and export crops,
iii. support for delivery systems of agricultural services,
iv. development of rural infrastructure,
v. the promotion of non-agricultural productive activities in rural areas, and
vi. program support and coordination.

RSSP reported the development of perimeter 8 (Muvumba) is one of the actions of component 1: marshland and arable hilly land. The general objective of the development of these marshes is to establish effective mechanisms for:

i. facilitate the adoption by beneficiary farmers' efficient and sustainable technologies and practices to manage a profitable way in the marsh cultures; and
ii. encourage and develop the skills of the private operators to intervene in the construction and maintenance of irrigation infrastructure.

The layout developed from livestock to rice covers a gross area of 2,236 ha. It is designed to allow the cultivation of rice in two seasons on 1625 ha. Cultivation of rice will be secured by the construction of a bypass dam development head.

The double rice crop is expected as many as the area allows the configuration of the marsh. Regarding soil science, all land consists of the marsh soils that are well suited to rice growing as evidenced by the gradual colonization of the valley Muvumba by this culture. Famers that have plots in the newly developed marshland have economically grown up but socially disturbed from their living habitat that was all used to.

4.2.1. Socio-Economic assessment of the situation before reclamation

According to the farmers' statements, before conversion, the marshland was primarily used for cattle husbandry which gave milk as the main source of income for farmers and on which they based on to live with their families. The interviewee stated that the cattle farming employed 276 shepherds who upkeep them. Each shepherd was paid about 5000 Rwf per month which cost 1,380,000 Rwf for all 1500 cows. The later provided about 864,000 liters of milk costing average 170 Rwf each liter. Cattle were mix of modern and traditional types. No goats and sheep were found in the baseline report provided by the interviewed agronomist.

The table below summarizes the benefits of the cattle husbandry for farmers;

Table 4: Economic baseline for cow livestock (2008)

Income	**Quantity/number**	**Unit cost**	**Total Cost (FRW)**
Cows	1500	200,000	300,000,000
Milk	864,000 liters	170Frw/L	146,880,000
TOTAL			**446,880,000**

Source: Agronomist interview

According to the discussion with some local farmers, there were many social benefits from the marshland ecosystem; local people were used to collect plants, hyparrenia and other plants for covering their houses, for traditional medicine, reeds, collecting water without chemicals, used Water River to wash clothes and watering cows, Etc.

4.2.2. Socio-Economic benefits after Conversion into Rice fields

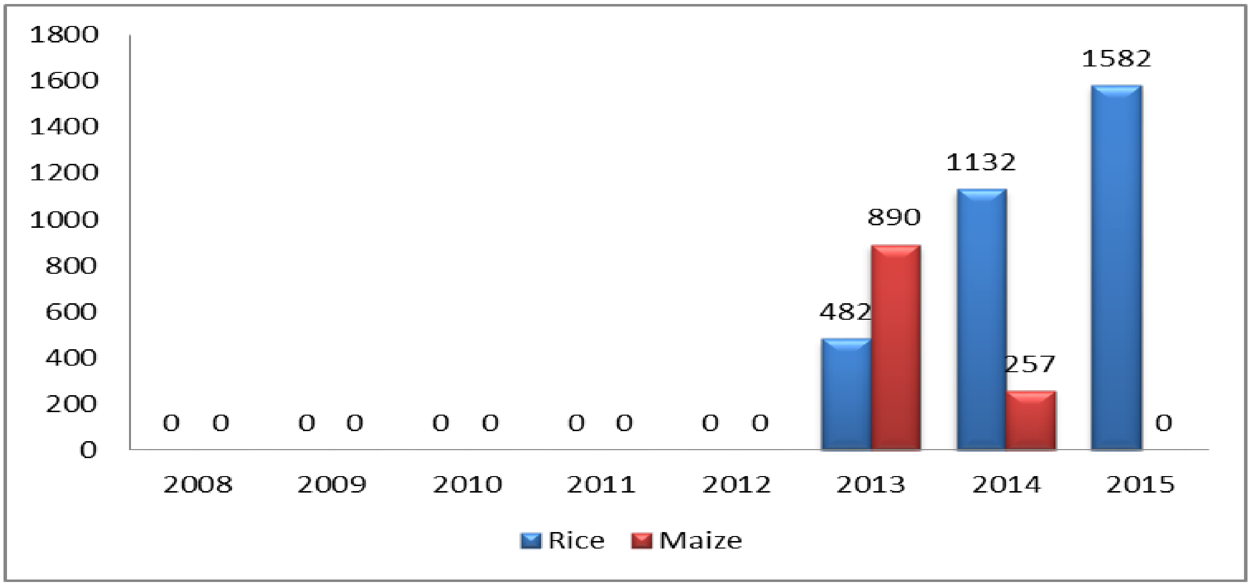
The RSSP report reveals that the government has injected $13 million (about Rwf 9 billion) to the project for extending Muvumba marshland irrigation (perimeter 8). The marshland currently has drying bays, storage facilities, and rice. Rice farmers in Muvumba marshland in Nyagatare district are expected to post increased production worth Rwf3.5 billion each season once they adopt best agricultural practices. With modern farming techniques, the yield is expected to hit at least 7 tons per hectare, but now the yield average reached 5.5T/ha.

Figure 17: Paddy after being processed by Nyagatare mill

According to the agronomist and with the use of high resolution 2015 Google Earth imagery, the total productive area of Muvumba marshland found to be 1,625 hectares (excluding all irrigation infrastructures), 700 of which have been given to Indian investor for rice production. The remaining area was distributed to individual local farmers.

