Towards a Model for Wetland Rehabilitation in South Eastern Zimbabwe

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DECLARATION

I, Makarati Fidelis (Student number 24253537) declare that this PhD Thesis entitled *Towards a model of Wetland Rehabilitation in South Eastern Zimbabwe* is solely a product of my own original work and has not been previously or in part submitted at any university, and that all references have been duly acknowledged.

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DEDICATION

To my late parents, Mr. Epheas Makarati and Mrs. Piwai Makarati, for a blessed upbringing and sending me to a mission boarding school where I got quality high school education which laid the foundation for all my academic successes.

I also dedicate this thesis to my wife, my son and daughter for their undying love during my absence in search of higher education and personal advancement.

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ABSTRACT

The rehabilitation of degraded wetlands is a very costly approach owing to the goals, options and funding as well as the involvement of different stakeholders and their different interests. This study investigated the different factors that influence the performance of rehabilitation projects. The investigation sought to design a wetland rehabilitation project that is feasible and ecologically sustainable. A quantitative research design was used to document and collect data. The observation technique was employed to gather data in the field. Field observations complemented the structured face-to-face interviews. Topographic maps and aerial photographs of the study area were used to identify settlements, wetlands and rehabilitation projects. Various statistical packages such as ANOVA, Pearson Correlation analysis and T-Tests were used to analyse and interpret the findings and draw conclusions on the set hypotheses. Literature reviewed in this study show that wetland loss is an on-going phenomenon that needs drastic efforts to reverse it. Data obtained from the Meteorological Services Department demonstrate that climate change is an on-going trend characterised by an increase in the intensity and frequency of drought. The findings from field observations and interviews reveal further the need for a paradigm shift from simple and basic rehabilitation measures to comprehensive state of the art rehabilitation interventions in order to re-establish the structure, function and biological integrity of wetlands. Wetland rehabilitation only covers 23% of the possible degraded wetlands that should be rehabilitated. Technical, managerial, financial and community circumstances contribute to the current poor state of wetland rehabilitation in Zimbabwe. Financial funding of wetland rehabilitation is limited and in cases where it is availed, rehabilitation structures do not reflect the massive amounts injected into the project. Given that the current wetland rehabilitation projects lack a systems thinking approach in addressing the underlying causes of wetland loss more needs to be done. The studies underscore that current rehabilitation efforts are commendable but fail to address the sustainability of the wetlands themselves and the rehabilitation projects themselves. The research findings suggest ways to improve rehabilitation projects. A national wetland degradation response strategy should include but not limited to wetland rehabilitation.

The rehabilitation plan should be site specific and comprehensive enough. Strong institutions such as Wetland Rehabilitation Committees or Teams responsible for rehabilitation should be established. The starting point would be to establish wetland district rehabilitation teams that should comprise of 10-15 project implementers. Their responsibility will be to install and maintain rehabilitation structures. These teams can be employed on a fulltime basis. Some of the proceeds from wetland production should be reinvested for wetland rehabilitation through buying fence and introducing agroforestry activities instead of over-reliance on donor fund. These results are used to design a Wetland Sustainability Model (WESUMO) that provides tools for wetland rehabilitation.

KEYWORDS: Wetland health, Wetland structure, Wetland function, Climate change, Ecosystem, Ecosystem approach, Ecosystem services, Sustainability, Model, SouthEastern Zimbabwe

DEFINITIONS

Dambo

A word used to refer to a class of wetlands conventionally found in Central and Southern Africa to denote shallow, seasonally or permanently water logged depressions at or near the head of the drainage network and sometimes occur independent of the drainage system.

Climate change

Climate change constitutes, a shift in meteorological condition lasting a few years or longer attributed to anthropogenic factors such as greenhouse gas emissions.

Ecosystem

An ecosystem is a distinct geographic area containing components that are living and non-living, natural and human-made and their processes. It contains unique biological community interacting with the physical environment

Ecosystem approach

An ecosystem approach is a strategy for the integrated management of land, water and living resources that promotes conservation and sustainable use in an equitable way.

Ecosystem services

These are goods and services that ecosystems provide to people for example provisioning and cycling of water leading to clean drinking water.

Wetland Sustainability Model (WESUMO)

A predictive theoretical framework and set of plans designed for wetland rehabilitation used to address wetland degradation and loss.

South-Eastern Zimbabwe

The region covers the Masvingo Province of Zimbabwe and comprises the Chiredzi, Zaka, Chivi, Gutu, Bikita and Masvingo Districts.

Sustainable Development

Sustainable development is defined as a development that meets the needs of the present without compromising the ability of future generations to meet their needs.

Wetland

A wetland is an area that is inundated or saturated by water at a frequency and for sufficient duration to support emergent plants adapted for life in saturated soil conditions.

Wetland conservation

This refers to the removal of a threat to or prevention of the decline of wetland conditions by an action in or near a wetland that does not result in a gain in wetland functions and size.

Wetland enhancement

Enhancement denotes increasing one or more functions of an existing wetland often with an accompanying loss or alteration of other wetland functions.

Wetland health

Wetland health can be defined as the ability of the wetlands to sustain production (plants, crops and fish) through maintaining the water and sediment balance. This also denotes its ability in maintaining hydrological, biological, chemical and climatic conditions.

Wetland function

Wetland function refers to surface and ground water storage, recharge and supply, floodwater and sediment retention, nutrient recycling, biomass production, reduction of erosion, and purification of water.

Wetland structure

The structure of a wetland or its parts include water quality, soil condition, geology, hydrology, topography, morphology, carrying capacity, species composition, food web support, and nutrient content.

Wetland rehabilitation

Wetland rehabilitation is a process towards the attainment of former ecosystem structures, functions and/or state.

Wetland restoration

Wetland restoration is almost similar to wetland rehabilitation but differs slightly. Restoration is returning a degraded wetland or former wetland to a pre-existing condition or one as close to the original as possible. Wetland restoration also means to restore former ecosystem structure and functions and re-establish its integrity as well. In addition it encompasses conditions in a degraded wetland to heighten intensity or revive specific functions such as provision of goods and services. **Wetland sustainability**

Wetland sustainability refers to people's use of a wetland so that it may yield the greatest continuous benefit to present generations while maintaining the potential to meet the needs and aspirations of future generations.

ABBREVIATIONS AND ACRONYMS

ANOVA: Analysis of Variance

ARC: Agricultural Research Council

AREX: Agriculture Research and Extension Services

CAG: Computer Aided Graphics

CAMPFIRE: Communal Areas Management Programme for Indigenous Resources

CBD: Convention on Biological Diversity

CBNRM: Community Based Natural Resource Management

CSO: Central Statistical Office

CPs: Contracting Parties

EBM: Ecosystem Based Management

EMA: Environmental Management Agency

EMA: Act Environmental Management Act

ES: Ecosystem Services

IKS: Indigenous Knowledge Systems

IGO: Inter Governmental Organisations

IUCN: International Union for the Conservation of Nature

FWP: Food for Work Programme

GCF: Green Climate Fund

GEF: Global Environment Fund

GEFSGP: Global Environmental Facility for Small Grants Project

LEAP: Local Environmental Action Plans

MCDA: Multi-criteria decision analysis

MEA: Millennium Ecosystem Assessment

MSD: Meteorological Services Department

NEPAD: New Economic Partnership for African Development

NEP: National Environmental Policy

UNDP: United Nations Development Programme

UNEP: United Nations Environment Programme

USDA: United States Department of Agriculture

US: IWWR- United States-Interagency Workgroup on Wetland Restoration

PES: Payment for Ecological Services

RDC: Rural District Council

SADC: Southern African Development Community

SMART: Specific, Measurable, Achievable, Realistic and Time-bound

SPI: Standard Precipitation Index

WBI: Wetland Biological Index

WCED: World Commission on the Environment and Development

WESUMO: Wetland Sustainability Model

WPDS: World Population Data Sheet

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CHAPTER 1: INTRODUCTION

1.1 Background

Wetlands provide water and water is life, yet the wetlands have often been neglected by national governments and environmental managers. Wetlands are the kidneys of the landscape; they are a vital organ of the environment to the extent that any harm on these delicate parts of the ecosystem renders the environment dysfunctional. This is particularly true for water scarce regions, such as South-Eastern Zimbabwe. Four components occupy the wetland ecosystem intersection and these are soil, water, plants and animals. The four components are dynamic systems that react to environmental disturbances, whether natural or anthropogenic. Hence, a disturbance to any one of the components affects the entire system as the components are intricately linked to one another. In addition, these systems are fragile and sensitive to human impacts (Pollard *et al*., 2006; Morardet *et al*., 2010).

IUCN, (2004). It is pointed out that wetlands are not wastelands, but are kidneys of the landscape and biological ―supermarkets‖. The supply of ecosystem services depends on the functioning of ecosystems (Silvestri *et al.,* 2013). Wetlands are multifunctional ecosystems that provide numerous goods and services. Barbier (2011) noted that wetlands are natural assets that generate multiple ecosystem services. They provide fertile and safe breeding grounds for migratory birds, regulate hydrological flows, underpin purification and pollination, and control soil erosion. They also perform provisioning functions by making goods available such as fruits, fish, fodder, peat, wild game and grains. Furthermore, wetlands are extremely valuable to both humans and wildlife (Balcombe *et al.* 2005), for they act as sponges that absorb nutrients and pollutants which purify downstream water (Ndebele-Murisa, 2012); and offer their buffering capacity for agricultural and municipal wastes, and support soil formation and nutrient recycling. Also wetlands have cultural significance in that they fulfil spiritual, inspirational, recreational, aesthetic and educational roles (Millennium Ecosystem Assessment, 2005).

The significance of African wetlands is confirmed by Kirsten (2005) in the view that they are an important natural resource that forms the basis for socio-economic activities in rural communities. It is evident in Zimbabwe that water supplied from dambos, pans, swamps and floodplains contributes to human livelihoods (Marambanyika *et al.* 2012). Moreover, these systems are important for grazing and watering domestic livestock and wildlife.

1.1.1. Impact and causes of wetland degradation

Worldwide, wetlands have been degraded over a long period of time. Nagabhatla et al. (2012) highlight that the actual extent of global wetland loss is not well known. Some put it at more than 50% (Ramsar Convention on Wetlands, 1971) and sometimes at more than 85% of specific wetland types. Depending on the region, 30–90 % of the world's wetlands have either already been destroyed or radically modified in many countries with no sign of abatement. For example, the United States of America's (USA) Midwest has lost 80-90% of its wetlands (Mitsch and Day, 2006). Riddell *et al.* (2010) pointed out that wetlands on the African continent are among the most damaged whilst others are fast shrinking.

The health of wetlands is under threat from global climate change, such that future wetland management will be more complex. The issue of climate change may present greater challenges to wetland conservation and restoration (Erwin 2009), and is a critical challenge affecting wetland rehabilitation options. It causes interconnected challenges around controversial political decisions and compels communities to adapt to appropriate technology. An analysis of the impact of climate change on wetlands ecosystems needs to understand the nature of climatic and ecological changes that are likely to occur regionally (Erwin 2009). This will assist in the establishment of proper wetland management and restoration plans at various catchment levels. Different wetland stressors require varying management techniques. If climate change and variability are not proactively taken into account, the potential for conservation plans to succeed may be much reduced (Hayal *et al.*, 2012; Ogato, 2013).

The observed and projected increase in rainfall variability and extreme weather events create environmental conditions that alter the ecology especially in climate sensitive resources such as wetlands (Dube and Chimbari, 2009). Recurrent droughts impact negatively on wetland health, with examples of changes in base flows and altered hydrology (Ramsar STRP, 2002). The water table in heavily degraded wetlands has been dropping over a long period of time. In addition, wetlands may drift spatially within the region depending on changes in precipitation and potential evapotranspiration rates (Hayal *et al.* 2012). Hulme, (2005) asserts that changes in rainfall patterns are also likely to alter the run-off pattern (reduced by 10-40%) which inherently poses serious threats to wetland integrity.

From an ecosystem perspective, wetland rehabilitation is influenced, to a great extent, by climate change. The future of wetlands is linked to the well-being of humanity, and the effects of climate change cannot be de-linked from human activities occurring in and around wetlands (Mitchell 2013). Rainfall variability alters the water supply and food production systems in a negative way. During drought episodes, wetlands are converted for agricultural purposes. Thus, there is need for more work that unpacks the relationship between rainfall variability and wetland health, an approach that calls for an understanding of socio-economic factors and ecological conditions that influence wetland rehabilitation. There is need for research on climate variability and wetland loss, which provides a model through which it is possible to rehabilitate degraded wetlands (Hayal *et al.,* 2012).

The disappearance of wetlands is largely linked to human activities. Water shortage for human use and ecological functions has been identified as the primary cause of wetland loss on a global scale (MEA, 2005; Mitsch and Gosselink, 2007). For instance, garden cultivation has promoted wetland fragmentation, over-cultivation and unsustainable agronomic practices like stream bank cultivation and the associated siltation. The production of crops such as sweet potatoes, vegetables, wheat, sugarcane, and bananas has altered the hydrological setup of these vital wetland resources to the extent that urgent remedial interventions have to be put in place to save this lifeline ecosystem. The degradation of wetlands arises from the impact of water demanding activities such as agriculture and land-use changes (Mharapara, 2002; Grenfell *et al.* 2005; Frenken and; Li, 2008; Dube and Chimbari, 2009; Erwin, 2009; Feresu *et al.*, 2010; Li, 2012). Intensive livestock grazing often leads to land-use changes (Dabbasso *et al.*, 2012). These human activities have alarmed environmentalists and general conservation practitioners in Zimbabwe where the exploitation of wetlands has reached alarming levels. Interventions are urgently required in water management for crop cultivation in wetlands.

Wetland desiccation to a large extent is caused by anthropogenic factors such as drainage, deforestation and overgrazing (Hamandawana et al., 2005; Mapanda and Mavengahama, 2011). This has resulted in the loss of 20% freshwater species in the Southern African Development Community (SADC) region. The loss of wetlands has been linked to increases in both flood severity, poverty and the occurrence of conflicts over shared resources (Erwin, 2009; Ogato, 2013). The majority of people's livelihoods are strongly reliant on natural resources. In addition, there has been an increase in the use of wetlands for agricultural purposes in many parts of Africa as more and more people seek new livelihood strategies. The increase in wetland agriculture is linked to environmental degradation of other farmlands due to population pressure. Hayal *et al.* (2012) reports that wetland ecosystems are most vulnerable to anthropogenic activities aggravated by climate variability. With approximately 70% of Zimbabwe's population deriving their livelihoods from subsistence agriculture, the most noticeable effects of climate variability are the devastating impacts on food security and the livelihoods of the poor. Zimbabwe has not yet developed an integrated climate change and adaptation policy to guide the nation's response to the issue. But there has been a proliferation of wetland rehabilitation projects aimed at increasing small scale irrigation projects to counter the trend of cultivation in rehabilitated wetlands. There is a need to develop infrastructure for improved water storage for irrigation purposes. This should ultimately lessen the pressure on wetlands.

1.1.2. Systems approach to Wetland management

The systems approach has been used increasingly to analyse water management issues. This approach requires stakeholder involvement and designing of mutually accepted solutions. The principle of ecosystem sustainability states that the management of water resources (wetlands included) should harmonise human and environmental requirements and recognise the role of water in supporting the system (Ramsar Convention Secretariat, 2007; Mombo *et al.*, 2013). Therefore, research on the development of a wetland rehabilitation model that incorporates an ecosystems approach and acknowledges the complex inter-linkages is necessary.

The relationship between population trends and sustainability has been investigated widely (Hamandawana *et al.*, 2005; Grenfell, *et al.*, 2005, Feresu, *et al.*, 2010). The increasing-population-environment-recovery thesis postulates that population explosion makes it difficult for the environment to recover from degradation. Research postulates that wetland degradation is exacerbated by growing population densities in many communal areas (Kyle and Leishman, 2009; Makwara and Gamira, 2012). However, such research has been conducted in cold and temperate countries which are different from Zimbabwe's ecological context. In Zimbabwe research that bridges socioeconomic influences on wetland rehabilitation and rehabilitation project feasibility needs to be conducted.

An ecosystem-based planning approach seeks to identify and understand the important ecological characteristics of a landscape (Coiacetto, 1996). It integrates geographical information systems (GIS) and systems approach to respond to pressure on wetlands. It considers multiple ecosystem services and then uses this information to design plans that guide the development of ecologically-responsible human activities (Mcdonald, 2009). Optimally, wetland and riparian habitat preservation and restoration should be guided by a comprehensive understanding of the ecosystem in its natural state (Stein *et al.*, 2010). Wetlands cannot be considered as a stand-alone resource that can be protected without due regard to the community interest in resource use.

Resource utilisation without resource management is not sustainable, just as resource preservation without utilisation is futile. Similarly, the use of wetlands without rehabilitation results in wetland degradation. Conversely, protection of wetlands without wetland production brings about resource conflicts. The Zimbabwean wetland policy is not sensitive to potential water conflicts between ecological conservation and agricultural development. The policy requires that wetland users get permits to use wetlands. Environmental impact assessments (EIA) are required for these permits. Yet, agricultural utilisation of wetlands has been promoted in the past by other development partners such as FAO and other stakeholders to achieve food security without an EIA. It is suggested that trade–offs be applied to balance the wetland ecology and wetland economy. However, the challenge is to reconcile environmental security and food security owing to the interface occupied by wetlands in the ecological-human sustainability interactions.

1.1.3. Status of wetland management and rehabilitation in Zimbabwe

Critical role players that contribute to wetland degradation in Zimbabwe include: government planners, natural resource managers and wetland users. Wetland users generally lack knowledge on ecological processes and benefits provided by wetlands. This is often due to lack of adequate and comprehensive wetland rehabilitation tools.
Prior to 2011, wetland protection received little attention and priority at a national level in Zimbabwe because there was an assumed low commercial value of wetlands (Gadzirayi *et al.* 2006 and Mbereko *et al.* 2007). Such a view arises due to lack of economic valuation of wetlands. Research carried out by Jogo and Hassan (2010) on the agro-economic value of wetlands led to more serious debates on wetlands at national level. Nonetheless, policy and decision makers face a common dilemma regarding balancing the short term benefits derived from unsustainable wetland use practices with those from long-term programmes that sustain wetland functions and values.

Wetland rehabilitation has gained momentum (Acreman et al. 2007) worldwide owing to the on-going wetland degradation. Degradation is a result of human dependence on natural resources, such as wetlands, for a number of ecological goods and services (Millennium Ecosystem Assessment, 2005). RAMSAR STRP (2002) supports the idea of wetland rehabilitation in the face of population pressure on this vital resource. The pace and performance of wetland rehabilitation projects is worrisome in Zimbabwe. However, it should be underscored that, wetland rehabilitation has several goals, including but not limited to re-establishment of wetland structure and functions that enhances their productivity and sustainability.