The agronomist stated that the valorized marshland shows a considerable economic positive change as the project boosted the agricultural productivity and commercialization of organized farmers in the marshland and their participation in market-based value chains was strengthened. With the average rice yield of 5.5Ha per hectare, the yield for one season of 2015 was more than 4 billion Rwandan francs of about 17,600 tons of rice harvested.

Figure 18: The economic evolution of the marshland cropping (unit of measure in hectare).



Source: Marshland Cooperative Committee interview.

Analysis of beneficiaries and area after marshland conversion came up with the following information on the land value distributed among local community;

- Beneficiaries with area less than 0.5 Ha are 94 and with (10.52Ha)
- Beneficiaries with area of 0.5 Ha: 391 (210.5Ha)
- Beneficiaries with area Between 0.5 and 1 Ha:122 (82.2Ha)
- Beneficiaries with area of 1Ha:387 (414Ha)
- Beneficiaries with area Between 1 and 2 Ha:65(98.5Ha)
- Beneficiaries with area of 2Ha and Above:20 (809.1Ha)
- **Total beneficiaries are 1079 with area of 1625 Ha**
- Storage facilities: 2
- Drying bays: 16
- Weir intakes: 24
- Water intake and Stilling basins: 48
- Water intakes: 115
- Stilling Basins: 51
- Bridges: 20

- Main Canal=27.8 Km
- Main Roads: 2=51.4 Km
- Dam reservoir: 3 and 1 Diversion weir

The cooperative stated that not only farmers benefited rice produce (average 5.5-7 tons per hectare per each season) but also job was created to local farmers. During two years about 3000 labors were employed per day; each one was paid 2000 Rwf per day after completing his/her task (almost 5-7 working hours) in land leveling, digging canals and dam and roads construction, etc. About 10 financial institutions are working with farmers for saving and credit. Farmers benefited more in mobilization and cooperative formation, capacity building in Improved production technologies, Business planning, and entrepreneurship as well as Marketing and Financial literacy.

TABLE 5: INCOME FROM RICE PRODUCTION (THE YEAR 2015)

Actor	Area cultivated in Ha	Average annual yield in Tons	Annual production (Kg per year)	Average price per kg (Frw)	Total cost (Rwf)
Local farmers	925	5.5	10,175,000	250	2,543,750,000
Indian investor	700	5.5	7,700,000	250	1,925,000,000
Total	**1625**		**17,600,000**		**4,468,750,000**

Source: Interview with agronomist

Table 5 illustrates that the rice production income is now more than 4 billion Rwandan francs which are ten times of the livestock production. Assuming that the production will not decrease in quantity and cost per kg, the production of three years should cover the cost of the project execution. Without counting other interests brought by the project like creating about 5000 jobs annually, feeding cows with rests from rice, health and food improvement and so forth.

The cooperative reveals that the major constraints identified by farmers in Muvumba-P8 that they have had before were a water shortage in the valley and lacked land for agriculture. Because all lands were for cows and now after the marshland was developed for rice, they have issues of difficulty to access of sufficient improved rice seeds on time and high prices of fertilizers.

The primary benefits from wetlands for farmers are income generation and food security. Rice is an important crop in the marshland today, whereas farmers continue extending rice planting in the whole sides of the marshland and they accepted to grow rice only after it has been tested for its adaptability and profitability. Farmers have now sufficient knowledge on the causes and the potential solutions to overcome most constraints (John Wiley & Sons, 2011).

Production of rice has been given high priority by Government, especially in the valley bottom marshlands, where it presents a unique opportunity (potential yield over 5 T/Ha) for each of two crops per year. Furthermore, with rice prices having risen substantially on international markets during the past years, rice has become for most farmers a valuable cash crop.

Among the infrastructure developed in Muvumba Valley include:

- A big river weir with two anti-flood dykes;
- Three compensating reservoirs along the main canal of 400,890 m^3;
- A central irrigation and drainage network of 28 km each;
- Access roads of 23 km along the main channel;
- Secondary irrigation & drainage system and adjacent roads
- Well demarcated plots for rice cultivation
- Environment protection measures (tree planting).

Land distribution followed rehabilitation works; this marshland currently accommodates different categories of farmers. A total of 1078 farmers mainly the vulnerable population was each given between 0.5ha and 2ha of land on a freehold basis and one international agribusiness company from India was given 700ha of land on a lease basis.

After land distribution, farmers were organized into groups based on land proximity, that is, farmers with rice plots in the same vicinity formed a group. Group formation is vital in that it is the building block for a strong cooperative. Currently there 1078 farmers which are in 34 farmer groups in this marshland. Farmers in these groups meet regularly and are guided and trained by the project staff on different topics such as making group savings, mutual support, integrated pest management and land consolidation. On a higher level, these groups are consolidated into zones based on land proximity. Then zones form a cooperative that oversees all activities.

The development and valorization of the Muvumba irrigation perimeter 8 contribute to food security through the production of rice in the managed marshes; the national priority is rice. This causes an increase in rice production line with the objectives of the National Rice Production Program (2006-2016) and securing the production operators. It will be the same with the cultivation of the hills where soil conservation techniques have been proposed (at the component "Watershed"). Production increases will improve the food situation (quantity and quality) of the local population; surpluses should induce marketing channels to deficit areas (inside the country and to the capital) and possibly to neighboring countries due to the proximity of the borders. Support for the organization and development of marketing channels (which will be part of the measures to accompany the development work and the valorization of perimeter) should help increase farmers' incomes and thus improve living conditions. This increased production and revenue for small farmers, women and youth, is particularly interested in exploiting the marshes. At the national level, food security is increased, and imports (rice in particular) are being gradually reduced.

4.2.3. Calculation of the economic rate of return (ERR)

In determining the economic viability of the project, the assessment assumed that: (i) the exploitation of the perimeter 1625 ha starts from 2013, (ii) cost of the development is of 10 billion RWF and (iii) if a price is 200 FRW / KG paddy (minimum) and 10T/Ha/year, the production cost should be 3,2 billion FRW/year. Thus, the ERR is 35%. If we consider the actual price of 250 FRW / KG paddy in 2015 for 11T/Ha/Year, the ERR is 44% per year.

The above proves that, for both assumptions of production, the project is profitable regarding rates obtained which show that the project is economically viable, to the extent that the calculations were only based on the benefits of rice production. For calculations of ERR, many other positive impacts brought by the project have not been taken into account in the calculations because they are difficult to quantify. Here, we can enumerate the improved living conditions of population such as improve access roads, improved agronomic capacity building, job created during and after implementation, greater access to education and health due to improved financial capability, etc.

4.3. ENVIRONMENTAL ECOSYSTEM RESOURCES BEFORE AND AFTER RECLAMATION

As defined by many scholars and by the Millennium Ecosystem Assessment, ecosystem services are the benefits people obtain from nature (MA, 2005). Many of these benefits are quite easy to observe and to quantify like production services such as crops or livestock. Other ecosystem services such as climate change mitigation, flood and erosion control or water regulation and purification are difficult to detect and therefore they are undervalued or not considered in decision-making processes or policy change. The costs of losses in those ecosystem services can go mostly unnoticed. It appears very difficult to give the exact value of the natural capital of wetland, the lack of indicators and market prices.

4.3.1. ENVIRONMENTAL VALUES BEFORE CONVERSION

The wetland values that were available before marshland development and that were assessed in this research thesis include water quality, water supply, flood control, wildlife habitat, recreation/culture/science and commercial benefits but this study was more focusing on the economic/commercial value.

4.3.1.1. Water Quality

Muvumba marshland was used for pastoral activities, and it improved the water quality of Muvumba downstream. Runoff and surface water pass through vegetated marshland and then remove or transform pollutants through physical, chemical, and biological processes. It used to eliminate a quantity of pollutants from watershed water resources. Local households and cows used that water. Sediment deposition in wetlands prevented a source of turbidity from entering downstream ecosystems. Thus, sediment deposition provided multiple benefits to downstream water quality. Forested part of the wetland played a critical role in removing metals downstream of urbanized areas (Hupp et al. 1993).

4.3.1.2. Water Supply

Muvumba P8 marshland was acting as a reservoir for its catchment; it is why farmers preferred to make it cattle farms as to find safe water and glasses for cows. Cattle grasses, cows watering and trees were easy to develop due to the availability of water. Along Muvumba stream, it is a forest of diversified trees, and the cows were used to drink Muvumba water. We expect that the marshland released the water retained from precipitation, surface water, river overflow and ground water into associated surface water and ground water to be used by local inhabitants.

4.3.1.3. Flood Control

Muvumba marshland helped to protect adjacent and downstream properties from potential flood damage. The value of flood control by wetlands increases with: (1) wetland area, (2) proximity of the wetland to flood waters, (3) location of the wetland (along a river, lake, or stream), (4) amount of flooding that would occur without the presence of the wetlands, and, (5) lack of other upstream storage areas such as ponds, lakes, and reservoirs (Mitsch and Gosselink 1993). The cost of replacing the flood control function of the 50 Hectares of wetlands drained each year was determined to be $1million (USEPA 1995). Muvumba downstream are especially valuable for flood protection because it retains the volume of runoff from Nyagatare built up area.

4.3.1.4. Wildlife Habitat

Diverse species of plants, trees, insects, amphibians, reptiles, birds, and mammals depended on Muvumba marshland and stream for food, habitat, or temporary shelter, etc (source: FGD with Cooperative Committee)

4.3.1.5. Recreation, Culture, and Science

Wetlands have archeological, historical, cultural, recreational, and scientific values. According to discussants' statement, Muvumba area was used several times by scholars and scientists for their research on different tree species and Muvumba river hydrology. The forest place lodged the village meetings with local authorities and also it was like a touristic place for local youth to relax sometimes.

4.3.1.6.Commercial Benefits

Marshlands have value because their functions have proved to be useful to humans. Commercially important products harvested from Muvumba marshland before conversion include pasture, milk production, medicine plants, hunting and natural products with domestic used such as various reeds used in housing construction, mat and basket making, etc. (Source: FGD). These benefits are not easily expressed in money, but according to the literature and from discussants' statement, the benefits were real and people enjoyed them.