Wetland rehabilitation is a highly contested approach in terms of its goals, because different stakeholders advance different interests. In fact, policies and legislation that govern the sustainable utilisation of wetlands are fragmented and often in conflict with each other (Birol *et al.,* 2008; Jogo and Hassan, 2010). Wetland rehabilitation should, however, recognise the complexity of environmental systems which integrate human and biophysical dimensions (Shackelton *et al.,* 2011). In addition, wetland sustainability can only be achieved through a balance between human and environmental goals. Therefore, there is a need to design a model that caters for these parallel interests; however, the challenge facing wetland managers is to access a rehabilitation model that leverages synergies among the socio-economic and ecological complexities. This study provides a rehabilitation model for wetlands in Zimbabwe with the view to assisting government planners and other stakeholders.

The management of wetlands in Zimbabwe is governed by the Environmental Management Act of 2003. This legislation bans cultivation on wetlands on the premise that wetlands are meant to replenish river flow during drier periods and cultivation degrades floral and faunal diversity. Despite this legislation, many wetlands in Zimbabwe are cultivated to produce a variety of crops including maize, rice, groundnuts and vegetables (Frenken and Mharapara, 2002; Svotwa *et al.*, 2007; Chigwenya and Muparamoto, 2009; Viriri, 2009). In the communal farming areas of Zimbabwe, thousands of hectares of wetlands are cultivated. The intensity of cultivation varies considerably (actual values vary from 5 to 75%), but in some communal regions an average of 30% of dambo area is cultivated and in some instances this cultivation has been continuous for decades (Frenken and Mharapara, 2002). This means that there is a need to review the current legislation on wetlands so that laws can also accommodate the agricultural needs of rural communities.

The major constraint in the management of wetlands is a lack of congruence between ecosystems and institutional frameworks that govern their administration. The connectivity is fraught with institutional fragmentation (Dale *et al.* 2010). Institutions responsible for wetland rehabilitation are fragmented and do not directly interact with wetlands on a daily basis. In addition, the community that is supposed to be at the centre of wetland rehabilitation does not get involved in designing wetland rehabilitation models. One major cause of wetland degradation is information failure where the general public is uninformed about the ecological basis of the environment. Therefore, wetland rehabilitation programmes should embrace the ecosystems approach and adopt public participation principles (Ramsar Convention Secretariat, 2007). This research raises awareness and advocates for the use of the ecological systems approach in wetland rehabilitation.

1.2 Research Problem

Research on wetlands has tended to concentrate on the influence of climate change (Mitchell, 2013; Ostrovskaya, 2013; Chikodzi and Mutowo, 2014), hydrological aspects (Bullock and Acreman, 2003; Riddell *et al.* 2012), agronomic utilisation (Manzungu and Mtali, 2012) and general conservation policies (Manjengwa, 2007). Recent studies on wetland rehabilitation are reported for South Africa, (Grenfell *et al.*, 2005; Grenfell *et al.*, 2007; Riddell *et al.*, 2010; Riddell *et al.*, 2011; Riddell *et al.*, 2012; Kotze *et al.*, 2013) but such work remains limited in some southern African countries such as Zimbabwe.

A search through conventional literature in the public domain shows a glaring absence of modelling efforts on promoting socio-economic development and the sustainability of rehabilitation. The extent of wetland rehabilitation is not well explored and recorded in Zimbabwe. Zimbabwe's National Environmental Policy (NEP, 2009) states that the government will conduct and encourage further research on the environmental impacts of wetland and stream bank cultivation. Such impacts could include loss of habitats for wildlife such as birds and other aquatic organisms such as fish. This is partly due to the limited financial resources allocated for wetland research in Zimbabwe. The other problem is the inappropriate delegation to the Agricultural Research Council (ARC) of Zimbabwe to assume the responsibility of wetland research because it tends to take an agronomic perspective. More so such studies like Riddell (2010) are too localised or site based to be representative of national trends and patterns. In some studies such as that of Marambanyika *et al.* (2012) information on limitation in performance current wetland rehabilitation projects has not been scientifically quantified. This creates a knowledge gap that needs to be addressed. Designing a wetland rehabilitation model should provide a structure for sustainably managing and repairing degraded wetlands.

Local communities and environmental agencies in most developing countries have embarked on wetland rehabilitation with disappointing results (Ramsar, 2008). A rehabilitated wetland must exhibit the conditions common to all wetlands; instead, the current nature of wetland rehabilitation projects and their performance in the entirety of Zimbabwe is below expectations. The future of wetlands and wetland rehabilitation projects depends on managing trade-offs between wetland economy and wetland ecology across time. It is envisaged that the findings of this research should allow for effective and appropriate adaptive rehabilitation approaches.

1.3 Aim

To design a model for wetland rehabilitation that simultaneously promotes socioeconomic development and wetland sustainability.

1.4 Objectives

To achieve the aim stated above the study came up with five objectives which are;

(i) to trace how rainfall variability in the study area is influencing the nature and success of wetland rehabilitation and changes in wetland size.
(ii) to examine socio-economic interactions that influence wetland rehabilitation projects.
(iii) to measure the level of performance of current wetland rehabilitation projects.
(iv) to design a wetland rehabilitation model.
(v) to carry out empirical testing of the model on existing projects.

1.5 Research Questions

1. How is rainfall variability influencing the nature and success of wetland rehabilitation?
2. What are the socio-economic factors that influence the need for wetland rehabilitation?
3. What is the cost-benefit of wetland ecological services versus direct wetland use for economic development?

1. 6 Hypotheses

Two hypotheses were proposed in this research:

(1) *Rainfall variability has no impact on wetland rehabilitation and recovery.*

(2) *Level of financial investment in wetland rehabilitation has no impact on performance of rehabilitated wetland*

1.7 Justification of the Study

A considerable amount of research has been conducted on wetlands in general, in Zimbabwe. This includes research by Mbereko (2007), Chigwenya and Muparamoto (2009), Dube and Chitiga (2011), and Fakarayi (2015). However, these studies do not include the socio-economic and ecological factors of wetland rehabilitation projects. Wetland rehabilitation requires due recognition by academics to empower rehabilitation managers to tackle critical wetland management challenges. No studies on wetland rehabilitation have been conducted in Zimbabwe, especially in South-Eastern Zimbabwe. Furthermore, the study seeks to design a model that integrates ecological and socio-economic parameters to ensure sustainability of wetlands.

There exists a global contradiction between wetland preservation/restoration and the needs of community development programmes. Controversy surrounds the importance attached to wetlands by different stakeholders. According to Yatsalo *et al.* (2007), controversy arises when stakeholders differ in their objectives or priorities. Therefore, there is a need to investigate how the nature of the community needs to increase agricultural production through the utilisation of wetlands on one hand, can be reconciled with wetland protection on the other. In addition, deciding on the best applicable option for wetland rehabilitation remains a challenging task.

In addition, while the basis of much contemporary literature is on wetlands as a particular ecosystem, the place of wetland rehabilitation projects which encompass more than the physical basis remains a poorly researched area. Climate change creates a situation whereby people over-rely on wetlands for survival (Seyam, 2000; Hamandawana, 2005; Vetter *et al.*, 2006; McCartney and Houghton- Carr, 2009) and this has resulted in the conversion of wetlands into other land uses (Kamusoko and Aniya, 2007; Hayal *et al.*, 2012). Rainfall variability in Zimbabwe has increased the frequency and intensity of drought episodes. Currently, in Zimbabwe, there is limited research that takes cognisance of the ecosystems approach in wetland rehabilitation. As a result, an understanding of the success of existing wetland rehabilitation projects has to be built on two bases: ecological and economic feasibility. Nonetheless, the interactions between the ecological basis of wetlands and the economic feasibility of rehabilitation projects, in the context of addressing the parallel demands of conservation and development, remains an outstanding knowledge gap. Therefore, the focus of the study is to design a model for wetland rehabilitation that simultaneously promotes socioeconomic development and wetland sustainability.

Although there are many wetland rehabilitation projects in Zimbabwe, there is a dearth of research on their current state and performance. In spite of the existence of considerable literature on the influence of climate change on wetlands, in South-Eastern Zimbabwe little has been reported on changing patterns in wetland use due to climate change. There is also scant literature on wetland competing needs between ecological services and economic needs. These are challenges facing wetland rehabilitation that need scrutiny in order to develop a model. Current rehabilitation programmes are unstructured and rudimentary. There appears to be no clear cut wetland rehabilitation model currently in place for Zimbabwe. This has brought a challenge of low wetland recovery levels. Therefore, this study intends to fill this knowledge gap.

1.8 Conceptual Framework

The context of this study is to determine whether the current rehabilitation techniques conform to the ecosystems approaches. Wetland rehabilitation is studied within an ecosystems paradigm because wetlands constitute various components such as soil, water and vegetation whose health is dependent on rainfall variability and human influences. It is critical therefore to trace the extent to which rainfall patterns influence rehabilitation plans and programmes. In recent years, increase in rainfall variability and extreme weather events have created environmental conditions that alter the ecology of climate sensitive resources like wetlands (Dube and Chimbari, 2009). Ecosystems have inputs, processes and outputs. Similarly, wetlands as ecosystems receive rainfall and recharge water as their inputs. But, processes like wetland cultivation, deforestation, preservation and even rehabilitation influence the condition of wetlands. Outputs from wetland processes include ecosystem goods and services such as water outflow, reeds, fish, recreation and habitat for birds. An ecosystem approach to understanding wetland dynamics and the impacts of any modification through wetland use is critical in designing a wetland rehabilitation model. The theoretical application of environmenthuman systems thinking is captured in Figure 1.1.

In Zimbabwe, encroachment into wetland areas by smallholder farmers in communal areas continues, despite the existence of the restrictive legislative instruments. This is pressured by the land shortage in these areas coupled with the recognition for more reliable soil moisture conditions in the wetlands. Designing a model for wetland rehabilitation requires a thorough examination of socio-economic influences on rehabilitation such as agricultural reliance on wetland moisture, financial feasibility of rehabilitation and institutional arrangements. Therefore wetland watershed activities influence its use, impact and management. Hence, there is need for an appropriate integrated model to address these factors.

A new model of wetland rehabilitation has to be designed on the basis of current weakness of rehabilitation projects. Thus, this research examines how current wetland repair activities in South-eastern Zimbabwe are conducted. The measurement of performance limitations of current wetland rehabilitation projects needs to be examined thoroughly so that the best options can be adopted. Riparian and non-riparian communities have different roles and responsibilities that influence the performance and success of rehabilitation projects. Moreover, the designed wetland rehabilitation models require to be empirically tested for the purpose of improving existing projects.

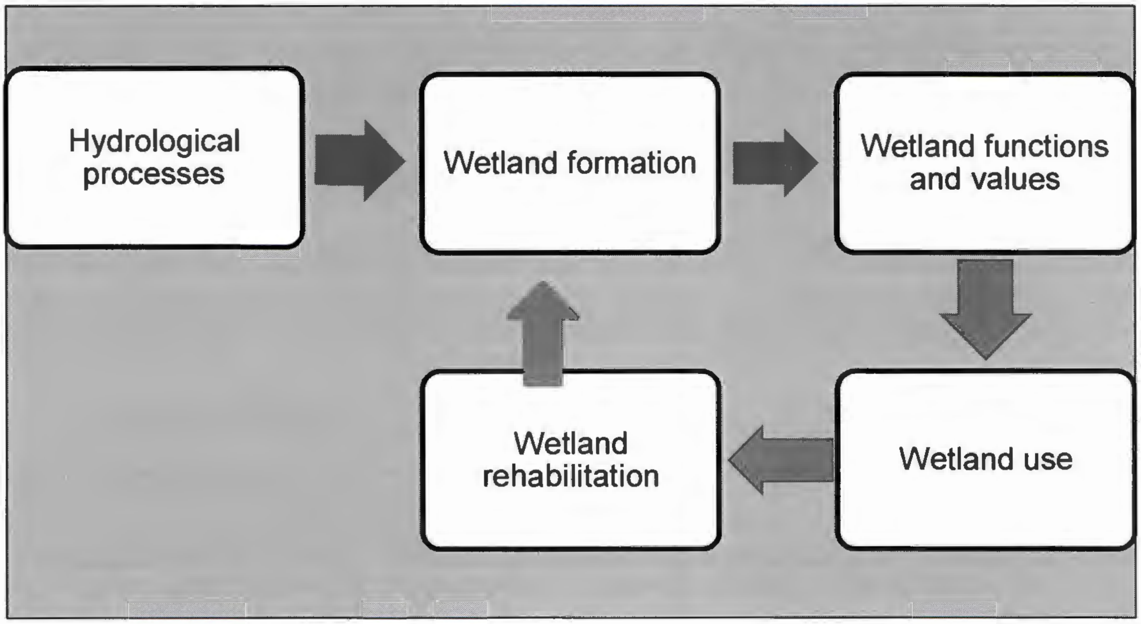


Figure 1.1 Conceptual framework

Compromising the livelihood needs of people renders rehabilitation goals unachievable. According to Chifamba (2013), the trade-off between environmental protection and development is most acute in dynamic and complex ecosystems such as wetlands. It is for this reason that a holistic approach to wetland governance which puts the environment and people's needs first is essential to overcome challenges posed by wetland degradation. It is feasible to achieve wetland sustainability and socio-economic sustainability by adopting a holistic approach to the complex environment-human interface. However, it needs to be pointed out from the research questions and hypothesis proposed that availability of capital is not an end in itself in achieving wetland recovery but still is critical in attaining all goals.

1.9 Scope of the Study

The study is limited to a focus on wetland rehabilitation with a view to the development of an appropriate model. In this study, wetland describes broad, flat, low-order valleys, often at the headwaters of drainage systems, which are seasonally inundated and that lack continuous stream channels (Sieben *et al.*, 2011; Ogato, 2013). Wetland describes an area that is saturated by water for sufficient duration to support emergent plants adapted for life in saturated soil conditions. Wetland rehabilitation is a process aimed towards the attainment of former ecosystem structures, functions and/or state. In this study, wetland rehabilitation and restoration are used differently. Rehabilitation is used to refer to the reparation of ecosystem processes and services, whereas restoration includes the reestablishment of biotic integrity. Issues that influence wetland rehabilitation such as rainfall variability, socio-economic drivers and performance recovery levels of rehabilitated wetlands were examined.

The research was confined to capturing information on;

i. Rainfall data sourced from the Meteorological Services of Zimbabwe. ii. Wetland sizes obtained from fieldwork and aerial orthophoto maps.

iii. Nature and success of rehabilitation projects from interviews with riparian and non-riparian communities, project officers and direct fieldwork observations

iv. Interviews and observations in the field on recovery performance of rehabilitated wetlands.

The underlying assumption of the study was that, Zimbabwe can develop its own successful wetland rehabilitation model.

1.10 Research Design

A quantitative research design was used to address the key questions of this research; the methods used generated the statistical data. This research was conducted through observation, measurements and structured interviews. This resulted in the collection of quantifiable data. The observation technique was employed through collection of data from individual wetland rehabilitation projects that formed a cross sectional sample of the population. In quantitative research, emphasis is placed on variables in describing and analysing human behaviour (Babbie and Mouton, 2001). In addition, Babbie and Mouton (2001) stated that, the greatest advantage of observation is the presence of the researcher at the scene of the action. Field observations were complemented by structured interviews. This improved the reliability of the information. The structured interviews were conducted face-to-face by the researcher. Topographic maps and aerial photographs of the study area were used to identify settlements, wetlands and rehabilitation projects.

1.11 Data Analysis

After collection of data, data analysis is presented in chapters three, four, five and six. To trace changes in rainfall patterns from 1980–2015, a Standard Precipitation Index (SPI) was applied. SPI was used to evaluate changes in rainfall patterns and predict relative departures from normality. This is a way of measuring drought that helps to predict encroachment of wetlands by agricultural land use and therefore possible interventions that can be implemented to reverse the predicted trends.

Tracing changes in the size of wetlands was done in order to measure wetland loss with a view to determining the level of intervention required to ensure wetland recovery and sustainability. Time-series analytical techniques were applied to test the results before conclusions and recommendations could be taken. Correlation analysis and regression analysis between change in wetland size and changing rainfall patterns were applied to determine any relationships.

General variables on socio-economic interactions that influence rehabilitation were analysed. A number of general variables on current state of wetland rehabilitation projects were analysed. Excel was used to analyse the data into frequencies and percentages. Descriptive statistics was employed in data analysis to characterise data sets from interviews on social, economic and biophysical factors that influence wetland rehabilitation.

In analysing the performance limitation of rehabilitation projects, the specific variable used was the levels of funding using correlation analysis. The model of rehabilitation projects was analysed over a period of two years by applying it to selected sites and wetland patches of Masvingo Province from October 2014 to October 2016 to determine if it fits the conditions prevailing in the province.

1.12 Study area

1.12.1 Location of study area

Zimbabwe is a landlocked country in the southern African region, with an area of 390 760 km^2. It lies within the tropics between latitude 15° 30' S and 22° 30' S and longitude 25° E and 33°E. The study area is South Eastern Zimbabwe (Figure 1.2). It lies between latitudes 20° and 22°S and 30° and 32°E in the Masvingo Province. The Masvingo Province, which is one of the country's 10 provinces, is 56 566 km^2 in area, and lies in the south-eastern part of Zimbabwe. Masvingo Province is divided into seven districts (Figure 1.2) which are; Gutu, Masvingo, Bikita, Zaka, Chivi, Mwenezi and Chiredzi. It borders Mozambique on its eastern border and the provinces of Matabeleland South to the south, Midlands to the north and west and Manicaland to the north east (Farai et al. 2012).

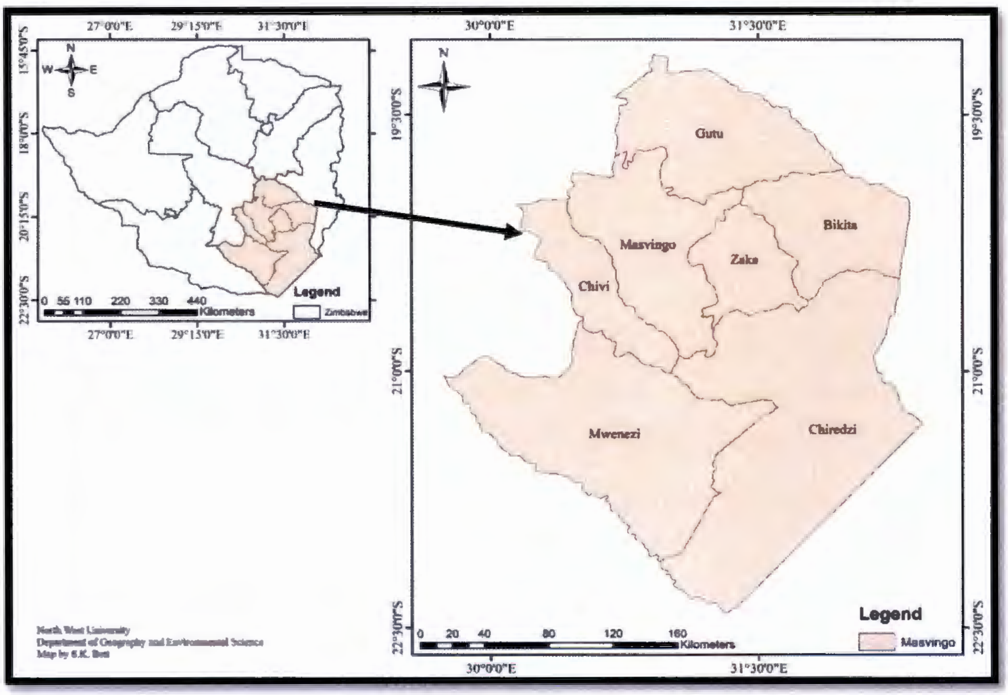


Figure 1.2 The study area.

Source: NWU (2017)

1.12.2 Geology and soils of study area

The geological setting of the landscape is characterised by rugged, granitic inselbergs made up of castle kopjes, hills and mountain ranges which dot the countryside especially in the Chivi, Bikita, Gutu and Zaka districts. The granite is the key source of the sand sediments. It is also postulated that the granites are the dominant source of clay particles through illuviation to the valley bottom (Riddell et al 2010). In order to understand the reasons for the drying up of the wetland in the area, and prescribe sound remedial action for rehabilitation, the geological structure of the rocks that lead to the occurrence and the form of the wetland need to be understood.

The origin of wetlands in the study area can be traced to a combination of pedological, hydrological and geomorphological processes which result in saturation of soil to a shallow depth, sufficiently long enough to promote anaerobic conditions in the root zone of emergent macrophytes (plants). Soil types include the sodic pans from the Mwenezi and Chiredzi low lying areas while some areas, such as Gutu, Chivi, Masvingo and Zaka, are dominated by sandy and clay soils. Wetland development can be attributed to the movement and accumulation of soil aggregates, solutes, and organic matter from the catchment areas to the lower areas by water.

1.12.3 Rainfall, drainage and ecology of study area

The mean annual rainfall in Zimbabwe varies from below 400 mm in the extreme south of the Lowveld to above 2 000 mm on isolated mountain peaks in the Eastern Districts. Midlevel rainfall ranges from 500 mm to 700 mm with that of the Highveld from 800 mm to 1 000 mm. The rainfall pattern in Zimbabwe is distinctly seasonal, with approximately 90% falling in the six months from October to March (Mubaya, 2010). The mean annual rainfall in the Masvingo Province ranges from 200mm in the drier Chiredzi District to about 800mm in the relatively wetter Gutu District. The altitude ranges from 150 m in the Lowveld to about 1400 m in the midlevel. The area is mainly dominated by communal farms, commercial farms, wildlife game parks and dotted urban centres like Triangle and Chiredzi.

South Eastern Zimbabwe or the Masvingo Province mainly covers agro-ecological region IV and V which receive erratic and unreliable rainfall. This makes wetlands vulnerable to encroachment as farmers seek for areas with significant moisture levels. Wetland invasion ultimately results in wetlands in the region more susceptible to irreversible degradation unless corrective remediation measures are put in place urgently. The principal wetlands in Zimbabwe are found around the Zambezi in the north, the Save in the east and the Limpopo in the south. The river systems that dominate the drainage system in the province are Save, Runde, Mwenezi, Mutirikwi and Limpopo. The Save-Runde river catchment system is currently experiencing unprecedented degradation which is evident in turbidity of the water. Miombo woodlands dominate the wetter parts while Mopani trees, which are drought tolerant and sturdy, are found throughout the province (Farai *et al.*, 2012).

1.12.4 Socio-economic profile of the study area

The province is largely populated by members of the Karanga ethnic group, who are the majority population group in Zimbabwe. They make up a sub-group of the Shona speaking tribes that also include the Zezuru, Manyika and Ndau (Farai *et al.* 2012). The total population of the Province was 1 486 604 (GoZ, 2012). Agricultural activities in this region vary from crop farming to animal husbandry, with most of the areas in the province devoted to cattle ranching, subsistence crop farming, and irrigated sugar growing also significant (Farai *et al.* 2012). The administrative districts in the Masvingo Province are presented in Figures 1.3.

1. 13 Structure of the Thesis

The thesis is structured as follows:

Chapter 1 outlines the background to wetland rehabilitation, a phenomenon that is slowly gaining momentum in southern Africa and Zimbabwe as well, particularly in light of the realisation of the ever increasing loss of wetland ecosystems. The chapter also describes how the extent of wetland rehabilitation is not optimally measured and recorded in Zimbabwe. It sets out the research problem, from which the research aim, objectives, questions and hypothesis were drawn. The conceptual framework, justification and scope of the research were outlined. The quantitative research design and data analysis used in this research was presented. The chapter ends with a mapping and exploration of the study area.

Chapter 2 focuses on the literature review. The literature review considers the rehabilitation measures that address both the causes and effects of degradation, with a view to improve wetland integrity and functioning of the system. The functions of wetlands and external threats to their survival are presented in this chapter. The chapter also examines the science and practice of wetland rehabilitation at different levels. It also highlights the role of the Ramsar Convention in influencing wetland rehabilitation programmes worldwide.

Chapter 3 discusses the changes in rainfall patterns and wetland size over time. It also tests whether rainfall variability and unreliability is responsible for the loss of wetlands, and their invasion and conversion by human beings as well. The changes occurring in wetland size are also traced and mapped in this chapter.

Chapter 4 presents the results of the observations, and results from interviews held with the communities (riparian and non-riparian). The results discussed here also focus on the socio-economic and human-ecological factors that influence wetland rehabilitation. Some of the socio-economic and ecological factors explored are family size, educational level, cropping patterns, income and sources of water usage that influence wetland degradation and rehabilitation successes.

Chapter 5 assesses the performance limitation of rehabilitation projects. These limitations are characterised as technical, infrastructural, financial, managerial, and community. The testing of the hypothesis is also presented in this chapter on the relationship between rehabilitation financial funding and size of wetland recovery.

Chapter 6 focuses on designing a practically applicable wetland rehabilitation model for implementation not only in Zimbabwe but other third world countries in similar circumstances. The model of wetland rehabilitation designed hereinafter draws on the empirical evidence resulting from field observations and interviews conducted in the study area. The results of testing the model are presented and discussed.

Chapter 7 is a summary outline that synthesizes and wraps up the research and draws conclusions and lists recommendations from the findings. The major contributions of this research and its limitation are pointed out.

1.14 Summary

Wetland rehabilitation requires adequate attention from national governments and environmental managers because they are not wastelands but vital natural assets. Society generally needs to be equipped with knowledge or understanding of the operation of wetlands due to their fragility and complexity. There is a need to research on developing and operationalizing a wetland rehabilitation model that takes an ecosystems approach which recognises the inter-linkages and complexities associated with such systems (wetlands). Rehabilitation approaches that are not grounded in the ecosystems approach fail to plan adequately and therefore fail from the outset.

It has also been noted in this chapter that wetland rehabilitation is highly contested because different stakeholders advance different interests. Multiple and conflicting uses of wetlands result from different stakeholders advancing different interests. Some prefer cultivation; others opt for grazing whilst others are of the view that wetlands should be preserved as pristine environments with utilisation limited to wildlife conservation. Currently there is a dearth of research that takes cognisance of the ecosystems approach in wetland rehabilitation has been done in Zimbabwe. Wetland sustainability can only be achieved through recognition of the balance between human needs and environmental needs. The ultimate desire is to design a wetland rehabilitation model that promotes the balance between the socio-economic influences and biophysical wetland complexities. Chapter two examines literature that is related to wetland rehabilitation from a global, regional and local perspective.

CHAPTER 2: LITERATURE REVIEW

2.1 Introduction

This chapter focuses on the control factors for wetland occurrence, distribution and sustainability; internal wetland process dynamics; and external threats to wetlands. The chapter also discusses the underlying theory for wetland functions within an ecosystem framework. This chapter, which also attempts to distinguish between restoration, conservation and rehabilitation, considers the state of global wetland rehabilitation efforts, with a special focus on wetland rehabilitation in Africa. In addition, the state of research on wetland rehabilitation in southern Africa is elaborated and it examines further the state of wetland rehabilitation in Zimbabwe.

2.2 Wetland Control Factors

Wetlands are unique systems characterised by set hydrologic, substrate and biotic factors that differ from upland and aquatic systems (US-Interagency Workgroup on Wetland Restoration, 2003). They can be classified as marine, estuarine, riverine, lacustrine, and palustrine, depending on their geographical formation. Factors such as geology initiate seepage and recharge of wetlands. Relief aspects such as gradient influence wetland occurrence in depressions. Hydrology is important in maintaining the wetland conditions, structure and functions. Wetlands are ecosystems where water collects and as such they act as a sponge that absorbs water during the rainy season and release it gradually during the dry season. They are variously named as swamps, marshes, everglades, bogs, or dambos.

Wetlands are characterised by shallow water tables, which control the degree of saturation of these sites (Svotwa *et al.* 2007). Chigwenya and Muparamoto (2009) report that wetlands are ecosystems that vary in their morphologic, hydrologic and pedological characteristics to the extent that each can be considered unique. Wetlands are subject to wetness in varying proportions for different lengths of time in a year, with surface runoff and seepage of groundwater from catchment areas together with incidence of precipitation contributing to their water budget. Wetland hydrology depends on factors such as rainfall, drainage, catchment characteristics, size and the physical features of the wetland (Chigwenya and Muparamoto, 2009).

Wetlands are dynamic and fluctuate in size during the year and between the years (USIWWR, 2003). The hydrologic factors operating at a site are most important in determining what kind of wetland it will be and the functions that it may perform. The factors that determine characteristics of wetlands are water depth over time, flow patterns, duration and frequency of flooding as well as saturation (US-IWWR, 2003).
Furthermore, wetlands occur where the water table is close to the earth's surface or is at the earth's surface. The depth of the water table has a significant influence on evapotranspiration and discharge. The deeper the water table, the lower the evapotranspiration and discharge.

Precipitation also influences the dynamic state of wetlands. Precipitation is another critical factor that influences wetland occurrence; it is for this reason that wetlands are widespread in wetter climates than drier regions. During excessive and incessant rainfall events they increase in size and during periods of persistent and severe droughts they shrink in size. Dambos, as wetlands are called in Central and Southern Africa, suck or allow seepage from precipitation and ooze recharge water that flows and sustains rivers downstream (Pollard *et al.*, 2006; Morardet *et al.*, 2010)

Wetlands are ecosystems that are very fertile due to organic matter that is decomposed at slower rates under anaerobic conditions forming black, mucky and highly humic top soil (Chigwenya and Muparamoto, 2009). The clay content of the wetland soils varies from one wetland to another and increases down-slope as the impermeable layer meets the surface. Soil erodibility is a critical factor in the sustainable management of wetlands. Clay soils are generally resistant to erosion than sand soils upslope that get eroded easily and result in the deposition of sediments in the valley where a wetland would occur.

Wetlands are open systems characterised by inputs, processes and outputs. The inputs include rainwater and flow through, while the processes include anaerobic respiration, greying, humification, translocation, claying and mottling. Outputs from wetlands include river recharge, flora, fauna, birds, fertile soils and peat. Wetlands exist when an area is wet enough to result in soils that are anaerobic and support hydrophytic vegetation (USInteragency Workgroup on Wetland Restoration, 2003). The hydrologic regime is the main driving factor that determines the entire wetland ecosystem.

2.3 Wetland Functions

2.3.1 Provisioning

Wetlands provide food to human beings, namely fruits, fish, wild game and grains. They provide fresh water for domestic, industrial and agricultural purposes. Wetland ecosystems provide a critical habitat for many plants and animals (Hong 2012). They play an invaluable role in providing materials such as clay used for brick making, peat, fuel wood, fibre and medicines (Millennium Ecosystem Assessment, 2005). These are invaluable services.

2.3.2 Regulating

Wetlands play a regulatory role in the way the ecosystems impact on climate by acting as a carbon dioxide sink (Erwin, 2009). Wetlands also control hydrological flows through ground water recharge and discharge (Millennium Ecosystem Assessment, 2005). In addition, due to the sponge effect these water-inundated zones prevent floods through water storage. Wetlands also facilitate the purification of nutrients, pollutants and control erosion.

2.3.3 Supporting

Wetlands also play a supporting function. They support things such as soil formation by enhancing sedimentation and accumulation of organic matter, which explains why such soils are rich and fertile. Nutrient recycling is a function characteristic of wetlands, they recycle, store, process and acquire nutrients (Millennium Ecosystem Assessment, 2005). This supportive role places wetlands in a key position of the ecosystem.

2.3.4 Cultural

Wetlands are very important from a cultural perspective (Millennium Ecosystem Assessment, 2005). Different communities, worldwide, use wetlands as places for worship and performing traditional and religious rituals (Chigwenya and Muparamoto, 2009). The Millennium Ecosystem Assessment (2005) also underscores that wetlands are globally considered as sacred and are attached with a religious and spiritual value throughout the world. Wetlands also fulfil spiritual, inspirational, recreational, aesthetic and educational role (Millennium Ecosystem Assessment, 2005). Therefore, one can conclude that wetlands play a significant cultural role throughout the world.

2.4 Wetland Rehabilitation and Ecosystems Services

A consideration of the immense contribution that wetland make to human beings makes it necessary that interventions such as rehabilitation be put in place to repair damaged ecosystems. Management responses, which emphasise on rehabilitation and restoration, have been proposed as ways to stop and reverse the degradation and loss of wetlands (Nagabhatla *et al.* 2012). Restoration reinstates the biotic integrity of severely degraded wetlands. The purpose of wetland restoration is to bring back the functions and values of the wetland ecosystems that would have been altered for agricultural purposes and other disturbances such as urbanisation (USDA, 2000). Wetland rehabilitation has been defined differently by different researchers, with Grenfell *et al.* (2007) defining rehabilitation as the progression towards the attainment of a former ecosystem structure, function and/or state. This means that rehabilitation is a process. Kotze *et al.* (2001) also define rehabilitation as the reinstatement of the ecological driving forces of a system so that it will return to a state in which it is of value to society.

Rehabilitation is however different from restoration. Ecological restoration is the process of repairing damage caused by humans to the diversity and dynamics of indigenous ecosystems (Harris *et al*, 1996). Finally, if a given system is returned all the way to its original state it would have been restored (Collins, 2011). A lack of clarity on the definition of both terms creates problems for different interventions because goals need to be spelt out clearly. Rehabilitation repairs the wetland structure and functions of partially degraded wetlands that can be salvaged whilst restoration brings back the structure, functions and biotic integrity of severely degraded wetland to their original position. Note that it is not possible to re-establish original biophysical conditions of a landscape given that changes have been occurring for millions of years. In short, restoration attempts to recover significant environmental elements to a level close to what the current local ecology would dictate.

Restoration ecology has moved beyond the restoration of small areas, such as sensitive wetlands, to large-scale areas such as the whole catchments and farms and entire districts (Shackleton *et al.*, 2011). Restoration science will require increased attention as attempts are made to revive and restore areas and ecosystems neglected over a century or a mind-set of limitless resources, and in that way increase the stock of available natural capital (Shackleton *et al.*, 2011). A mind-set of limitless resources does not appreciate that partially and severely degraded wetlands are both important in socio-economic sustainability.

Ecosystem services are the benefits that people obtain from an ecosystem, which are indispensable to the well-being of people in all places (Silvestri, 2013). Ecosystem services can be defined as goods and services that ecosystems provide to people, for example, provisioning and treatment of water leading to clean drinking water. The provision of such economic services declines when wetlands are degraded (Brander *et al.* 2011). Wetland ecosystems are a critical component of the hydrological cycle and as such they should be managed in the context of their catchment areas (Trepel, 2007).

Despite the abundant literature on sustainable use of wetlands, there are few decision support tools that have been designed to assist stakeholders in their choices relating to wetland utilisation. Decision-making in environmental projects requires a consideration of trade-offs between socio-political, environmental and economic impacts, which are often complicated by various stakeholder views (Hajkowicz and Collins, 2006; Huang, 2011). The use of multiple evaluation criteria and methods is essential in systems as complex as wetlands that also have multiple uses, users and values (Brown, 2001). Some of these multiple uses include grazing, agriculture, fishing, and irrigation. As a result, multi-criteria analysis (MCA) techniques offer a transparent, accountable and auditable procedure for decision making involving multiple objectives (Hajkowicz and Collins, 2006).

MCDA provides a systematic methodology that combines these inputs with cost/benefit information and stakeholder views to rank project alternatives (Huang, 2011). Common approaches to addressing trade-offs include economic valuation, multi-criteria analysis (Brown *et al.* 2001), and a range of modelling approaches linking biophysical and socioeconomic systems dynamically (Morardet *et al.* 2010). Many studies concluded that the application of MCDA methods provide a significant improvement in the decision process and public acceptance of the suggested remedial or abatement policy (Huang, 2011). The MCDA method can again be used to evaluate the potential of different agricultural activities within a valley and to find synergies, or at least compromises between different ecosystem services (McCartney and Houghton-Carr, 2009).

The MCDA has been widely used in management related scenarios. Many researchers conclude that the application of MCDA methods provide a significant improvement in the decision process and public acceptance of the suggested remedial policy (Huang, 2011). The MCDA method can again be used to evaluate the potential of different agricultural activities within the valley and to find synergies, between different ecosystem services (McCartney and Houghton-Carr, 2009). The application of MCDA in wetland rehabilitation in Zimbabwe has not been reported in known literature. MCDA can be used to formulate wetland rehabilitation programmes that integrate people's economic needs and environmental objectives at a local level. The study is also relevant to other developing countries with a comparable socio-economic and environmental set up (Balana, 2010). Indeed, aligning food production with biodiversity conservation is an important future challenge for agronomic and environmental research (Verhoeven and Setter, 2010).

Ecosystem Based Management (EBM) strategies require hybrid management approaches. EBM when applied to wetland rehabilitation entails re-establishment of the wetland's structure and function to sustain and foster ecosystem services. The interconnectedness of ecological, social, and economic parameters, such as income from agriculture for the development of the site-based management of an ecosystem is explicitly recognised. According to Dale (2010), a major constraint in the management of wetlands lies in the lack of congruence between the ecosystems and institutional frameworks that govern their management as connectivity is overlain by institutional fragmentation.

Ecosystem based wetland rehabilitation approaches are part of a wider body of systems thinking that takes a holistic approach to natural resource management and use (Pollard, 2009). An ecosystem approach is a strategy for the integrated management of land, water and living resources that promotes conservation and sustainable use in an equitable way (CBD, 1993). A number of scientists in Southern Africa have shed light on the use of the ecosystems approach in wetland management. Whittington *et al.* (2013) concluded that our understanding of changes to water pans is important for the conservation of these wetlands. In a study conducted in the Midlands region of KwaZulu-Natal, Grenfell *et al.* (2005) highlight the need to consider the ecosystem approach in wetlands rehabilitation. However their study does not recommend the consideration of rainfall variability in designing wetland rehabilitation projects. Pollard *et al.* (2006) investigated the North-Eastern region of South Africa and points out that there is a need to integrate social and ecological considerations in wetland rehabilitation. There has been an appraisal of the South African Working for Wetlands Rehabilitation Programme, which hopes to create jobs for poverty stricken communities and at the same time rehabilitate the habitat for wildlife (Lande, 2008). This study reports on wetland rehabilitation projects undertaken by the Working for Wetlands programme, but it does not offer a model or a framework of wetland rehabilitation.