4.3.2. ENVIRONMENTAL VALUES AND IMPACTS AFTER CONVERSION

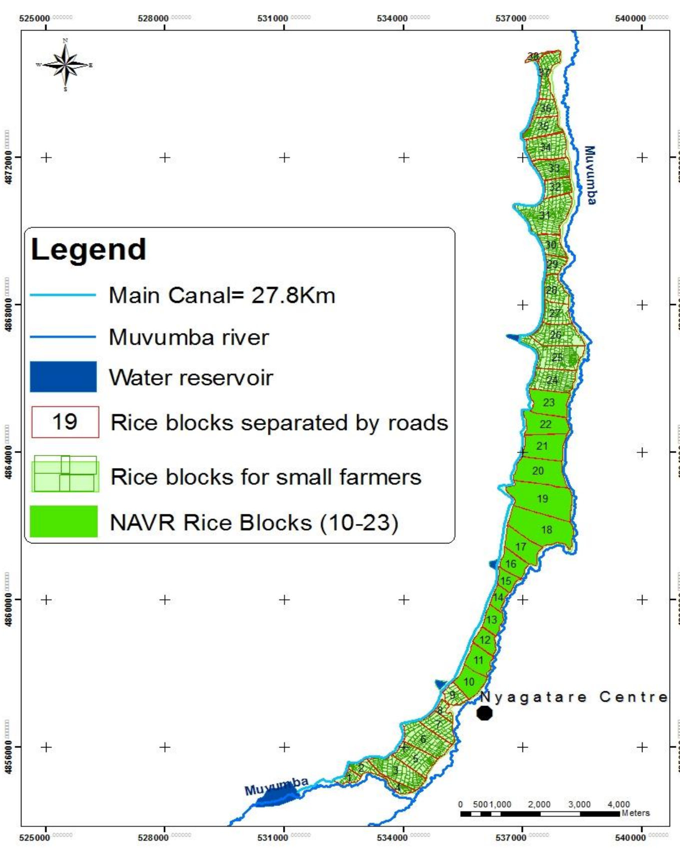
FIGURE 19:PLOUGHING WORKS DURING RECLAMATION OF MUVUMBA MARSHLAND

As shown in the picture above, most of Rwanda's marshlands are being reclaimed under government schemes with the aim of growing rice as the main crop. In this section, we highlighted environmental values and function existing after marshland conversion from pastoral lands to irrigated agriculture fields. The area grieved the loss of biodiversity where varieties of cows such traditional and breaded types were resettled away from the valley with more restrictions to access that marshland. The marshland was a good place for cows to find water and grasses. The marshland contained Nile crocodiles and hippopotamuses which provoked populated areas. Savannah and natural vegetation that reduced considerably accommodated many varieties of plants, insects, amphibians, reptiles, Hares, wild boar, monkeys and other rodents as well as birds such as prey, guinea fowl, partridges, herons, etc. for the priority to develop irrigated marshland.

4.3.2.1. Water Supply and Contamination of Surface Water

In new marshlands, the water is available in enough quantities as the residual moisture and the water supply are fresh. However, the equitable distribution of water is a major constraint here. According to discussants and people interviewed, Water equity is often the most fundamental cause of frictions amongst the rice farmers in marshlands. The schedule of receiving water in their plot should be clear enough to avoid plants water dispossession. According to interviewees, about 300 households use water from central channel of 27.8km in which water from the reservoir dam, are dirty, but not yet polluted. While about 1000 households use Muvumba River water taking pollutant from rice plots to drink and watering cows (the river drains the residual of N, P, and K and pesticides from fertilized rice plots).

FIGURE 20: MUVUMBA-8 NETWORK IN THE VALLEY



After conversion of the marshland, the water was drained and used for irrigation. Cattle and vegetative cover were removed from the marshland (2236ha gross, 1625Ha net were reconverted to irrigation agriculture). According to the cooperative and NAVR discussion, the dangers of contamination of surface water by chemical fertilizers (eutrophication) and by pesticides. This problem is still on a small scale given that the utilization of agricultural inputs (100kg of NPK / 1ha) by the people of the region is still low. However, it is necessary to keep in mind this potential danger as there is currently an incentive policy or a tax exemption on agricultural inputs which make them much more accessible to farmers which directly improves agricultural yields. Runoff and surface water are well directed to pass through mud canals which reduce its quality. Sediments from the watershed are stopped by the silt trap grass and tree layers before reaching the downstream. About 300 households are using water in the Muvumba central channel and more than 1000 cows are watered with the polluted water of Muvumba river.

Waterborne diseases – Basing on the statistics published by MINISANTE, Nyagatare is among districts with big numbers of malaria patients. A number of water-borne diseases are associated with irrigated rice cultivation, especially schistosomiasis, and also malaria. These diseases are inherent in stagnate water used by the population. However, they should not be aggravated by the fact of the development of the marsh Muvumba. If the clearing of channels is done regularly, there will probably a decrease of schistosomiasis.

4.3.2.2.Flood/Erosion control

The layout of the Muvumba IP 8 must not significantly interfere in principle with the water regime of the river system in which the it belongs. Access roads can be prone to important erosion. Directly roads can gully strongly to become impassable. Indirectly, the water flows into the longitudinal drains of the roads can cause gullies that endanger them and causing damage to agricultural land by promoting erosion and by bringing large amounts of sediment. Similarly, the work of stabilizing embankments and dykes can cause soil loss by landslides and mudslides because the slopes will initially be unstable. The new built slope is also subject to erosion. However, the extent of this impact is limited in space and time following the work of building the embankment.

Muvumba marshland is not controlling floods like before when it was a land cover of wild or natural grasses, there are no meanders anymore. Water channels form a regular grid pattern with straight layout. In such conditions, water flows smoothly and quickly because there are no meanders. Even tough water has been drained, it requires a continuous much effort to manage a probable flooding. Currently, the area is fully used for growing rice. Rice plantation allows water to flow always within fields. Main, secondary and tertiary canals are percolated by the flowing irrigation water which causes a high loss of water due to infiltration and reduces high flood damages of many fields.