Le Maitre (2007) notes that ecosystem services in South Africa are a research theme that can involve environmental, economic and social scientists in the development of sustainability solutions. It is suggested that research specifically focus on wetland rehabilitation in order to make a contribution to sustainability science. Other research findings have concluded that the negative effects of agriculture, such as loss of biodiversity, need further collaborated research (Hall *et al.*, 2009). The Zimbabwean government states that the state will conduct and encourage further research on environmental impacts of wetland and stream bank cultivation (GoZ, 2009). This endeavour is highlighted in a generalisation of environmental policy of Zimbabwe.

However, more research needs to be carried out on developing a new model of wetland rehabilitation that can help to re-establish ecosystem services.

Dini (2008) looks at wetland rehabilitation and takes into account the South African ecological, hydrological and socio-economic elements. Malan *et al.* (2009) state that wetland rehabilitation in South Africa also brings negative impacts on the wetland, especially if there are no trade-offs between competing land uses. Another study envisages harmonisation of livelihoods and wetland ecosystem services in an integrated dynamic model for the Ga-Mampa wetland in South Africa (Morardet *et al.*, 2010). The preceding study cited is comprehensive but its major limitation is that it is too localized and focuses on a small site without due consideration of large areas. According to Tooth and McCarthy (2007), the quest for ecosystem integrity places significance on understanding wetlands. To this end, hydro-geomorphic settings are critical in ensuring the success of such intervention by focusing on the causes of wetland degradation rather than the symptoms. This course should be incorporated in rehabilitation planning.

Dube and Chitiga (2011) point out that dambos in Zimbabwe are a common property resource with no specific entity responsible for their management. These dambos require both urgent attention and research. Jogo and Hassan (2010) carried out a study in South Africa that attempts to balance wetland ecology and communities well-being through trade–offs and diversification. However, it is suggested that its recommendations also include the impacts of climate change that influence sustainability. The effects of overgrazing on Lesotho's peat land wetlands were observed at length by Du Preez and Brown (2011). The research advocates exclusivity in wetland rehabilitation but current livelihood challenges require an integration of wetland conservation and livestock grazing. Townshend (2012) examines the effectiveness of civil engineering techniques in wetland rehabilitation. There is a strong need to integrate technocratic rehabilitation techniques with a systems approach (Millennium Ecosystem Assessment, 2005; Ramsar, 2007; Pollard *et al.* 2009) for rehabilitation projects to become sustainable and feasible.

Handa *et al.* (2012) analysed the effects of agriculture on native weed species in Tanzania. The effects of agriculture on wetland degradation and rehabilitation need to be analysed within the context of advancing indigenous plant species. In Zimbabwe, Simbarashe (2013) identifies the influence of climate change and variability on the sustainability of agriculture in the country. It is evident that sustainable agriculture also hinges on wetland utilisation and socio-economic considerations. Therefore, these factors need consideration in any wetland rehabilitation planning, implementation, evaluation and monitoring. Dini (2008) advises that best international practices require that wetland rehabilitation planning be at the catchment level. Ultimately, rehabilitation planning should be done hydrologically from a catchment and sub-catchment level, and policy wise from a national, provincial, district and ward level, while geomorphologically from a watershed point of view.

Rehabilitation measures should address both causes and effects of degradation, with a view to improve wetland integrity and the functioning of the system. Efforts that have yielded successful wetland rehabilitation are a wetland in the Kamiesberg uplands of Namaqualand in the Northern Cape, the Killarney wetland in KwaZulu-Natal, Manalana wetland in Mpumalanga in South Africa (Pollard *et al.*, 2006; Dini, 2008; Morardet *et al.*, 2010; Sieben *et al.*, 2011; Townshend, 2012), and Chebvute wetland in Zvishavane, Zimbabwe (Marambanyika *et al.*, 2012). Sustainable wetland rehabilitation is key to the recovery of wetland ecosystem structure and functions. In addition, wetland rehabilitation monitoring should use both quantitative and qualitative methods. Ultimately, wetland rehabilitation can only succeed through the development of a framework for monitoring and evaluating the ways in which the programme will benefit the poor and by extension the ecological integrity of the wetland itself.

2.5 The Ramsar Convention

Wetland rehabilitation is derived from the Convention on Wetlands held in Ramsar, Iran, in 1971. The treaty deals with wetland management issues. The convention had more than 160 members by 2011 (Junk *et al.* 2013). The aim of the Ramsar Convention is to conserve and use judiciously wetlands through local, regional, and national actions and international cooperation, as a contribution towards achieving sustainable development throughout the world. There is a set of principles governing rehabilitation for wetland management that are stipulated in the Ramsar Convention guidelines. For example, it adheres to the concept of the judicious use of wetlands, with the aim of maintaining their ecological character. This is achieved through the implementation of ecosystem approaches, within the context of sustainable development' (Ramsar Handbook 1, 2007). Figure 2.1 shows designated Ramsar Sites. One of the sites is Driefntein which is located in the study area. Driefontein has a designated Important Bird Area (IBA), but it has been ravaged by an on-going decline of its wetlands.

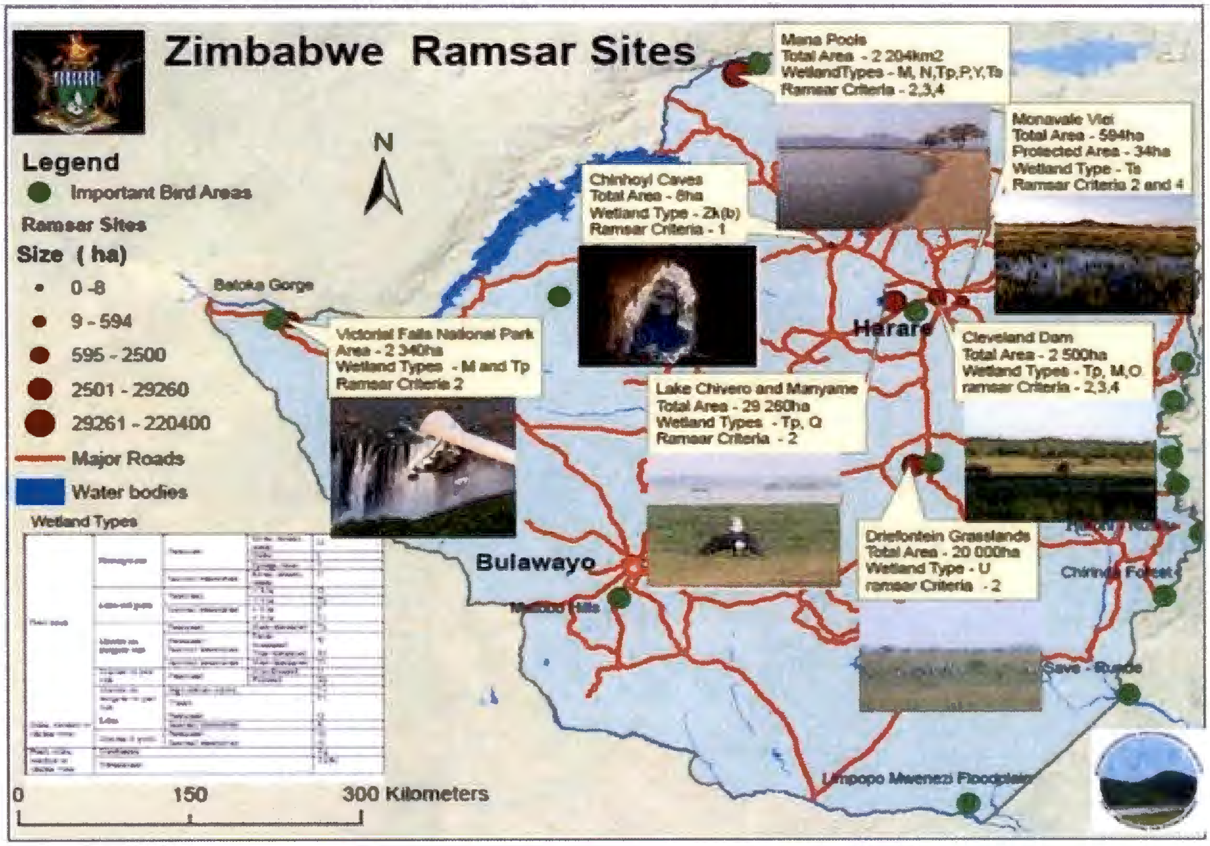


Figure 2.1: Ramsar Sites in Zimbabwe. Source: EMA (2013).

The Ramsar Convention has several sites of varying sizes worldwide of International Importance, as shown in Table 2.1 (Junk *et al.*, 2013). Zimbabwe has 7 wetland sites of International Importance. The number of African Contracting Parties (CP) to the Ramsar

Convention in 2013 had risen to 47. Wetland rehabilitation projects have been implemented in more than half of the African CPs.

Table 2.1: Number and area of Ramsar Sites

Major area	**Sites (number)**	**Area (km^2)**
North America	185	227, 002, 84
Europe (except Russia)	936	153, 981, 91
Russia	35	103, 237, 67
China	37	31, 685, 35
South America	95	290, 703, 99
Africa (excluding islands)	277	823, 966, 99
Tropical Asia	163	97,476, 30
Australia	64	75, 101, 77
Zimbabwe	7	54,142

Source: Adapted from Junk et al (2013)

For example countries such as Namibia, Uganda and South Africa have developed wetland policies that are underpinned by the requirement for rehabilitation of degraded wetlands. For instance 23 (59%) African CPs report having implemented some wetland rehabilitation projects, 5 (13%) CPs indicated that this was in progress, and 3 further CPs reported that they have partly implemented their rehabilitation programmes (Ramsar COP, 2010). These statistics show that a lot still needs to be done to address wetland rehabilitation on the African continent.

2.6 External Threats to Wetland Health

Wetland health lies at the core of rehabilitation because the maintenance of a healthy wetland allows for the flow of ecosystems' goods and services that sustain people's livelihoods and other living resources (Pollard, 2009). Wetland health can be defined as a measure of the similarity of a wetland to the natural reference condition (Macfarlane et al., 2007). Pollard et al. (2008b) define wetland health as, the ability of the wetlands to sustain production (plants, crops and fish) through maintaining the water and sediment balance. Wetland health or condition focuses on wetland structure and wetland function. The structure of a wetland includes water quality, soil condition, geology, topography, morphology, carrying capacity, species composition, food web support, and nutrient content (Pollard, 2009). Wetland function refers to surface and ground water storage, recharge and supply, floodwater and sediment retention, nutrient recycling, biomass production, reduction of erosion, and purification of water (Pollard, 2009). Therefore, a wetland is defined as healthy if its structure is good and it can perform almost all of its functions. Some of the external threats to wetland health are crop cultivation, catchment clearing, human settlements and overgrazing.

2.6.1 Crop cultivation

Agriculture is the main source of livelihoods in most communal lands in Southern Africa (Manzungu and Mtali, 2012). A study on the Driefontein Important Bird Area (IBA), by Fakarayi (2015) notes that local farmers cleared wetlands for cultivation and cereal production. Coleman et al. (2008) observed that a considerable wetland loss has occurred due to conversion for agriculture. According to Townshend et al. (2012), wetlands are lost every year mainly due to agriculture. Wu et al. (2016) estimated that 50% of the wetlands have been lost to drainage. Wetlands are also being degraded due to the impact of water demanding activities like agriculture and other factors such as land-use changes (Grenfell, *et al.,* 2005; Feresu, *et al*., 2010; Li, 2012). As a result, wetlands are threatened by water abstraction, alteration of natural flow pattern and agriculture (Millennium Ecosystem Assessment, 2005). Natural and anthropogenic pressures that contribute to loss are estimated at 1–2 % per annum (Dale, 2014).

2.6.2 Catchment clearing

A major threat to wetlands is deforestation. People living in rural areas cut down trees indiscriminately for firewood, timber, cultivation and fencing. According to Townshend et al. (2012), wetlands are lost every year through degradation. Catchment clearing affects the hydrological attributes and the material inputs depending on factors such as the preexisting vegetation and the scale and method of clearing. Clearing may also result in a higher and possibly less stable groundwater level (Coiacetto, 1996).

2.6.3 Human habitats

The US has lost 52% of its wetlands since the European settlement on the continent (Acreman *et al.*, 2007). The real reason behind the losses in early settlements in America when wetland management knowledge was limited was land use methods which were not sensitive to the ecological potential of the wetlands leading to rapid degradation. A population explosion and the associated pressure contribute to wetland desiccation as human beings expand into marginal lands like wetlands. The situation is the same in Africa, as noted by Handa (2012), who states that population growth, infertile upland soil and erratic climatic conditions are some of the reasons behind the increasing use of wetlands in East Africa. Population pressure has impacted negatively on resources like dambos and stream banks (Makwara and Gamira, 2012). In fact, the pressure from agriculture on wetlands may lead to degradation of these systems. Feresu (2010) observes that wetlands are supporting about 60% of communal farmers in Zimbabwe, thus supporting the notion that human habitats are responsible for wetland degradation. Human habitats threaten wetlands in Kampala, Uganda through urban housing (Baragira and de Wit, 2017)

2.6.4 Overgrazing

Grazing in a wetland's catchment may increase soil erosion and increase the level and instability of sediment inputs to the wetland system (Coiacetto, 1996). Grazing in wetlands, as is practised in some places during drier periods, may lead to a reduction in the area of the wetland through trampling. Trampling produces tracks which alter the micro hydrology (Coiacetto, 1996). Grazing in wetlands results in trampling, compaction and increased surface runoff (Dabbasso *et al.*, 2012; Marambanyika *et al.* 2012). Bare soil resulting from overgrazing, (Marambanyika *et al.* 2012) is a major threat to wetland health because compaction by livestock hooves results in accelerated water velocities. The change has often been associated with intensive livestock grazing (Dabbasso *et al.*, 2012). Wetlands are characterised by clay soil properties which, when exposed to overgrazing are susceptible to development of numerous footpaths. These tend to concentrate runoff and contribute to rill erosion, sheet erosion and ultimately formation of gullies.

2.6.5 Burning

Frequent burning, particularly immediately after the harvests, reduces the organic content of the upper 1–2 cm of the soil (Kotze, 2013). In communal areas, burning crop residue after harvests is done as part of clearing land in preparation for the next planting season. These effects, in turn, result in reduced water infiltration, which increases in surface runoff during storm events and decreases the sustained supply of ground water to the wetland. There is also a possibility that this could potentially cause gully erosion in those wetlands which are inherently prone to erosion, particularly for wetlands that are intensively grazed (Whitlow, 1985). Whitlow (1985), warns over long-term nutrient losses resulting from annual burning used to enhance grazing for livestock. This is especially severe on the inherently nutrient-poor dambo wetlands of the granitic landscapes of Zimbabwe.

2.6.6 Alien Invasive Species

Alien invasive species are a threat to the survival and sustainability of wetlands. Their threat lies in the way they displace native plant species from the wetlands. Alien species like *Lantana camara*, sedges and grasses invade and displace indigenous plants thereby compromising species diversity and integrity. This alters the ecosystem's structure and functions in a significant way. In addition, Townshend et al. (2012) assert that wetlands are lost every year through alien invasion. It has been noted that alien species such as a single eucalyptus tree consumes between 757 and 1136 litres of water a day that is the reason why they are discouraged close to wetlands.

2.6.7 Peat harvesting

People harvest peat from wetlands for construction purposes. Peat and clay are extracted for brick making in both urban and rural areas thus leading to degradation of wetlands. Townshend *et al.* (2012) confirm that wetlands are lost every year through erosion mainly due to mining. This inevitably undermines the health of the wetland and when erosion sets in, the wetlands get negatively affected through a lowering of the water table and a loss of wetness.

2.6.8 Drainage for agriculture

Drainage canals are usually excavated in wetlands for irrigation structures and this channelization of wetland waters is a threat to wetland health. The likely impacts of drainage works and canals are changes to the frequency and duration of flooding of a wetland and changes to the groundwater level and stability (Coiacetto, 1996). According to Mwendera (2010) the effects of drainage for agriculture on wetlands is huge. The frequency and level of flooding of a wetland is likely to be affected by the construction of levees. It can also affect the input of sediment and nutrients and the groundwater level (Coiacetto, 1996). Therefore, hydraulic engineering works need careful investigation, planning and monitoring to ensure perpetuity in wetland life.

2.6.9 Climate change

Global climate change is recognised as a threat to species survival and the health of natural systems (Hulme, 2005; Schwarzel *et al.* 2006; Erwin, 2009). Brander *et al.* (2011) observe that climate change is expected to have numerous and complex impacts on the provision of ecosystem services from wetlands in Europe. It is anticipated that climate change in Europe will induce a wetland loss of 8% between 2000 and 2050. Ultimately, the effects of climate change will impact on the provision of goods and services (Brander *et al.* 2011).

Wetlands are also affected by pressure from climate change, (Kamusoko and Aniya, 2007; Hayal et al. 2012). Droughts force people to convert wetlands for agriculture (Parker *et al.* 2008). Erwin (2009) even stated that climate change will make future efforts to restore and manage wetlands more complex. Global warming-induced climatic change impacts on ecosystems, as such; wetland restoration and management should take climate change into consideration (Erwin, 2009). Hence, the influence of climate change, in particular rainfall variability on rehabilitation projects need further attention in the southern African region and in particular, in Zimbabwe.

The influence of climate change and variability on sustainability of agriculture in the SADC region has received widespread attention. Relatively small changes in precipitation, evaporation, or transpiration can alter ground water level by only a few centimetres. But this is enough to generate negative impacts not only on agriculture but on the size of wetlands. In Europe, it is anticipated that climate change will induce a loss of 8% between 2000 and 2050 (Brander et al., 2011). Climate change, as noted by Erwin (2009), will present greater challenges to future wetland rehabilitation efforts because conflict of interest arises over wetland utilisation options and trade-offs. Therefore, the combined effect of climate change and other stressors, such as population explosion, agricultural encroachment and urbanisation, will have far reaching impacts on the benefits traditionally received from wetlands.

2.7 Wetland Rehabilitation at a Global Scale

Wetlands cover 6% of the world's land surface (Mitsch and Gosselink, 2002; Erwin, 2009; Junk *et al.*, 2013; Ogato, 2013) and are thus a vital component of the environment. They are, however, amongst the world's most threatened fragile ecosystems (Millennium Ecosystem Assessment, 2005). Wetland research and management have, in the past few decades, become increasingly important (Junk et al., 2013). For instance, the

International Union for the Conservation of Nature and Natural Resources (IUCN), the Ramsar Convention and Wetlands International deal extensively with different aspects of wetland protection at a global level (Junk *et al.,* 2013). Furthermore, several international environmental agreements have been introduced that have bearing on global wetland conservation, and these include the Ramsar Convention on Wetlands, and the Convention on Biological Diversity (Schleupner and Schneider, 2013). These conventions have one common aim, which is the protection and restoration of certain natural sites (Schleupner and Schneider, 2013).

Existing European wetlands are relatively well protected through EU-policy measures (Junk *et al.* 2013; Schleupner and Schneider, 2013). However, climate change is expected to have numerous and complex impacts on Europe's wetlands' capacity to provide ecosystem services (Brander *et al.* 2011). Several pilot projects aimed at wetland restoration in China were supported by the government (Junk *et al.* 2013). All South American countries have protected large wetland areas by creating different types of reserves including the large Ramsar sites (Junk *et al.*, 2013). In addition, they note that little is known about the wetlands of Russia and the influence of scientists on Russian wetland policy is limited. Wetland modelling, especially over a larger catchment scale is still in its infancy and the issues point towards the need for models that can work on both site specific and catchment areas (Acreman, *et al.*, 2007). It is possible to design models that allow for agricultural practices to co-exist with wetland rehabilitation. Strategic conservation planning always has to be weighed up against other environmental, economic, and societal objectives (Schleupner and Schneider, 2013).

2.8 Wetland Rehabilitation in Africa

Wetlands cover 7% of Africa (Junk *et al.*, 2013), which constitutes a significant part of the continent. In Sub-Saharan Africa, 9% of the land area is covered by wetlands (Mitchell, 2013). It is estimated by the International Union for the Conservation of Nature (IUCN) that 13% of Southern Africa is covered by wetlands (IUCN, 1994). This represents a vast area that deserves attention. Wetlands in Southern Africa, as in most parts of the world, are vulnerable to anthropogenic pressures and climate shifts, which influence the

hydrologic and geomorphic processes that otherwise maintain the equilibrium of the wetlands' dynamic state (Du Toit, *et al.*, 2007; Dube and Chimbari, 2009; Riddell, 2010). The aim expressed for wetland management by the New Economic Partnership for African Development (NEPAD) Action Plan for the
Environmental Initiative (2003) is that African countries and their people must have healthy and productive wetlands and watersheds that can support fundamental human needs like clean water and food security (Junk *et al.* 2013).

A number of studies reflect the potential for harnessing indigenous knowledge systems (IKS) in wetland rehabilitation as shown in South-Eastern Ethiopia (Dixon and Wood, 2003); the Mazvihwa communal lands in Zimbabwe (Mbereko *et el.*, 2006); and the Mauritanian wetlands (Cooper *et al.* 2006). Viriri, (2009) pointed out that totems and taboos attached to certain tree species have helped to preserve particular wildlife and vegetation in Zimbabwe since ancient times using IKS. Dixon (2002) notes that despite the agronomic pressures on wetlands of the Illubador region of Ethiopia, agricultural practices are hydrologically sustainable, and attributed this to the indigenous knowledge of these systems. This reinforces the importance of orally passed historical wetland rehabilitation efforts by local farmers.

Developing nations, which face strong demands for socio-economic development, are encouraged to use and conserve wetlands in a sustainable manner. Hein *et al.* 2013, however, warn that it is generally recognised that addressing the on-going loss of global biodiversity requires substantial increase in funding for conservation activities, particularly in developing countries. There is a need to develop additional funding mechanisms specifically targeted at biodiversity conservation in low-income and middleincome countries (Hein *et al.*, 2013), especially with the whole of southern Africa having also been identified as vulnerable to the impacts of climate change, (Du Toit, *et al.*, 2007).

A number of countries have made great strides in wetland rehabilitation. For instance, the Rwandan government decided to opt for the wetland conservation of the Gikondo wetland over industrial development (Twesigye and Mulisa 2006); in Uganda the Namatala wetland intervention measures have been implemented; in South Africa the Ga-Mampa and Craigieburn wetland has been rehabilitated successfully (Riddell, 2012), while in Zimbabwe the Intunjabili wetland in the Matebeleland Province has been rehabilitated nominally (Mbereko *et al.* 2007). Successful wetland rehabilitation in Gikondo, Namatala, Ga-Mampa, Craigieburn and Intujambili wetlands was demonstrated by recovery in biological integrity, bird life, increased hydro-periods and wetland structure.

Southern Africa is characterised by recurrent droughts, which impact negatively on the ecology of the wetland systems by lowering their water table and water holding capacity. This ultimately reduces the size of the wetland areas (Chigwenya and Muparamoto, 2009) as they dry up. In South Africa, the Manalana sub-catchment was the target of integrated wetland rehabilitation where the major focus was the stabilisation of erosion gullies by large retaining structures (Riddell *et al.* 2012). A sustainable utilisation of wetlands may be achieved through the identification of hydrologically sustainable micro-regions within the Sand River wetlands. This has to be simultaneously combined with suitable rehabilitation of degraded regions (Riddell *et al.* 2012). Malan *et al.* (2009), highlight that considerable effort is now being directed towards wetland rehabilitation.

Studies carried out on the Sand River catchment of South Africa highlight some requirements of current rehabilitation approaches (Riddell *et al.* 2012). The need for comprehensive ground–truthing of wetland systems when costly rehabilitation measures are taken is noted. The South African Working for Wetlands programme uses wetland rehabilitation as a vehicle for job creation, skills development, and judicious use of wetlands. This undeniably implies that the rehabilitation objective has partly been borrowed from the Ramsar Convention that initiated the judicious use paradigm. Therefore, the Ramsar Convention is the cornerstone of wetland rehabilitation projects worldwide. Local adaptation of Ramsar principles on wetland rehabilitation is required to suit local circumstances in the planning stage. This, it has to be stressed, helps to balance socio-economic development and ecological sustainability.

Rehabilitation is meant to re-establish wetland hydrology. The success of any wetland rehabilitation project depends on the type of rehabilitation measures that have been put in place in the degraded ecosystem. In a study of a wetland close to Nottingham road in

KwaZulu-Natal midlands region, Grenfell *et al.* (2005) observed that the *Eucalyptus grandis* plantation has reduced the primary sources of water input to the wetland and hence the store of water available to hydrophytic vegetation has been affected.

Therefore, the rehabilitation approach failed to reclaim wetness. The demerits of unscientific and defective rehabilitation interventions point to the need for models that give direction to the nature of the needed rehabilitation measures. In South Africa, robust predictive models of wetland processes are required to facilitate appropriate and successful rehabilitation measures (Riddell, 2010). Models designed for wetland rehabilitation projects in South Africa and for the wider southern Africa region are not reported in conventional literature. However, very little research has been carried out to assess the impact of rehabilitation projects on wetland functions. Hence, more work has to be done to address wetland rehabilitation weaknesses in southern Africa.

2.9 Wetland Rehabilitation in the SADC Region

The southern African region comprises 17 countries that are members of SADC; Angola, Botswana, The Democratic Republic of Congo, Lesotho, Madagascar, Malawi, Mauritius, Mozambique, Namibia, Seychelles, South Africa, Swaziland, Tanzania,

Zambia and Zimbabwe. The Comoros became the 17th member state of SADC IN 2017. Frenken and Mharapara's (2002) study on SADC countries' observed that the region generally prioritises wetland development and use with little focus on rehabilitation. Wetland research is not new to Southern Africa; however, it needs to be reviewed regularly to offer appropriate improvements on intervention. Different researchers such as (Kotze *et al.*, 2001; Grenfell *et al.*, 2007; Erwin, 2009), have studied wetlands from different perspectives. However very few studies have zoomed in on the topical issue of wetland rehabilitation with a view to improve results. New knowledge on best practices in wetland rehabilitation is, therefore, key in unlocking perennial challenges to wetland recovery. These challenges include lack of rehabilitation tools.

Wetland ecology is influenced not only by natural elements but anthropogenic forces as well. The issue of climate change may present greater challenges to wetland conservation and management (Erwin, 2009). Availability of enough water is a central subject that needs to be considered in the design and implementation of sustainable restoration/conservation practices for wetlands, particularly with regard to the predictions of future climate change (Schwarzel *et al.*, 2006). Riddell *et al.* (2012) focus on results of wetland rehabilitation in the north east of South Africa but there is no assessment of the link between wetland rehabilitation and socio-economic development. Scientific knowledge of wetland hydrology is key to understanding wetland restoration, (Acreman *et al.*, 2007).

In recent years increased rainfall variability and extreme weather events have created conditions that alter the ecology of climate sensitive resources like wetlands (Dube and Chimbari, 2009). These trends are evident in the SADC countries. Wetlands are also affected by pressure from climate change (rainfall variability), land use and land cover change (Kamusoko and Aniya, 2007). Such investigations give minimal attention to issues relating to wetland rehabilitation. In communal areas of Zimbabwe, it has been noted that communal areas in the drier regions of Zimbabwe's natural agro-ecological regions IV and V have driven people to opt for wetland cultivation (Mapanda and Mavengahama, 2011). The classification of these natural agro-ecological regions is in Table 2.2

Table 2.2: Classification of Zimbabwe's natural regions

Agro-climatic region	**Rainfall description**	**Examples from study area**
I	Above 1 050 mm/annum with some precipitation in all months of the year.	Mutare
II	750–1 000 mm/annum seasonally confined with infrequent short dry spells.	Harare
III	650–800 mm/annum with fairly severe midseason dry spells.	Masvingo, Gutu, Bikita, Zaka
IV	450-650 mm/annum with periodic seasonal drought and severe rainy season dry spells.	Chivi
V	Too low and erratic for even drought resistant fodder and grain crops.	Chiredzi

Source: CSO. (1997) Statistical Yearbook, Harare

Some of the reviewed literature on wetland rehabilitation in Southern Africa advocate for the consideration of physical factors in wetland rehabilitation decision making. Barnes *et al.* (2002) report on water quality in rehabilitated wetlands in South Africa's KwaZuluNatal's Midlands region but they do not address the impact of rehabilitation on improved hydrology which is usually the major objective of any rehabilitation effort. Bullock and Acreman (2003) investigate dambo influences on the hydrological cycle in southern Africa; however this study does not consider rehabilitated and non-rehabilitated wetlands. In addition, Sieben *et al.* (2010) consider the hydrological and geomorphologic influences on wetland rehabilitation. This study does not take into account the influence of rainfall variability and the need to introduce irrigation to curb further encroachment after rehabilitation. Riddell (2010) argues that South Africa's wetland rehabilitation planning should be from a hydro-geomorphic point of view with little regard for socio-economic influences on wetlands. Riddell *et al.* (2012) warn that a detailed hydrological monitoring of a technical rehabilitation should be undertaken to measure its success.

Zimbabwe and Zambia are mostly agro-based economies than South Africa which has an extensive mining and manufacturing sector. Research conducted in southern Africa advances the argument for agronomic utilisation of wetlands with minimal conservation. Makombe's (2001) research in Zimbabwe urges the agronomic use of wetlands to enhance people's livelihoods. However, it disregards prioritisation of wetland conservation. In another study, Seyam (2001), focusing on Zambia and Zimbabwe, calls for the promotion of a wetland economy and partial conversion for agriculture. This cited research is shallow in that it lacks the systems approach to wetland management.

McCartney (2004) argues for sustainable utilisation of wetlands in Tanzania as a livelihood enhancement strategy. Masiyandima *et al.* (2004) analysed wetland management in Zambia and Tanzania and argued for the sustainable utilisation of wetlands as a livelihood enhancement strategy. Such studies fail to acknowledge and articulate the negative impacts of agriculture on wetlands. It is acknowledged that wetland hydrology is likely to be affected by multiple cropping and fruit trees that are heavy water consumers (Svotwa *et al.*, 2007). Furthermore, such literature keeps a blind eye on the need to balance a wetland economy for food security and wetland ecology (environmental security).

Population driven land use changes (Hamandawana *et al.*, 2005) affect the environment and wetlands in Zimbabwe. Population increase usually translates into an increased demand for food and resources (Whitlow, 1992; Kotze, 2004; Grenfell, *et al.*, 2005; Feresu, *et al.*, 2010). Wetlands have been degraded due to the impact of water demanding activities, such as agriculture and land-use changes in SADC countries that include Zimbabwe (Feresu *et al.*, 2010). However, Feresu *et al.* (2010) make a generalisation of the state of environment in Zimbabwe without giving hints on practical steps that can be taken to rectify population-induced pressures. Although wetlands have been converted for agriculture due to droughts (Manzungu and Mtali, 2012) little or scant attention is directed towards wetland rehabilitation matters. Instead, great emphasis is put on the agricultural potential of such ecosystems. These are serious challenges that require new knowledge.

Gujadhur (2000) argues for community participation in natural resource management in Botswana, Namibia, Zambia and Zimbabwe. There are successful models which focus on community based natural resource management (CBNRM) in Zimbabwe, such as the communal areas management programme for indigenous resources (CAMPFIRE), which have benefited the country in wildlife conservation. The CAMPFIRE programme looks at natural resources in general but the same strategies can be extended to wetlands. Manjengwa (2007) investigated grassroots public participation in wetland management in Zimbabwe. Finally, Tagarirofa and Chazovachii (2013) examined the rehabilitation of small dams in Zimbabwe using public participation but their work focuses on rehabilitation of artificial wetland and not natural wetlands. There is still an outstanding knowledge gap in research that focuses on rehabilitation of natural wetlands.

Gadzirayi et al. (2006) scrutinise the application of Indigenous Knowledge Systems (IKS) in wetland utilisation and management. Tanyanyiwa and Chikwanha (2011) also advance for the integration of technical and IKS in the management of forest resources. The utilisation of IKS is indeed critical in dealing with ecological challenges as noted by Mbereko *et al.* (2007). Viriri (2009) argues that the application of Indigenous Knowledge System is a critical area of research in Zimbabwe. Current research needs to elaborate further on how IKS can be tapped to solve wetland rehabilitation challenges in communal lands.

Rehabilitation projects in Southern Africa are concerned with the issue of sustainability. Wetland sustainable utilisation is defined as human use of a wetland so that it may yield the greatest continuous benefit to present generations while maintaining the potential to meet the needs and aspirations of future generations (Ramsar Convention Bureau, 2010). Wetland restoration is based on retaining high water table levels on the site (Acreman *et al.* 2007). The availability of enough water is indeed a central subject that needs to be considered in the design and implementation of sustainable restoration/conservation practices for wetlands, particularly with regard to the predictions of future climate change (Schwarzel *et al.* 2006). Small water retaining walls are therefore key to any successful wetland rehabilitation effort. Finally, rehabilitation can only be successful and sustainable if stakeholders take ownership of on-going rehabilitation projects. This has been the case with projects such as Chebvute wetland in Zvishavane, Zimbabwe, (Marambanyika *et al.*, 2012) and Shedagan wetland in Iran, (Kaffashi *et al.*, 2015).

2.10 Distribution of Wetlands in Zimbabwe

The literature on the extent and distribution of wetlands in Zimbabwe is conflicting. Figures quoted from Whitlow (1992), who is highly regarded as the father of wetland research in Zimbabwe differ from current figures suggested by the Environmental Management Agency (EMA) which uses modern mapping methods such as GIS. Whitlow could have been using physical methods of mapping as opposed to remote sensing and GIS. Wetlands, which are estimated at 3, 5% of the total surface area of Zimbabwe cover 1.28 million hectares (Mutambikwa, 2000; Dube and Chitiga, 2011). The distribution of wetlands in Zimbabwe is illustrated in Figure 2.2. Currently there is no existing comprehensive and clear picture of the extent, distribution and condition of wetlands in Zimbabwe.

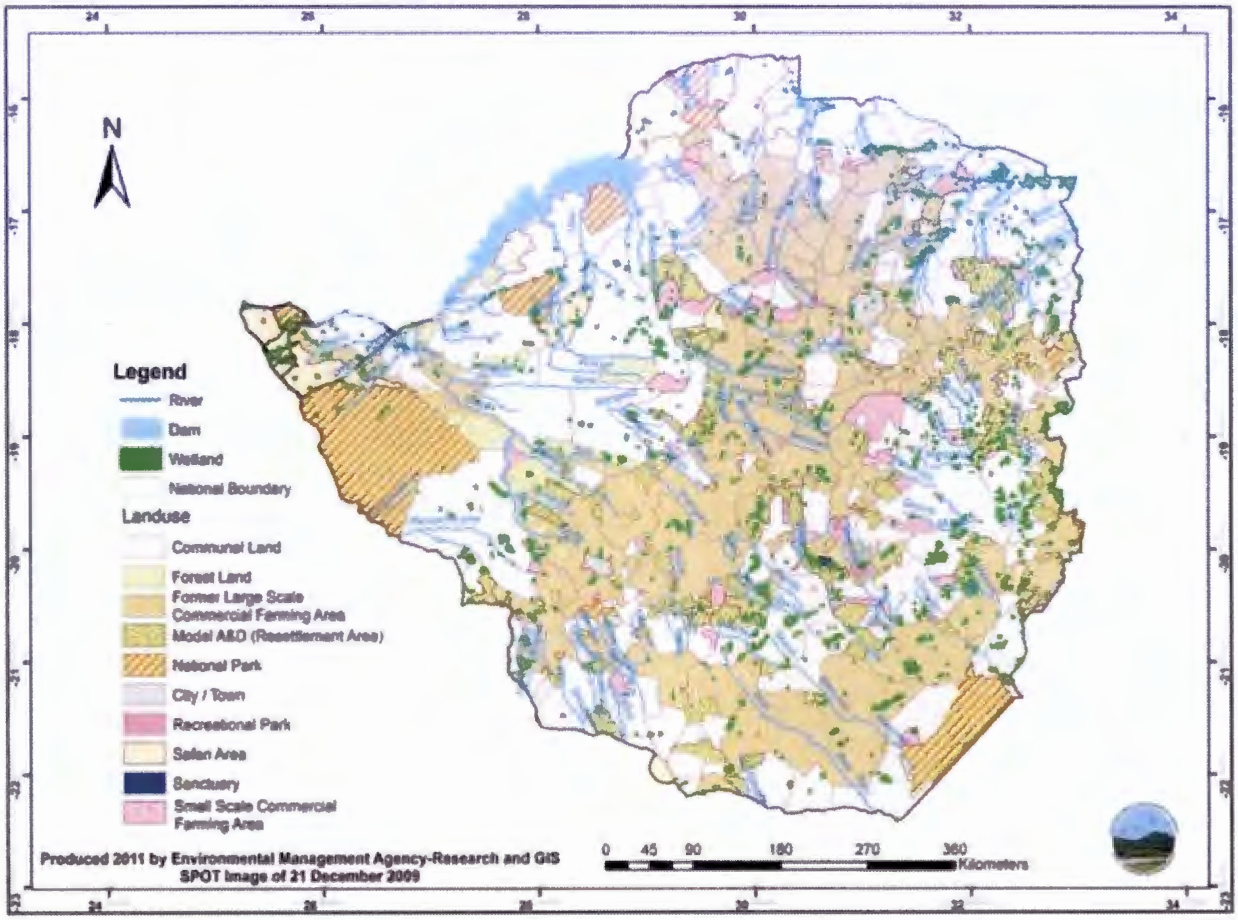


Figure 2.2: Distribution of wetlands in Zimbabwe. Source: EMA, (2012)

Wetlands in Zimbabwe occur on gentle slopes which usually make them suitable for cultivation. The angle and length of the slope influence erosional processes that require various interventions (Whitlow, 1985; Chikodzi *et al.*, 2012). Wetlands are known for the occurrence of hydrophilic or hydric plants such as reeds, which are good pointers for the occurrence of wetlands. Hydrophilic plants are adapted to surviving in water logging conditions for the greater part of the year. However, the ecosystem services provided by wetlands are driven by hydrology, hence an understanding of how changes in hydrological processes affect the delivery of these services is critical.

Wetlands in Zimbabwe differ in their hydro-geomorphic formation; some occur as headwaters of stream and rivers, whilst others are riverine wetlands. Although wetlands in Zimbabwe are small in size, they are spectacular for their diversity and uniqueness.