Indirect environmental impacts - These are impacts on the watershed and extended progressively on the irrigation Perimeter. They have the consequence of a widespread or localized watershed degradation that manifested itself by problems such as sediment transport due to erosion, the upheavals flood plans, low water, etc.

This is reflected by accelerated erosion, major floods in the rainy season. For low flows, lack of infiltration depletes aquifers.

4.3.2.3.Wildlife habitat

Wildlife is only available in the gallery forest along Muvumba River than in the marshland due to marshland exploitation with rice. Many cow friendly birds' species and other endangered species were threatened by the conversion from cattle breeding to rice and migrated from the locality.

4.3.2.4.Land ownership issues

The development of the IP 8 of Muvumba has been a cause of land loss for some individuals whose plots were confiscated by the project irreversibly. This is a subtraction of a production tool and compensation was only a partial solution as the compensation with the same production potential would not be available to them. The project also caused the destruction of homes (10Ha) located within the perimeter and also caused involuntary displacement. However, the authorities have mobilized in advance the local population about the imminence of the development to make arrangements on time. Nevertheless, this project could block the economic and social activities of these people, and their effect was small.

4.3.2.5. Recreation, Culture, Science *and Damages related to work*

This function has been disturbed by fields' activities. The forest diversity is still there but reduced by size. The forest reduced the size as it has been cut to release enough lands for rice.

According to the discussants, there is also the damage that is primarily related to the lack of rigor in the performance of work and gaps in the specifications. These include: Lack of appropriate rehabilitation of borrow pit. This exposes them to be more vulnerable to erosion. This is accentuated by the presence of the rainy season. Also, the borrow pit zones often end up with shallow depressions where rainwater can accumulate. The borrow pit finally became a nuisance and a medium growth of microbes thus increasing the occurrence of waterborne diseases. Also, there were potential work accidents caused by construction plant and vehicles. This was accentuated by dust clouds that reduced visibility. However, the impact on the health of residents was low because it is localized and limited in time. Labor worksites were also exposed to accidents. This is especially the borrow areas, places of landslides and rock falls slopes that has more risk. Also, promiscuity that is created by the staff of sites and the affluence of the local population of site installations and the export of labor. This would have disrupted the socio-cultural balances in terms of depravity of morals, of desecration of customs and spread of sexually transmitted diseases including the scourge of HIV / AIDS, which was until now a very high 7.2%.

4.3.2.6. Economic/Commercial benefits

This section plays important place as it was the one primordial to evaluate economic values in details given that other environmental values were difficult to quantify. Money values were discussed above in 4.3. According to discussants, important commercial products have been introduced after development of the valley like rice/maize production and fishing in the constructed water reservoirs. The remaining natural vegetation is still used in traditional medicine, hunting and some wood for charcoal and construction. The new commercial products have considerably increased the economic value of marshland. As seen, this function was developed in this research amongst others. According to the interview with the environment officer of the RSSP project, the development of the marshland for agriculture purpose has improved the standard of living of local population as it considered some environment safety measures. The silt rap zone of 20m belt of trees and grasses were established to protect the dam, water reservoirs and the scheme against silting and flooding. Access roads were constructed and modern wells were installed to access safe drinking water. Youth and women were employed at the local level, with the work-intensive labor as well as capacitating them for environmental protection and infrastructure maintenance and operations.

Therefore, the project of reclaiming the perimeter 8 of Muvumba valley considerably increased agricultural production, movement of goods and persons and therefore revitalizes trade in this part of the country by creating an accessible market. Furthermore, though the project disturbed some vegetation cover and water regime but leads to socio-economic growth induced with opportunities for rapid flow of production on different axes, this contribute to the reduction of poverty, a priority of GoR in EDPRS2 and Vision2020.

4.3.3. Comparison of both scenario (before and after conversion)

Since significant resources and effort are invested in the development of an irrigated perimeter (IP), the main environmental concern is the sustainability and proper functioning of networks and irrigation infrastructure. This survival depends on two important factors: From the involvement and mobilization of the people involved; this is the users of irrigated area are farmers in the irrigated area, farmers in rainfed areas and farmers for watering and livestock grazing. It should be noted here that the big losers are socially farmers who lost pastures to the detriment of the project. To these principal activities are grafted producing the service timber, firewood and charcoal.

Overall, the degradation of a watershed is manifested by signs easy to observed such as:

- Sheet erosion or gullies
- A decrease in agricultural yield (per hectare by total production) due the degradation and the cultivation of marginal lands
- A decline in the carrying capacity of pastures
- Active sedimentation in rivers, water reservoirs, and irrigation infrastructure
- A loss of forests and or natural vegetation.