South-Eastern Zimbabwe, has the highest area of land covered by wetlands and these are widely distributed.

2.11 Wetland Degradation in Zimbabwe

Dambo's or vleis in Zimbabwe are experiencing severe degradation in the form of gullying, drying up, shrinking and loss of biodiversity. At the same time the degradation of dry lands poses a serious threat to the sustainability of human habitation. The trampling by cattle, drainage of wetlands dry land cultivation, monoculture summer rice and winter wheat production put a strain on this vital resource, just as overgrazing, smallholder cultivation and brick making poses a serious threat to wetland hydrology and ecology.

Rangeland degradation is exacerbated by growing population densities in many of these communal areas and a lack of economic development, which make people strongly reliant on natural resources for their livelihoods (Seyam, 2001; Hamandawana, 2005; McCartney and Houghton- Carr, 2009). Population pressure is one of the drivers of wetland loss and Zimbabwe on average has a population density of 32 people/km^2, (Population Reference Bureau, 2009, 2009). It should also be noted that there is an escalating pressure to expand agriculture within wetlands due to the increasing population and efforts to increase food security.

Zimbabwe is experiencing a rapid population growth. The national population has almost doubled from about 7.5 million in 1980 to the current 13.6 million (GoZ. 2012). According to the Population Reference Bureau. (2009) Zimbabwe has a population density of 32 people/km^2, with some communal areas such as Zimunya having 200 people/km^2, (Hamandawana, 2005). Although these demographic forces influence wetland loss, it must be acknowledged that a net migration of -11 per 1000 (Population Reference Bureau, 2009) around 2008 has not yielded the desired result of lessening the pressure on wetland loss. Many wetlands face population pressure from both humans and animals and this has resulted in habitat change and loss of species (IUCN, 2004).

Wetland degradation in Zimbabwe is largely due to crop cultivation. The desiccation of wetlands is both poverty-induced and drought-induced. Garden cultivation is an important source of income for communal households and hedge against unpredictable rains and periodic droughts (Frenken and Mharapara, 2002; Hamandawana *et al.*, 2005; Mapanda and Mavengahama, 2011; Chikodzi and Mutowo, 2014). Zimbabwe experiences unreliable and erratic tropical summer rainfall and as such the cultivation of dambos in Zimbabwe is a form of insurance against droughts as it ensures a reliable crop harvest in comparison to rain fed agriculture and thereby guarantees household food security. Food prices have been on the rise in Zimbabwe and thus there has been a tendency for the poverty stricken communities to rely heavily on wetlands for their livelihoods.

Agriculture is the main source of livelihoods in most Zimbabwean communal lands (Manzungu and Mtali, 2012). This creates over-reliance on wetlands and conflict of interest between different stakeholders and calls for the harmonisation of wetland management goals. Desbiaz *et al.* (2009) are of the opinion that threats, such as deforestation, land degradation, fire and landscape alteration may also impact on habitat quality. In another study, Kioko and Okello (2010) note that wetlands used for dry season grazing have significantly reduced in the last 30 years in Southern Kenya. Thus, wetland degradation is becoming a major problem, not only in Zimbabwe but in other African countries as well.

Wetlands in communal areas suffer the tragedy of the commons, which has occurred since the Iron Age. Common property refers to property that is owned by a group. Common property resources have open access which result in resource degradation. Poor institutions in communal areas contribute to resource degradation. The tragedy of open access to common property resources such as wetlands result in them suffering a tragedy of the commons. Dube and Chitiga (2011), confirm that dambos are a common resource with no specific person responsible for their use or misuse. One can, therefore, conclude that this has turned resources into ―open access‖ natural resources with the potential to suffer a tragedy of the commons. This eventually makes rehabilitation efforts a challenging task.

2.12 Wetland Rehabilitation in Zimbabwe

Research shows that there is a complex inter-linkage between ecosystem services (ES), poverty, and climate change (Howe *et al.*, 2013). There is a need for new empirical research on these pathways in order to begin to understand these pathways (Howe *et al.* 2013). Wetland rehabilitation, however, needs to take into account many different aspects of the wetland and its context (Sieben *et al.*, 2011). Various efforts have been implemented to protect wetlands from being degraded and damaged by human activities. However wetland rehabilitation is sometimes very costly to accomplish (Chigwenya and Muparamoto, 2009).

Zimbabwe is one of the countries that are facing serious institutional problems in wetland management. These have existed in Zimbabwe since the pre-colonial times when reserved wetland grazing was regulated and enforced by traditional authorities, such as village heads and chiefs. Traditional institutions depend on indigenous knowledge systems (IKS) in their land use decisions, (Gadzirayi *et al.*, 2006; Mbereko, *et al.*, 2007; Viriri, 2009). Today policy makers tend to ignore local knowledge, yet indigenous knowledge systems (IKS) are based on an intimate interaction with the environment and observations made over a long period of time. The application of IKS is a bottom-up approach to wetland problems than technocratic approaches which are top-down.

Agricultural extension staff have not been able to support farmers at Intunjambili wetland in Zimbabwe because of their poor understanding of wetland legislation. The Environmental Management Act (EMA) of 2003 states that the cultivation of wetlands without a permit from the minister is not allowed. As a result, wetland cultivation occurs unsupervised or unsupported, with cases of local level utilisation of wetlands for grazing purposes resulting in conflicts when stray animals break into nutrition cropping plots.

The country seems to appreciate that wetlands are important for food security, water security, and environmental sustainability. The challenges, however, are multifaceted and include the fact that mainstream economists and politicians in third world countries concentrate on economic and political growth in ways that ignore humanity and the environment (Gadzirayi *et al.*, 2006; Mbereko, *et al.*, 2007; Viriri, 2009). Nevertheless, there are sizeable pockets of societies at local and national level where wetlands are still considered to be of no significance ecologically, economically, socially and culturally.

There is growing international concern on wetland rehabilitation. It has been more than 20 years since the beginning of the Zimbabwe Wetlands Conservation Programme in 1994, with the year 2013 standing out as a milestone for wetland management. Zimbabwe acceded to the Ramsar Treaty as the 164th member, having ratified the convention in 2011. After signing the Ramsar Convention, Zimbabwe has stepped up efforts to rehabilitate degraded wetlands. In addition, stringent measures have been taken by EMA to prevent development projects such as housing encroaching into wetlands. Such proactive strategies are commendable. The signing of the Ramsar Convention in 1971 marked a significant growth in wetland conservation, but membership has grown at a snail's pace in Africa. The main aim of this convention is to halt the worldwide loss and degradation of wetlands and to conserve, through judicious use and management, of those that remain.

There are conflicting approaches and views on wetland rehabilitation in Zimbabwe. Rudimentary wetland rehabilitation approaches, such as fencing, are widely used but these are not without their own weaknesses. Wetlands provide socio-economic functions that should be fully taken into account when planning an intervention in such areas (Chigwenya and Muparamoto, 2009). Developed countries, such as Australia, see value in wetland conservation. Developing countries, such as Uganda and Rwanda, which value wetlands, have put in place wetland management systems that are sound and sustainable. The system includes sound wetland policies, comprehensive wetland legislation and rehabilitation programmes.

Zimbabwe's wetland management is, however, fragmented between various institutions. The Ministry of Water Resources Development and Management is responsible for the management of water in wetlands, while the Ministry of Environment, Natural Resources and Climate Change oversees the general administration of wetlands. In addition, the Ministry of Lands and Land Reform has its own stake in wetland management. There is therefore a need for a harmonisation of the activities of these institutions. Currently the Environmental Management Agency (EMA) has an overall supervisory role on wetlands. The Environmental Management Act provides for the sustainable management of natural resources and protection of the environment, as well as the prevention of pollution and environmental degradation. If wetlands are to be utilised at all, they can be used as recreational facilities like parks or golf courses.

At times wetland rehabilitation is done within the context of food for work programmes, which is a government initiated poverty alleviation strategy. However the challenge is to strike a balance between poverty alleviation, job creation and wetland rehabilitation (Mbereko *et al.*, 2007; Manjengwa, 2007). Wetland rehabilitation in Zimbabwe fails to reconcile poverty alleviation or job creation and/or wetland utilisation and wetland conservation. The utilisation of wetlands and their conservation are key issues that need to be taken in any wetland rehabilitation plan.

2. 13 Legal Institutions for Wetland Management

Wetland legislation in Zimbabwe can be traced to as far back as 1926 with the promulgation of the Environmental Management Act. This law prohibited stream bank and wetland cultivation. The utilisation of these ecosystems is now governed by the Natural Resources Act of 1942, which forbids cultivation within 100 m from the stream and the Water Act of 1998 prohibiting cultivation within 30 m of the stream bank, which seeks to protect the ecosystems from degradation caused by cultivation, (GoZ, 2003; Chirisa and Muzenda 2013). The problem with a fragmented legislation is that people do not know which legislation to follow.

Wetland systems are complex but their management is sometimes fragmented amongst numerous authorities and departments, each with differing levels or types of expertise as well as diverse and sometimes conflicting interests and agenda (Coiacetto, 1996). The EMA's general recommendation is that all cultivation activities must be at least 30 m from a stream. However, in recent years, increased pressure for land has led to a non-compliance with this stipulation. An absence of the close monitoring of the land use and other human activities taking place within the proximity of the catchment area is noted. This has led to rapid siltation and water quality impairment of the rivers (BowyerBower and Tengeh, 1995; Muchibwa, 2007).

Only in very special cases is permission granted for a farmer to cultivate wetlands by the Natural Resources Board (Act) which is the authority with the responsibility to administer the legislation. Another Act that aimed to manage wetlands was the Land Husbandry Act of 1951, which, despite its racist grounding in practical essence it called for was a destocking exercise in overpopulated communal lands. The Natural Resources Act of 1952 outlawed dambo cultivation and drainage, but allowed for grazing without the realisation that grazing is just as degrading as cultivation. Wetland cultivation continued unabated despite this progressive law. The Environmental Management Act Chapter 20: 27 stipulates that; ―no person should reclaim or drain any wetland and introduce an exotic plant species into wetlands unless authorized‖ (Government of Zimbabwe, 2003). The Act allows for limited cultivation of wetlands but with a permit obtainable from the responsible minister (EMA, 2003).

The EMA Act (2003) provides for the sustainable management of natural resources, protection of the environment, and prevention of environmental degradation (Tanyanyiwa and Chikwanha, 2011). However, managing the prohibition of stream bank cultivation and wetland avoidance does not work because rural communities need economic incentives to preserve wetlands. The implementation of the Act is under the Environmental Management Agency (EMA) and the Ministry of Environment and
Natural Resource Management, yet other departments' involvement may be desirable, even necessary, given that they regulate or are responsible for activities which impact on the wetland environment (Coiacetto, 1996).

2. 14. Role of Wetland Modelling

The challenges of wetland rehabilitation span a range of spatial scales and institutional levels, from the national and provincial to the level of specific wetland sites involving individual landowners. A number of wetland rehabilitation models have been developed and applied in different parts of the world. Modelling wetland rehabilitation does not need re-inventions as it is continually evolving. Dale *et al.* (2010) reports on wetland rehabilitation using an interactions matrix model. This model is a revision of one originally devised for the evaluation of the management of coastal wetlands associated with North Creek at Ballina in New South Wales, Australia. Although devised for an Australian situation, the model has potential for application elsewhere, particularly in rapidly developing tropical and subtropical regions.

Kaffashi *et al.* (2015) proposed a willingness to pay (WTP) framework for wetland conservation. The model reports that users are supposed to have a better perception and valuation basis compared to non-users of a resource (wetland). A hypothetical market situation was devised for Shadegan wetland, with an area of 537,700 hectares. This is the largest wetland in Iran located in the coastal area of the Persian Gulf. The wetland was designated as a Ramsar site in 1975. Modelling has been used as an important tool in wetland rehabilitation design for Shadegan wetland by Kaffashi et al (2015). Such modelling plays a role in supporting foresight in rehabilitation programmes.

Another example of an existing conceptual wetland rehabilitation model was given by Pollard *et al.* (2006). This model explains the degradation of the Craigieburn wetlands in South Africa (Pollard *et al.*, 2006). The model describes the different biophysical and human parameters that contribute to wetland degradation. However, it does not give a comprehensive blue-print of a model for rehabilitation. Other wetland scientists that have come up with a conceptual wetland rehabilitation model include Dini (2008) and Townshend (2012). Nkosi (2007) also developed a conceptual framework linking wetland rehabilitation and the retrieval of ecosystem goods and services. Conceptual models of wetland rehabilitation are therefore many and well reported on.

One of the models discussed in literature is the integrated approach model. Agnalu (2014) argues that relevant institutions such as environmental protection agencies, water research institutes, and governmental agencies should appreciate the need for a participatory integrated approach. This would include the various physical, vegetative, and human components within watersheds. Watershed management practices should thus be implemented in a manner that solves soil and water degradation problems but at the same time is socially and politically acceptable and economically feasible. Good watershed management will require the striking of a balance between economic objectives for productive land use and ecological objectives for the maintenance of ecosystem integrity.

In South Africa, the Working for Wetlands is a tool that has been used successfully in the rehabilitation of a number of wetlands. The programme uses wetland rehabilitation as a vehicle for job creation, skills development, and judicious use of wetlands. The ecological rehabilitation actions implemented by Working for Wetlands include alien clearing, re-vegetation, the installation of gabion structures, concrete structures, and earth structures. As an indication, Kotze and Ellery (2008) found the cost of rehabilitating the Killarney wetland in KwaZulu-Natal, South Africa, to be R223 000 per hectare, and the cost of rehabilitating the Manalana wetland in Mpumalanga, South Africa, to be R947 000 per hectare. Wetland rehabilitation is thus a costly exercise. The urgent need for rehabilitation set against a background of limited resources, clearly demands a more holistic approach.

The Working for Wetlands adds diverse value to society and the environment, and presents an international role-model of what is achievable in wetland restoration. As an example, it has created 12 000 jobs and 1.5 million person-days of paid work, and has restored over 600 wetland sites in South Africa. The very complex links between people and wetlands mean that actions aimed at sustainably rehabilitating and conserving wetlands will depend on the dedication and commitment of all stakeholders, especially landowners and wetland users.

The judicious use of wetlands has been advocated by the Ramsar Convention (Ramsar, 2010). The application of this method is demonstrated through a case study of wetland rehabilitation in the Kamiesberg uplands of Namaqualand in the Northern Cape, South Africa. This is a semi-arid region which is home to pastoralist communities. A similar approach has been applied in Keiskamma catchment, in the Eastern Cape Province, South Africa which requires a holistic approach that integrates community regulatory frameworks, legislation, and stewardship, together with socio-economic transformations. Morardet *et al.* (2010) and Sieben *et al.* (2011) report on the decision making tools provided by the Wetland Management Series. The series provide an interesting perspective on wetland restoration accommodating both the detailed and expensive types of restoration aimed at the level of the plant community, as well as restoration aimed at broad-scale processes within the entire catchment such as water retention. Ramsar (2010) asserts that the conservation of wetlands in least developed countries should be based on the principles of integrated water resources management (IWRM) since IWRM recognises the need to manage water resources at different scales, from local to basin, to ensure that local needs can be sustainably met. Sustainability is critical to wetland rehabilitation.

Msusa (2011) and Dixon and Carrie (2016) proposed the Striking a Balance (SAB) model. The model explores how seasonal wetlands in Zambia and Malawi could be managed in a way that balances and sustains ecosystem service provision alongside livelihood benefits. Such a wetland rehabilitation model offers the possibility to understand the most sensitive parameters for improving wetland hydrology at a system scale, as well as improved speed of wetland recovery, the ability to simulate the interactions between model components and enhance socio-economic and ecological sustainability.

In Zimbabwe studies by Chigwenya and Muparamoto (2009) propose an integrated wetland system restoration model that should fully take into account the existing wetland activities in the area and its environmental features, especially eco-function performance. Research work by Mharapara (1995) has shown that wetlands (dambos) can be cultivated safely using the Ngwarati Cultivation System (use of ridges and furrows). The system also has the potential to rehabilitate degraded wetlands. Studies by Mharapara (1995) and Frenken and Mharapara, (2002), report on the use of ridges and furrows in an attempt to achieve a balance between wetland rehabilitation and wetland utilisation. In contrast with the use of existing models, the construction of specific models for wetland rehabilitation projects involves a system dynamic approach. A predictive model for wetland rehabilitation designed as an alternative to conceptual models can offer a new tool to enhance wetland recovery.

2.15 Knowledge Gaps in Literature

It has been noted from this literature review that levels of wetland rehabilitation differ between the developed countries and the developing countries. Wetland utilisation and rehabilitation are widely contested and conflicting issues that deserve immediate attention especially, in Zimbabwe where economics and politics seem to override environmental considerations.

So far a research gap exists in:

i. Lack of studies that deal with wetland utilisation and rehabilitation in Zimbabwe. Although notions of compatibility of sustainable wetland agriculture utilisation and rehabilitation are gaining ground, a comprehensive model for wetland rehabilitation that is suitable to Zimbabwe is yet to be designed.
ii. Research on wetlands in Zimbabwe remains extremely limited, (Frenken and Mharapara, 2002; Chigwenya and Muparamoto, 2009).
iii. There is a disconnect between rehabilitation science and the practice of rehabilitation

This study will particularly address research gap on a wetland rehabilitation model suitable for Zimbabwe. The intention is to offer rehabilitation practitioners with tools that can assist them to repair degraded wetland ecosystems.

2.16 Summary

This chapter revealed that wetland rehabilitation research in southern Africa is in its infancy. Wetland rehabilitation is not a widely researched field of science, which is important for policy and decision makers in the region. Little ground has been covered to adequately address the numerous challenges confronting wetland rehabilitation. The chapter also focused on wetland control factors and wetland functions.

This literature review also discussed wetland rehabilitation at a global scale and went on to focus on wetland rehabilitation in Africa, the SADC Region and Zimbabwe. The limitations of previous studies are that, they do not capture the synergies between wetland rehabilitation, climate change driven wetland threats and food security among poverty stricken communities. As a result, there is need for a full investigation into a comprehensive and wider scope of a wetland rehabilitation model in Zimbabwe that uses an ecosystems approach.

Chapter 3 discusses the changes in rainfall pattern and wetland size that have a bearing on wetland rehabilitation.

CHAPTER 3: TRACING CHANGES IN RAINFALL PATTERNS AND WETLAND SIZE

3.1 Introduction

The aim of this chapter is to trace changes in both rainfall patterns and wetland size over time. There is a need to test the relationship between rainfall variability and wetland loss in an attempt to establish wetland rehabilitation intervention strategies thereof. Climate plays a critical role in influencing water, vegetation and even soil components of wetlands. It is regrettable that wetlands are being converted to agriculture worldwide as a coping strategy to climate change and grinding poverty (Frenken and Mharapara, 2002; Li, 2008; Dube and Chimbari, 2009; Erwin, 2009). No meaningful adherence to limits is given in as far as climate change induced wetland invasion, conversion and cultivation is concerned. These are pertinent concerns that need urgent consideration and redress to reinstate the ecological integrity of wetlands.

Rainfall variability is a key wetland issue for Zimbabwe because it has a lot of influence on wetland loss and rehabilitation programmes and projects. Climate change is a critical challenge affecting wetland rehabilitation options. Rainfall has been on the decline in Zimbabwe resulting in the increase in frequency and intensity of drought episodes leading to the conversion of wetlands for agriculture. This poses challenges for reconciling wetland productivity and preservation as wetland conversion for cultivation ensures household food security. Hayal (2012) states that wetlands are among the ecosystems most vulnerable to anthropogenic activities being aggravated by climate change. Yet Zimbabwe has not yet developed an integrated climate change and adaptation policy to strategically and holistically guide the nation to respond to climate change.

Developing countries are generally seen as more vulnerable to climate change than developed countries with African countries in a more precarious position due to their high reliance on natural resources, limited ability to adapt financially and institutionally, low per capita GDP and high poverty (Thornton et al. 2006). Rainfall variability impacts on wetland health and functions. Lack of understanding of the hydro-geomorphic and climatic influences on wetlands can result in an inappropriate implementation of wetland rehabilitation measures (Riddell, 2012). Therefore, wetland rehabilitation techniques should be linked to rainfall variability.

There is limited literature focusing on the importance of climate change in influencing the design and implementation of rehabilitation actions and the influence of climate change on poverty alleviation through its impacts on ecosystem services (Howe, 2013). Zimbabwe has undertaken more research (Gadzirayi *et al.*, 2006; Manzungu and Mtali, 2012) focusing on the agricultural use of wetlands. However, there appears to be scant information in the literature on the impact of climate change on wetland rehabilitation of degraded wetlands. A few studies, such as that of Ogato, (2013) propose that wetland rehabilitation projects should factor in climate change in their designs. Nonetheless, there is dearth of research in Zimbabwe that recognises the influence of rainfall variability on wetland rehabilitation. The study therefore aims to design a model for wetland rehabilitation that simultaneously promotes socio-economic development and wetland sustainability in Zimbabwe.

The next section discusses materials and methods used to gather rainfall data. It also highlights the maps used to measure changes in wetland size, and presents the mathematical formula used to calculate the spatial changes of wetland sizes over time.

3.2 Materials and Methods

The Masvingo Province's rainfall data for the period 1980-2012 was obtained from the Meteorological Services Department (MSD) of Zimbabwe. The period 1980-2012 was selected because the data reflects current rainfall patterns which are critical in influencing the design of a rehabilitation model. In this study, a rainfall season will be defined by a distinct year, for example the 1984/85 season will be denoted as 1985; 1989/90 will be denoted as 1990 and so on. This was done because rainfall seasons overlap from one year to another. Time intervals of 5 years, that is, 1980, 1985, 1990, 1995, 2000, 2005 and 2010 are used for analysis. The Meteorological Services Department (MSD) has 8 weather stations in the Masvingo Province which are for rainfall measurement, as shown in Figure 3.1. The data sets obtained are for weather stations within a radius of 70km to each of the wetlands (Figure 3.4) where change in wetland size was measured. The assumption was that measurements from rainfall gauging stations nearer to wetland patches are indicative of the rainfall conditions within which the rehabilitation interventions have to be undertaken.

Rainfall figures were used to compute the standardised precipitation index to establish peaks of wet, dry, and drought episodes. The resultant trends were used to provide possible explanations for wetland shrinkage and corroborated with measurements carried out during field observations. This information assisted in tracing changes in rainfall trends in the area during 1980-2012 and establishing the relationships with wetland loss.

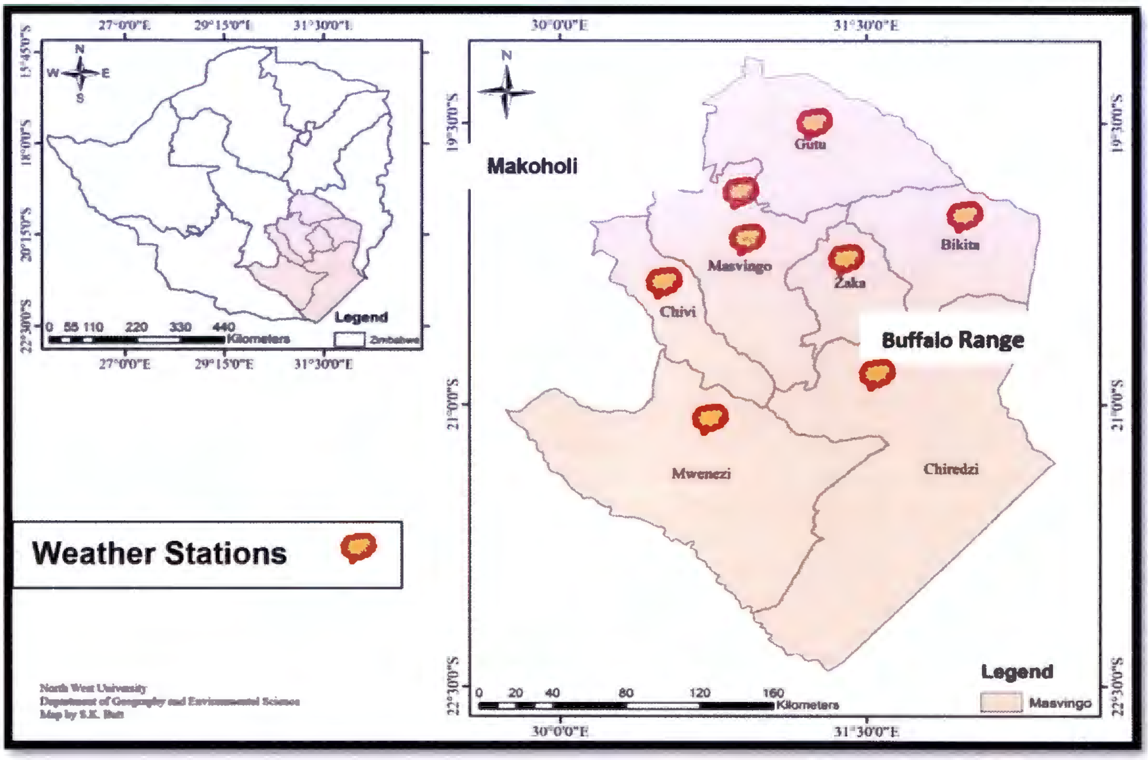


Figure 3.1: Location of weather stations in the study area. Source: NWU (2017)

3.3 Sampling Weather Stations and Wetland Patches

3.3.1 Sampling weather stations

Purposive sampling of weather stations where rainfall records were measured was used in this research. This was done because these weather stations provide official weather records of the Meteorological Service Department of Zimbabwe. These records are accurate, reliable and consistent. The 8 weather stations sampled were Bikita, Buffalo Range, Chivi, Gutu, Makoholi, Masvingo, Mwenezi and Zaka.

3.3.2 Sampling wetland patches

The number of wetland rehabilitation patches for each district was determined by aerial photographs, topographical maps and land-use maps. The Province has a total of 163 wetlands, (EMA, 2009). A sample size of at least 30% of the wetland patches was used to measure changes in wetland size over time. At least 1 wetland was randomly selected from each district. As a result 7 wetland patches were selected from among but not limited to the 22 wetland rehabilitation projects. This sample was selected using the stratified random sampling technique. Each wetland patch was assigned a number and therefore had an equal chance of getting selected. Each of the seven districts formed a layer of the wetland patches from which a random table of digits was used to select wetland patches. The breakdown of each district and the sampled patches are shown in table 3.1.

Table 3.1: Sample Distribution for Wetland Patches

District	**Total number of patches***	**Sample Size****	**Name of Wetland Patches**
Gutu	34	3	Makanda, Mutubuki, Zidya
Masvingo	27	0	Nil
Bikita	23	1	Maturure
Zaka	18	1	Mupunga
Chivi	23	1	Magwenzi
Mwenezi	0	0	Nil
Chiredzi	17	1	Manjinji
TOTAL	**163**	**7**	

*Source: (EMA, 2009) &, ** author's computations (2013)

Topographical maps obtained from the Surveyor-General's office, for the period 1972 to 2008, provided data on wetland location, their sizes and change in size over time. The identified sections of the maps that show wetlands were digitised from aerial photographs of the years, 1972, 1984, 1995 and 2008 to trace spatial-temporal changes in wetland size. Aerial photographs are taken once in a year in Zimbabwe. However, due to socio-economic and political circumstances, the period 2008-2016 has not witnessed any aerial photographs taken in Zimbabwe.

The next section focuses on the changes in rainfall patterns 1980-2012. The area's changes in the size of wetlands patches from 1972 to 2008 are illustrated using timeseries analysis.

3.4 Results and Discussion

3.4.1 Rainfall patterns in the area from 1980-2012

Rainfall data obtained from the Meteorological Services Department vary from year to year for each district in the Masvingo province. Table 3.2 shows that rainfall has generally been on the increase in the Chivi District from 1980 which recorded 924.6 mm and rose to 1067.4 mm in 1985. Between 1990 and 1995 there was a decrease in the amount of rainfall received (from 828.4 mm to 433.7 mm). However, the year 2000 experienced Cyclone Eline, which recorded 1 077.8 mm and therefore an extremely wet year, only for the rainfall to decrease by more than 50% to 508 mm in 2005. The rainfall amount later increased by 320 mm in the 2005 season to 828 mm in 2010. Extreme rainfall variability creates uncertainties in decision making on climate change compliant rehabilitation approaches. Hence, rainfall variability poses challenges for wetland rehabilitation. These include deciding on alternative sources of livelihood, especially when alternative options to wetland utilisation and cultivation are not readily acceptable to affected communities.

Table 3.2: Annual rainfall totals for districts in the Masvingo Province Zimbabwe (mm)

YEAR	RAINFALL							
	BIKITA	CHIREDZI	CHIVI	GUTU	MAKOHOLI	MASVINGO	MWENEZI	ZAKA
1980	1033.5	706.1	924.6	667.2	615.1	632.8	681.6	596.3
1981	1607.9	718.5	867	1086.6	916.3	773.6	762.3	1030.4
1982	628.3	449.5	435	439.9	384.4	341.1	339.2	329.2
1983	924.8	309.7	456	476.2	239.6	241.7	258.4	362.2
1984	1148.9	653.3	534	576.1	604.4	588.8	463.7	872.9
1985	1273.9	672.0	1067.4	976.5	746.0	838.3	652.6	336.5
1986	1009.9	657.0	687	713.6	632.6	515.6	582.0	690.7
1987	807.0	427.4	460	555.2	490.9	591.2	309.9	629.9
1988	982.6	403.0	480.0	784.5	609.5	586.7	433.8	489.1
1989	878.2	425.2	433.4	674.0	457.7	600.3	307.2	573.5
1990	857.5	431.0	828	723.6	748.1	680.8	471.8	531.7
1991	672.8	354.4	231.4	373.0	315.0	219.7	304.1	412.3

1992	460.6	371.6	374.2	583.8	507.0	513.7	291.9	436.4
1993	1200.0	922.4	493.8	988.2	579.7	630.9	429.0	559.1
1994	886.1	287.8	398.5	559.9	499.4	348.0	239.5	433.6
1995	919.8	478.9	433.7	343.4	479.7	592.8	393.1	519.9
1996	872.3	705.0	730.9	422.2	839.7	797.0	754.0	883.8
1997	921.3	531.0	604.8	662.2	1092.9	667.8	443.2	914.8
1998	1228.7	561.6	664.0	753.4	662.0	635.6	680.0	665.1
1999	1129.3	661.7	609.5	547.7	591.8	698.3	342.5	1022.9
2000	1820.2	1176.6	1077.8	986.6	1041.6	1134.8	1024.6	1474.4
2001	1490.0	673.4	800.4	983.3	736.9	1022.2	725.8	1342.4
2002	594.1	314.4	217.6	641.9	368.5	421.2	410.0	331.2
2003	1424.7	714.7	516.0	804.2	958.3	1013.4	427.5	1036.1
2004	1342.7	578.7	491.8	258.5	790.0	836.3	585.0	520.9
2005	848.5	285.9	508.0	772.5	674.7	515.3	272.2	420.9
2006	951.0	471.7	348.5	564.3	841.4	719.8	569.2	580.2
2007	1538.2	749.2	435.7	615.0	1005.9	729.3	617.2	1025.6
2008	806.6	315.1	528.9	376.0	366.4	474.2	396.0	515.0
2009	932.2	633.7	472.8	649.0	759.0	644.4	383.7	425.2
2010	857.7	498.3	828.0	619.5	741.2	673.3	424.0	647.4
2011	1005.4	591.8	417.3	751.9	675.1	768.8	539.9	787.2
2012	575.8	306.6	241.9	338.1	381.5	308.2	248.2	344.8
2013	1233.8	574.0	369.1	230.8	756.5	488.5	436.5	752.5
2014	1306.8	713.3	554.6	648.2	889.8	839.4	506.6	1096.0
2015	726.6	330.6	367.7	377.6	349.9	347.3	356.9	360.0

Source: (Meteorological Services Department of Zimbabwe, 2014)

There is a general decrease in rainfall in the area from 1980 to 2015 and variations from the mean. However, this variation is not significant. The lack of correlation does not mean that change in water balance is not involved in the changes in wetland size because factors such as temperature and evaporation were not considered in this study which are very important features to the up-keep of the wetlands. The rainfall amount recorded at Bikita was 1 033.5 mm in 1980 and it rose to 1 273.9 mm in 1985. This amount dropped by 416.4 mm to 857.5 mm in the 1990 rain season. Wetland utilisation increases during such dry episodes. Crop failure occurs in 3 out of every 5 years mainly due to poor distribution of rainfall within a wet season (Hamandawana et al., 2005). Again in most cases there is some indication of possible relaxation of wetland cultivation restrictive policies in Zimbabwe (Taruvinga, 2009). There is also an increase in rainfall to about 919.8 mm in the 1995 season and a further increase to 1 820.2 mm in 2000. This amount declines by more than half to 848.5 mm in 2005. The rainfall fluctuations in Figure 3.2, therefore, illustrate the changes in precipitation patterns over time.

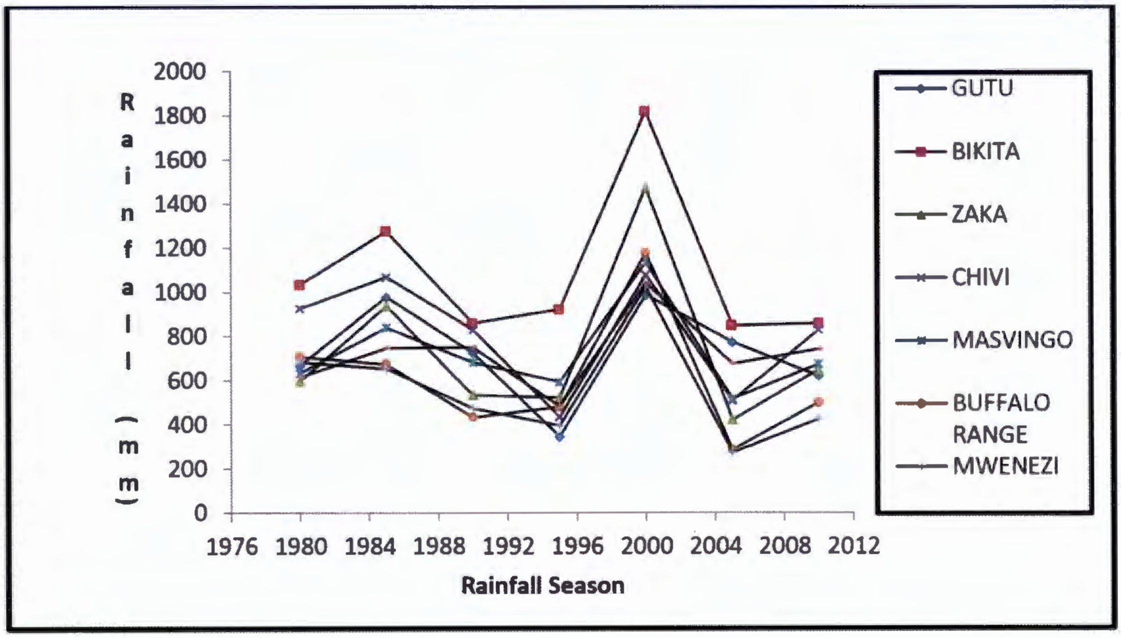


Figure 3.2: Rainfall trends in Masvingo Districts 1980-2010.Source: Author

Mwenezi District is the driest in the study area. It experienced a decline in rainfall figures in 1980 from 681.6 mm to 652.6 mm, a decline of 29 mm, with the district receiving 471.8 mm in 1985 and the amount dropping by 78.7 mm to 393.1 mm in 1990. The semi-aridity of Mwenezi District explains the none-existence of wetland patches in the Provincial wetland inventory. Although the district recorded a rise in rainfall to 1 024.6 mm in 2000, there was a decline to 272.2 mm in the 2005. This has a large impact on wetland integrity since it affects groundwater recharge. Climate change and climate variability have affected and continue to affect individuals, populations, species and ecosystem composition and functions (Gitay, 2004). On the basis of these observations and rainfall results, appropriate rehabilitation intervention or wetland management plans can be designed.

The rainfall statistics of the Gutu District are quite instructive. The district recorded 667.2 mm in 1980 and 976.5 mm in 1985, which declined to 723.6 mm in 1990, with a further dropped further to 343.4 mm in the 1995 season. The driest year for Gutu district was 1995 with 343.4 mm recorded. The low rainfall during dry episodes leads to the conversion of wetlands to agricultural use which halts its recovery from previous wetter episodes. Nevertheless, one can observe from these trends that precipitation is on the decline in the Gutu District. Erratic and unreliable rainfall in the Gutu District explain the overexploitation of wetlands with water demand crops such as sugar cane and bananas, at the Chibvongodze and Mutubuki wetland rehabilitation projects.

The Buffalo Range rainfall gauge station is representative of the Chiredzi District. The Samson and Manjinji pan are located in the Chiredzi District and close to Buffalo Range weather station. The pan had 706.1 mm in 1980 which declines to 672 mm in 1985. This drops further to 431 mm in 1990. In addition, 478.9 mm is recorded in 1995 followed by a record of 1176.6 mm in 2000, with the trend, showing a fall to 285.9 mm which is a fall by 990.7 mm from the 2005 annual amount. The area, however, receives slightly higher rainfall amounting to 498.3 mm in 2010. The general observation is that there is rainfall variability from one year to another. Thus, rainfall variability and continued land transformation will result in an increase in both human pressure on wetlands and human influence over the drivers that affect wetland functioning (Kotze, 2013).

The Makoholi research station recorded 615.1 mm in the 1980 rainfall season, which increased to 746 mm during the 1985 season. In 1990 it recorded 748.1 mm which declined to 479.7 mm in 1995. However the *cyclone Eline* episode of 2000 resulted in a record rainfall of 1 041.6 mm before it declined to 674.7 mm. These variations point to the influence on people to opt for wetland cultivation (Mapanda and Mavengahama, 2011). These patterns are more acute in Zimbabwe's agro-ecological regions IV and V.