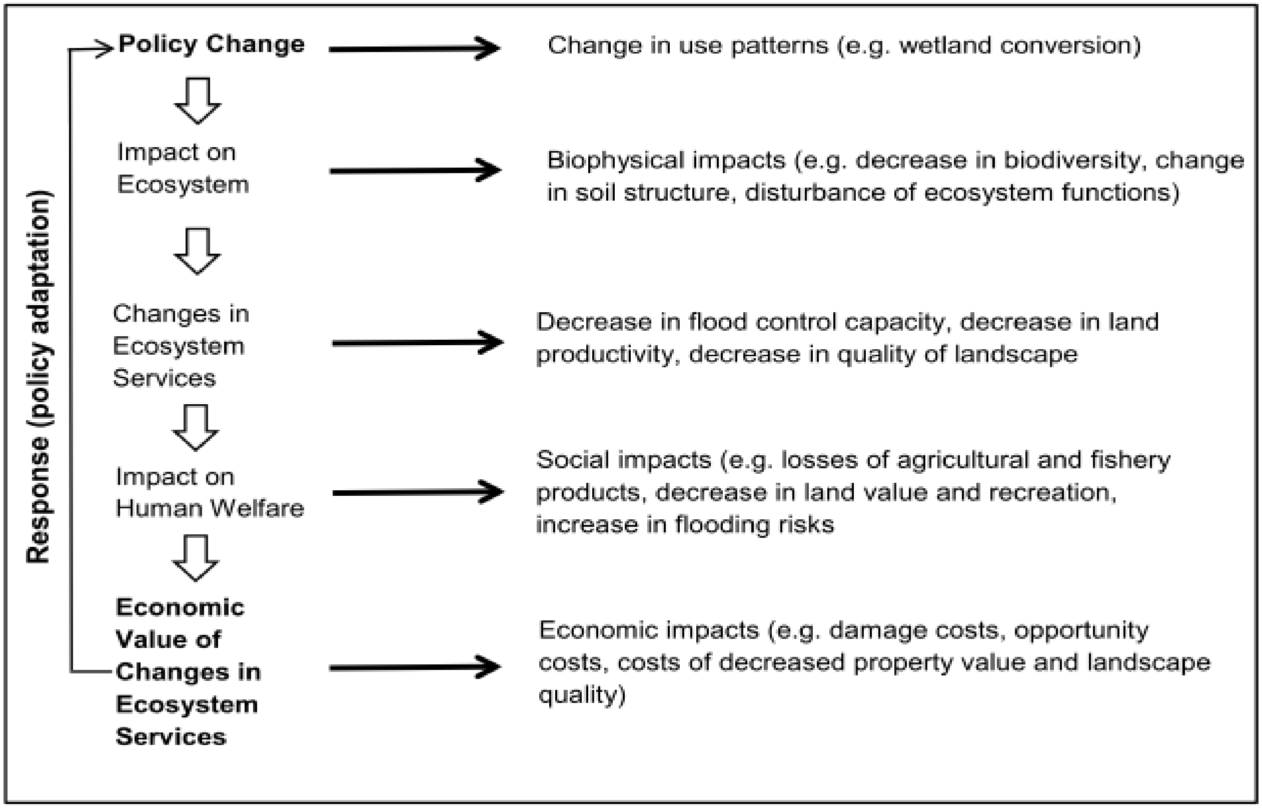
Thus, spatial perimeter 8 of the Muvumba may cause changes level of the water table, upsetting the water regime of some plots in the IP as well as in adjacent plots. However, the damage that will be caused to renewable natural resources (flora and vegetation) will reversible over time.

To improve access to water resources many programs have been developed, but they have not given adequate consideration to harmful trade-offs with other services provided by wetlands. Many conversions of wetlands have favored provisioning services (mainly food production) at the expense of losing or reducing delivery of regulation and supporting services (MA 2005 cited in agriwaterpedia.info).

When wetlands are converted or degraded a cost can be incurred by society if the ecosystem services that were previously provided (at no cost) by wetlands may be needed to be replaced by building infrastructures such as water treatment plants. Examples of increased cost are: illness and health care costs (water contamination); infrastructure costs such as costs for construction, operation, maintenance, and monitoring; threats to biodiversity and increased carbon emission; decreased property value of the land due to the degraded aesthetic qualities; decreased recreational opportunities; increased insurance costs due to the high flooding risks; and the decreased income from tourism activities associated with healthy ecosystems.

Figure 21 illustrates the scientific evidence of an ecosystem services approach and the valuation sequences.

FIGURE 21: THE PATHWAY FROM POLICY CHANGE TO SOCIO-ECONOMIC IMPACTS.



Source: cited on Agriwaterpedia.info based on TEEB (2009)

TABLE 6: COMPARISON OF ENVIRONMENTAL IMPACTS BEFORE AND AFTER MARSHLAND CONVERSION

Value	Before	After
Water quality	No water pollution	Contaminated surface water by chemical fertilizers (eutrophication) and by pesticides. Waterborne disease: schistosomiasis& malaria.
Water supply	Watering inhabitants and cattle	Water available but Polluted: Average 300 Families & 1000 cows use polluted water
Flood control	retained the volume of runoff from Nyagatare built up area and upstream watershed	Active sedimentation in rivers, water reservoirs, and irrigation infrastructure
Wildlife habitat	Species of plants, trees, insects, amphibians, reptiles, birds, and mammals were abundant.	Fauna and Flora were threatened
Recreation/ Culture/Science	archeological, historical, cultural, recreational, and scientific values	A loss of Savannah and decrease of natural vegetation.
Commercial benefits	People enjoyed the value of pasture, milk production, medicine plants, hunting and natural products with domestic used such as various reeds used in housing construction, mat and basket making, etc.	Rapid flow of Rice and Maize commodity, economic growth, postharvest facilities, access roads were constructed and modern wells were installed to access safe drinking water, jobs created, accessible market, etc
Land ownership	Settlement and Land utilization	land loss/or decreased, destruction of homes, involuntary displacement

TABLE 7: COMPARATIVE TABLE OF THE BEFORE AND THE AFTER OF MUVUMBA ENVIRONMENTAL VALUES

Value	**Before**	**After**
Water quality	*V*	*X*
Water supply	*V*	*V*
Flood control	*V*	*X*
Wildlife habitat	*V*	*X*
Recreation/Culture/Science	*V*	*X*
Commercial benefits	*V*	*V*
Land ownership	*V*	*X*

The letter of ***"V"*** was used where the presence of environmental value is still playing a big role to servicing the local population and the letter of ***"X"*** was used where the environmental value has been disturbed considerably by marshland reclamation.

CHAPITER 5: CONCLUSION AND RECOMMENDATIONS

5.1. CONCLUSION

Marshlands are critical to playing multiple functions in hydrological, chemical, biological ecosystem cycles and have great agricultural potential when properly used. Marshlands are multi-functional natural reservoirs on which communities can depend upon for the economic and environmental benefits. These marshland benefits are particularly important in the dry parts of Rwanda where their efficient reclamation for agriculture development can be rural livelihoods.

According to Rwanda Agriculture Board, Rwanda has numerous marshlands that have been developed from basic use to commercialized agriculture since 2000 where area developed so far reached about 19,000Ha in 2015 yielding more than 90,000T per year. With rice and other crop fields being widely cultivated across marshlands of the country, it is a challenge for MINAGRI to be able to monitor constantly the practices being carried out.

This research main objective was to analyze the change of marshlands value in Rwanda, with particular focus on land use/land cover dynamic change over time since 2008 to 2015 and how it impacted environmental values of the marshland. In this research, field observation, focused group discussion and analysis of different imageries for land cover/ land use change detection have been used to attain research objectives. The study was also designed to use the capability of Geo-Information to monitor the development of marshlands and related modern practices.

Currently, management practices are based on ground survey data by ministry specialists as well as data obtained from local farmers in the fields. With rice and other crop fields being widely developed across the country, it is a challenge for the Ministry of Agriculture to be able to monitor constantly the practices being carried out. Therefore, the satellite images and analysis provided by this study will facilitate the Ministry of Agriculture's efforts in the monitoring and advancement of marshland management practices in Rwanda.

The marshes of the Muvumba, like all of the Eastern Province, are usually large marshes low altitudes or collector's marshes. They are concentrated along the primary river system. The floors are almost always organic. They have an important buffer function (rainy season floods and maintains a high flow during the dry season). They have little exploited the agricultural point of view but more from livestock because of well-developed herbaceous cover and making a meadow. The marsh purpose of this study is located in Nyagatare District, Eastern Province.

In this research, using the imagery change detection from 2008 to 2015 hit the notable conversion of 89.5% of land use/land cover changed from natural vegetation, grasses, pastoral lands and built-up to agriculture rice intensification. The furnishings in the marsh covers a gross area of 2236 ha. It is designed to allow the cultivation of rice in two seasons on 1,625 hectares. Rice cultivation is secured by the construction of a diversion dam in development head. The double rice cultivation is practiced on as area that allows the configuration of the marsh. In terms of soil science, all the land of the marsh consists of soils that are well suited to rice growing as evidenced by the gradual colonization of the valley Muvumba by this culture.

The results showed that the development of Muvumba marshland leads to a rice yield of over 5.5T/ha (2015) of paddy for a total of 17,600 MT per year with two growing seasons. The development of the marshland costed RWF 10 billion (USD 13 million) with funds from both the World Bank and the Government of Rwanda. The impact of this marshland development is economically positive for the local community though reduction and/or negatively impacted ecosystem services.

The layout of the perimeter of the VIII Muvumba generates impacts globally positive. Also, the project facilitates the increase of agricultural production, communication and above all ensure greater movement of goods and persons. Therefore, promote trade, the development of this marshland comes in the strategic economic development of Rwanda and particularly of the District of Nyagatare which put in its 2020 strategic plan this development. Thus, the project contributes to cost reduction and rice transport time reduction for residents of Nyagatare, which revitalizes the economy in this part of the country by creating an accessible market. Furthermore, said project leads to socio-economic development induced with opportunities for rapid flow of production on different axes. There is also, job creation at the local level, with the work-intensive labor.

In addition, due to the ripple effects created by this development, the project generates other monetary activities at local, regional and national. There are opening new opportunities for women and children. This will contribute to the reduction of poverty, a priority of the Government of Rwanda program. Aesthetically, the planting of trees in individual stands belts, plantation fixing hedges, slope protection of the central channel allows improving plant cover, reduction of erosion with as resulting improve the welfare of local populations, soil fertility and increased agricultural production. It is why this watershed management approach is recommended everywhere in Rwanda in any marsh development project.

The project could generate negative impacts; especially the impacts on the gallery forest of Muvumba, nuisance noises of machinery and construction vehicles, vibration, gas and dust emissions, constituting sources of alteration of the quality of the air. This constitutes a nuisance to local residents. These impacts could affect human health and increase the prevalence of respiratory diseases and ophthalmological diseases.

Another important impact is the involuntary relocation of people from the marshland to develop. This affects social change in several dimensions: disturbance in the economy of households, etc. However, these impacts are small because the benefits reflect their development. In addition, the risk of the accidental oil spill, leaks hydrocarbons, oils or grease of construction equipment, could also be sources of soil and water pollution. On the other hand, the pressure on the water resources can generate potential conflicts. Also, promiscuity that is created (by yards of staff and the influx of local populations of site installations, the export of labor) could disrupt the sociocultural balance in terms of depravity of morals, desecration of customs and spread of sexually transmitted diseases including the scourge of HIV / AIDS, which was until now a high 7.2%. Throughout the watershed, the development of perimeter VIII may have adverse effects on the water balance with accordingly lowering amounts of water, changes in flow rates, low retention capacity and regulating water flows, etc.

5.2. RECOMMENDATIONS

A series of coherent and integrated recommendations in safeguarding irrigation infrastructure developed, crop productivity and livelihood of farmers, while implementing adaptation and mitigation measures for negative impacts on reclaimed lands;

The marshland development cannot be limited to the establishment of hydro-agricultural infrastructure, but must be accompanied by a series of measures to implement at the amenities and operating phases indication, actions accompanying expected already identified in the marshland development master plan could include:

1. Measures of technical support to production: to ensure the transfer of technology adapted to the specific conditions of the marshes. Be expected actions:

- Training farmers for management and maintenance of developed agro-infrastructure facilities, irrigation techniques, management of farmers' organizations, business development plans ...)
- Board support with specialist advisors (to form) in the development of marshland,
- Of action research oriented mainly on crop diversification in marshes, monitoring fertility of marshland soils.

2. Support for the marketing of products: We have seen a significant constraint intensification and diversification of crops constituted by the low capacity absorption of local markets. Information Studies and systems markets may occur.

3. Accompanying infrastructure: access infrastructure to facilitate access to the area developed to allow the flow of production and input supply.

4. Support for the timing of agricultural inputs: such as seed varieties adapted to the characteristics of the marshes.

5. Clarification of the land: We already reported that the land in the managed marshes is allocated by the government, which can be a constraint to the development RMS Marsh (reluctance of farmers to land investments, maintenance of water infrastructures in the absence of long operational safety
term).

Continuous education and mentoring of the rural farmers is very much imperative if they need to adapt to climate change and negative impacts. A successful agricultural adaptation requires better and clearer information combined with investments and advisory services to disseminate the information to the local farmers as well as strengthening the liaison between the bottom–down farmers and the top-up officials. Adequate extension information services to ensure that farmers receive up-to-date information about climatic patterns in the forthcoming season so that they can make well-informed decisions about their planting dates. They could also play a role in land use changes and crop-farm management practices of farmers that could play a role in adaptation and concomitantly mitigation of negative impacts and climate change.

Stable and supportive policies should be implemented to improve risk management of subsistence farmers and would require the engagement of core ministries. The core programs of development must encompass the impacts of climate change as it affects poverty, food security, and economic development of the rural poor.

Trees and grasses that are planted around the land reclaimed should be well maintained until they grow big. This is to tackle the issue of surviving rate after spending much money on their planting. It is a good strategy to control floods and silting that come from upper catchments.

The government should continue to assist local farmers in the operations and maintenance of the irrigation infrastructures for a certain period of time until local farmers own enough financial capacity and great understanding to manage it themselves. This is to prevent the destruction and step back of development reached so far.

Valuation and Compensation of lands and assets should be clearly done to satisfy people to move from the area to be reclaimed or developed. This is very crucial in Rwanda as people are affected by developments before being compensated. This study recommends to use this strategy to mitigate the negative impacts that might occur after lands being reclaimed and as a way of fighting extreme poverty and injustice.

Financing of the rural area by setting up suitable financial systems that will allow smallholders subsistence farmers to have access to credit. These policies that improve household welfare as well as access to credit are also a priority for both short and long-term adaptation measures.

Best crop varieties and hybrids that can withstand climate issues and mature early could enable the farmers to be ready to meet the challenges of climatic variability and fight hunger and poverty.
New Water supply sources should be created for the local people and their cows instead of using the water from the canal and the river polluted one. The polluted water of Muvumba river is an exposure of their lives to diseases and death.

The current study can contribute not only to improvements in the Muvumba environment but the study of and improvements to other coming reclaimed marshlands as the rapid reclamation of marshlands is one of the most pronounced environmental trends of recent times.

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APPENDIX

GUIDE FOR FOCUSED GROUP DISCUSSION AND INTERVIEW

Kindly provide the following information and discuss on the following questions about the perimeter 8 of Muvumba Marshland.

- Name ……………………………. ……………….
- Position …………………………...…. ……….....

All questions responding to specific objectives of the research:

1. What types of land uses that were in place before Muvumba marshland being reclaimed? Where were they located?

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   ………………………………………………………………………………………

2. Which land uses occupied big areas?

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   …………………………………………………………………………………………

3. How much cows and their shepherds affected by the marshland conversion

   ……………………………………………………………………………………………
   …………………………………………………………………………………………

4. What types of vegetation, animals and birds were affected by the conversion of this valley?

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5. Did local residents used water from Muvumba river? How was its quality? Can you compare it with the water you use today from Muvumba river/Canal after its conversion?

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6. What about soil erosion and floods before and after? Where did you find more erosion and floods?

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7. Was there any cultural and recreational function that was disturbed by the development of Muvumba P8?

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8. What are other negative and positive impacts brought by Muvumba P8 irrigation development?

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9. Can you explain clearly all benefits for the farmers from this marshland before its transformation into Irrigation agriculture

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10. Can you make a kind of comparison between benefits from livestock and the ones from rice production?

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11. How agriculture irrigation system developed is working now? Who do operate and maintain that system?

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……………………………………………………………………………………

12. How farmers are organized to manage this rice/maize intensified agriculture?

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