The Zaka District's rainfall gauging station recorded 596.3 mm in 1980, which increased to 935.5 mm in 1985. Quite often, rainfall comes in thunderstorms, particularly in the early phases of the rainy season. The rains therefore are particularly violent during the early part of the season, the very time when the land would be cracked and practically bare and devoid of vegetation cover (Makwara and Gamira, 2012). The district recorded 531.7 mm in 1990 which declined to 519.9 mm in the 1995 season. The year 2000 rainfall record shot up, due to *Cyclone Eline*, to 1474.4 mm and then declined to 420.9 mm in 2005. *Cyclone eline*, although a short term event caused wetland recovery from dry episodes to some extent. Nevertheless, the 2000 heavy rainfall was responsible for gully incision and desiccation of the Mupunga wetland. Furthermore, rainfall increases to 647.4 mm in 2010. It is clear that the Zaka District, a semi-arid, mountainous area with erratic rainfall averaging 600–800 mm/year (Makwara and Gamira, 2012), contributes greatly to the exposure of wetlands to all year round cultivation.

The Masvingo District, which has the same name as the name of the entire Masvingo Province is located in agro-ecological region IV. The Masvingo District's monthly rainfall totals as presented in Appendix 1, show that Masvingo weather station records 632.8 mm in 1980, which increases to 838.3 mm in 1985. In 1990 it records 680.8 mm which declines to 592.8 mm in the 1995. Kamanga *et al.* (2003) observes that, Masvingo receives annual rainfall of between 450–650 mm and at the same time experiences dryness during the summer seasons and recurrent droughts. Nonetheless, the *cyclone Eline* in 2000 resulted in the rainfall recorded rising to 1 134.8 mm before it declined to 515.3 mm in 2005.
Of the seven districts, the Masvingo District was selected due to its central location in the study area. An analysis of monthly rainfall figures assists in evaluating the meteorological factors that impact on wetland loss, utilisation and implications on size. It does so in the sense that yearly rainfall data tends to mask intra-seasonal dry periods that cause agricultural drought despite a year not experiencing a meteorological drought. Agricultural drought is one that affects mainly crops whilst meteorological drought denotes a year that receives rainfall amounts far below the expected average. Trends in wetland utilisation increase when low rainfall, such as 208 mm, 272.6 mm, 293.1 mm and 109.7 mm received in 1983, 1987, 1991 and 1992, respectively (Appendix 1), occurs. Wetland loss and utilisation are key inputs in the design of a wetland sustainability model for Zimbabwe.

Annual rainfall figures tend to blur precipitation deficits during the course of the year which impacts on wetland wetness and associated human activities. For example Table 3.2 and

Appendix 2 illustrate that in 1985, Masvingo District records 838.3 mm of rainfall, however most of the rainfall fell in November and January, that is, 133.1 mm and 365.3 mm respectively. The other months recorded less than 10 mm which denotes very dry phases even with an overall relatively wet season. The need for dry season based agriculture in Zimbabwe drives farmers to opt for wetland cultivation which explains wetland loss in the study area evident at Zidya (Table 3.5). Although the Masvingo District recorded 1134.8 mm in 2000, most of it fell in one month of February, that is, 412.3 mm and the rest of the year was generally dry which negatively affects wetland health demonstrated by limited or no water discharge from the wetland.

The Masvingo District experiences notable dry years in which the received total annual rainfall falls well below mean rainfall such as in 1983, 1987, 1991 and 1992 which recorded 208 mm, 278 mm, 293.1 mm and 109.7 mm respectively. Dry seasons contribute to wetland loss and degradation as communities abandon upland agriculture in preference to wetland-based cultivation. What might drive wetlands into ecological distress are the extremely dry years such as 1991 and 1992 which were successive in occurrence. Such trends cause communities to encroach into wetlands as a coping strategy. These trends occur especially in rural areas where uplands are predominantly defined as regions of low agricultural potential due to poor soils and low unpredictable rainfall (Ellis-Jones and Mudhara, 1995).

The standard precipitation indices (SPI) are calculated for the districts to help analyse the changes in rainfall patterns and the implications there-of on wetland loss (Table 3.3). The observed precipitation deviates from the long-term mean for a normally distributed random variable is calculated using the following equation:

$$SPI = (x - \bar{x})/\sigma \qquad \text{Equation 2}$$

Where x is the long term precipitation, $\bar{x}$ is the mean precipitation for a specified period of time and σ is the standard deviation.

SPI is a commonly used meteorological drought indicator as it is solely based on precipitation. The index ranges between +3 and -3, and the condition is near normal if the SPI is between +0.99 and -0.99 (Tirivarombo and Hughes, 2011). SPI that are ≥1.5 show extremely wet spells and ≤1.5 denoting extremely dry spells (Tirivarombo and Hughes, 2011).

Table 3.3: SPI Values for the Districts

DISTRICT/YEAR	1980	1985	1990	1995	2000	2005	2010
GUTU	-0.29	1.22	-0.17	-1.87	1.27	0.22	-0.52
BIKITA	-0.16	0.56	-0.70	-0.51	2.22	-0.72	0.70
ZAKA	-0.4	0.60	-0.59	-0.63	2.20	-0.92	-0.25
CHIVI	0.49	1.10	0.08	-1.60	1.14	-1.28	0.08
MASVINGO	-0.48	0.60	-0.23	-0.69	2.15	-1.09	-0.27
BUFFALO RANGE	0.37	0.24	-0.66	-0.48	2.13	-1.20	-0.41
MWENEZI	0.53	0.40	-0.38	-0.72	2.00	-1.24	-0.59
MAKOHOLI	-0.67	0.16	0.17	-1.52	2.02	-0.29	0.13

In some years this SPI is <-1.0, as noted in the 1995 cases of Gutu, Chivi and Makoholi. However in the year 2000, a positive SPI values of >+1 and +2 in the majority of the rainfall stations is recorded. Wetland remediation measures need to factor in possible impacts of double exposure. The concept of double exposure refers to the fact that ecosystems and social groups will be confronted both by the impacts of rainfall variability and other factors that are not climate-related. Rainfall data above can help to inform wetland remediation options and demonstrate rainfall variability. The standardised precipitation index time series for each of the 8 weather stations in the Masvingo District shows the degree of variation from the norm (Figure 3.2). A normal rain season has value between +0.1 to -0.1 while >+1 and <-1 denote extreme rainfall events. Values >+1 mean very wet years and values <-1 mean extremely dry year. SPI values that are outside this range indicate anomalies in rainfall (Figure 3.3).

Based on the anomalies in Figure 3.3, Chiredzi, Zaka, Makoholi and Gutu experienced extremely dry seasons in 1995 which could have resulted in short to medium term decline in wetland size. Furthermore, in 2005, Bikita, Zaka, Chiredzi, and Makoholi experienced very dry conditions and possible losses in wetland sizes. These results point to the fact that rainfall variability should, to some extent, be factored into wetland rehabilitation techniques. Although other causes such as anthropogenic factors may contribute much to wetland shrinkage, the influence of rainfall variability cannot be ignored. According to Mharapara and Frenken (2002), it was discovered that 10 years ago, the water table was on average 15m. But due to mismanagement of wetlands, the water table dropped to 30m on average suggesting future scarcity of water in Zimbabwe.

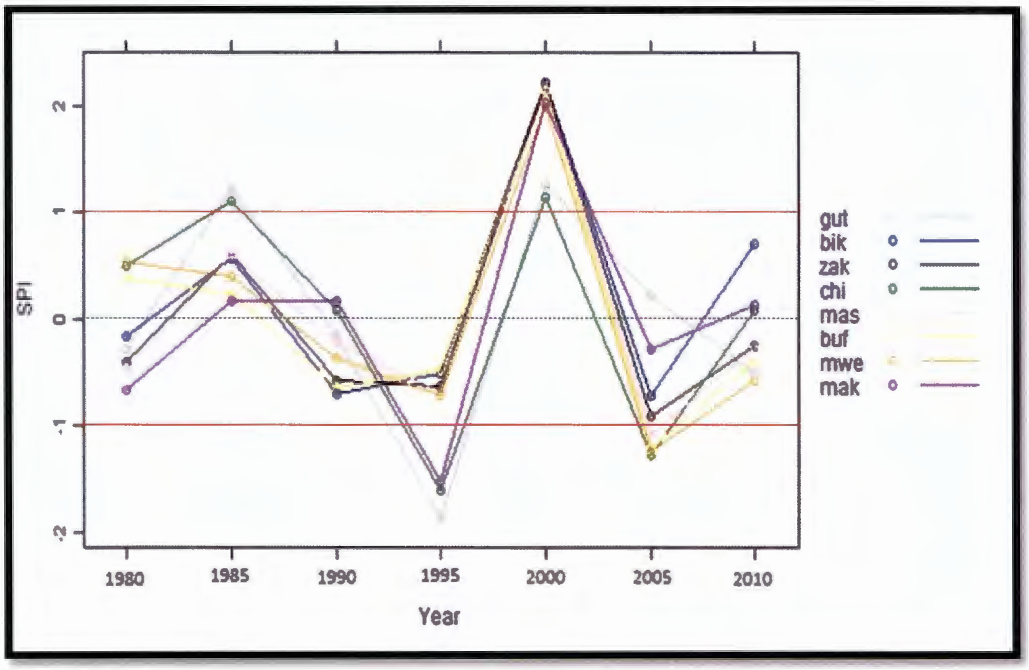


Figure 3.3: SPI values for the districts.

The SPI values in Figure 3.3 for 1995 and 2005 indicate very dry years whilst 1985 and 2000 were generally wet years. Although after a flood it takes some time for a wetland to retain to its base level, floods have a positive effect on wetland recovery. The amplitudes of SPI time series for 1985 and 2000 illustrate extreme wet weather events which have a strong bearing on wetland health and ultimately the success of rehabilitation models. Very dry years such as 1995 mean that wetland loss becomes a norm due to the abandonment of upland agriculture and increased demand for wetland based cropping. Farai *et al.* (2012) found an increase in the number of seasons recording below normal rainfall since

2002. Very wet years, such as the year 2000, cause flooding which results in wetland recharge. Flooding not only impacts positively on wetlands by recharging but negatively causes soil erosion which incises and entrenches gullies such as the one at Mupunga and Machingambi. During floods the hydraulic impact of fast flowing water causes a scouring effect thereby intensifying gullyfication. Soil erosion causes serious wetland degradation. Therefore, effective rehabilitation structures dealing with floods could include structures such as gabion blocks. An analysis of SPI values in Table 3.3 enables the tabulation of the percentage of occurrence and their meaning as shown in Table 3.4.

Table 3.4: Analysis of wetness and dryness using SPI (1980-2010)

SPI value occurrence	% occurrence	Nominal SPI class
>1.645	10.7%	Extremely wet
1.644 to 1.282	1.7%	Severely wet
0.842 to 1.281	5.3%	Moderately wet
0.524 to 0.841	10.7%	Slightly wet
−0.523 to 0.523	46.4%	Normal
−0.841 to −0.524	3.5%	Slight drought
−1.281 to −0.842	10.7%	Moderate drought
−1.644 to −1.282	8.9%	Severe drought
<−1.645	1.7%	Extreme drought

It should be noted first that, reliable SPI data values needs at least 30 years of continuous precipitation records (Jayanthi *et al.* 2013). Table 3.3, however shows SPI values occurrence over a period of 31 years, with over 5 year intervals, which is credible enough to analyse impacts of rainfall variability not only on wetland ecology but rehabilitation successes as well. Table 3.4, illustrates nominal SPI classes that interpret the meaning of SPI values in qualitative terms. From the nominal SPI classes, it can be observed that severe and extreme droughts have a combined occurrence of 10.6%. Slight and moderate droughts have a combined occurrence total of 14.2%. The effects of drought on wetland size are huge. Extreme drought worsens wetland shrinkage such as Magwenzi that shrunk by 4.1% between 1984 and 1995. From the analysis of wetness and dryness information using SPI, a community-based drought mitigation and preparedness plan can be fused into wetland rehabilitation modelling to achieve both socio-economic development and wetland ecological sustainability. Such a plan can allow for partial wetland utilisation as opposed to entire wetland usage as an insurance against hazards such as drought. Therefore, there is need to design wetland rehabilitation models that can enhance wetland sustainability in the context of current climate trends.

3.4.2 Changes in size of wetland patches 1980-2012

One of the key objectives of the research was to measure changes in the size of wetlands patches with a view to determine the level of intervention required to ensure wetland sustainability. A wetland patch is defined as a distinct delineated piece of wetland occurring within the landscape or catchment. The following formula, after Mtisi (2014) was used to determine spatial changes in wetland areas per patch:

$[(X - Y) / X] \times 100$;..Equation 3

Where;

X – Previous wetland area;

Y - Recent wetland area

Correlation analysis and analysis of variance, (ANOVA) between change in wetland size and changing rainfall patterns was applied to assess the relationship between the two variables, before conclusions and recommendations could be drawn. The sample wetland patches are shown in Figure 3.4.

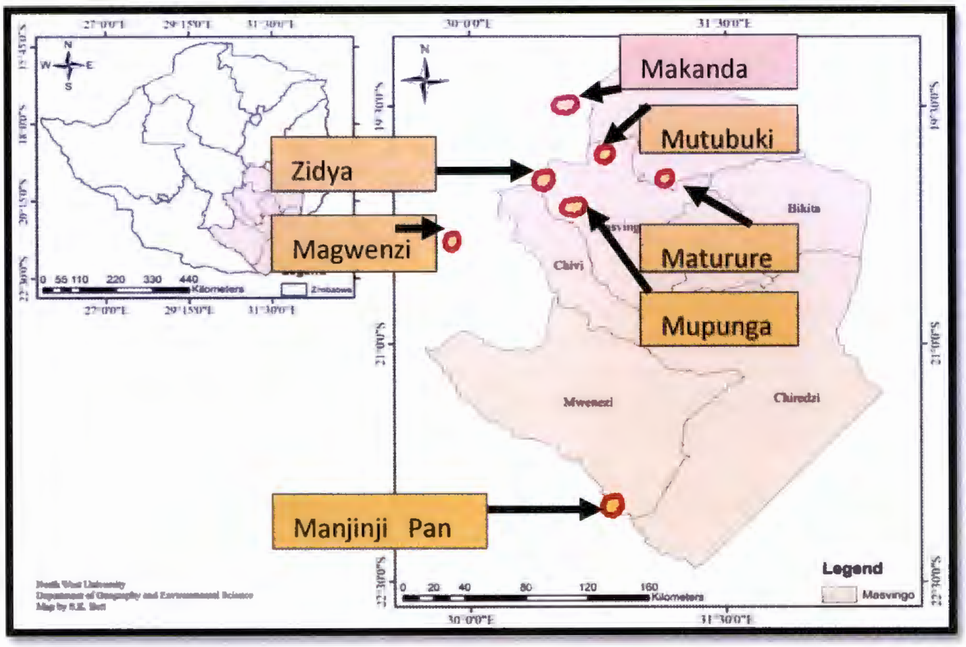


Figure 3.4. Distribution sample population of wetland patches.

For all the seven wetland patches, each one selected from each district in the study area showed a decline in wetland size between 1972 and 2008. Digitised aerial photographs were used to measure the change in the size of wetlands. The results showing the change in wetland size, the over time period are presented in Table 3.5 The varying changes are attributed to differences in biophysical factors, such as vegetation density, rainfall amounts in the catchment area, topography, geology, gradient, pedology and human influences. Although these factors were not part of the research, they exert some influence on wetland size, structure and functions.

Table 3.5: Changes in wetland size over time in South-Eastern Zimbabwe

Wetland Name/Years	Area (m^2)	Interval % change in wetland area
MAKANDA		
1972	20163	Baseline
1984	19865	1.5
1995	19456	2.1
2008	19000	2.4
MUPUNGA		
1972	74941	Baseline
1984	73543	1.9
1995	71890	2.3
2008	70000	2.7
MAGWENZI		
1972	91099	Baseline
1984	88360	3.1
1995	84880	4.1
2008	80000	6.1
MUTUBUKI		
1972	70845	Baseline
1984	67600	4.8
1995	64320	5.1
2008	60000	7.2
ZIDYA		
1972	1083142	Baseline
1984	1060864	2.1
1995	1036000	2.4
2008	1000000	3.6
MATURURE		
1972	56442	Baseline
1984	56161	0.5
1995	55715	0.8
2008	55 000	1.3
MANJINJI		
1972	15886	Baseline
1984	15698	1.2
1995	15420	1.8
2008	15000	2.8

Source: Author

The Makanda wetland measured 20 163m^2 in 1972, which declined to 19 865m^2 (1.5%) in 1984. By 1995 the size had dropped further to 19 456m^2. Over a 13 year interval the wetland shrank in size by 2.4% to almost 19 000m^2. The trends indicate that unless effective and sustainable wetland rehabilitation measures are taken to reverse the situation, some wetlands can dry up. Hove and Chapungu, (2013) state that the drying up of wetlands can be explained by excessive water abstraction and climatic changes.

The decline of the wetlands over the time period is shown in Figure 3.5.

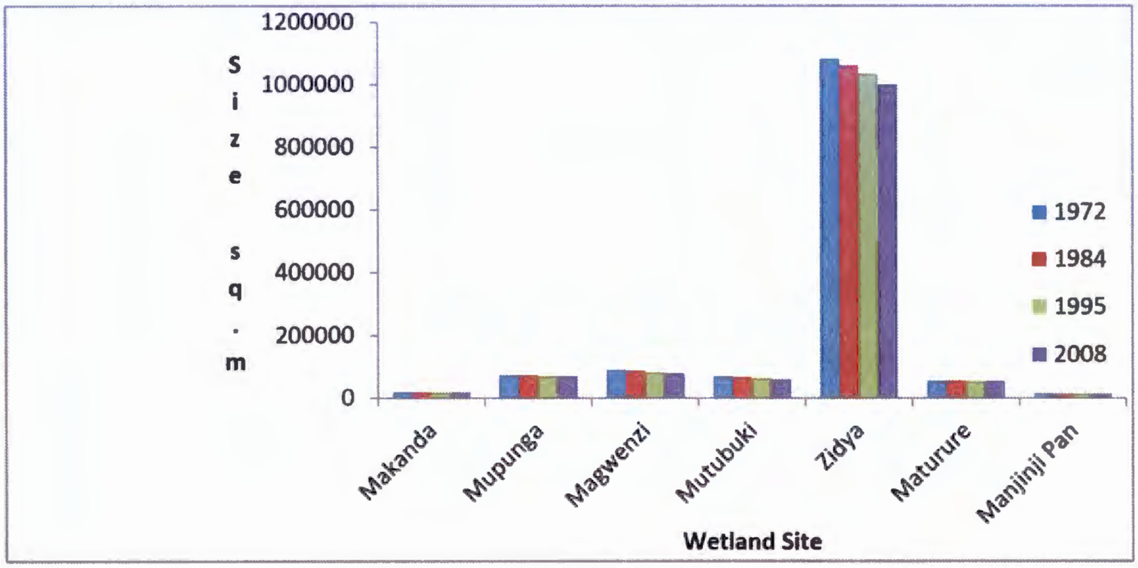


Figure 3.5: Spatio-temporal wetland loss

The Mupunga wetland experienced a slight decline in its size between 1972 and 1984, as it declined from 74 941m^2 to 73 543m^2 amounting to a 1.9% decline. Further spatial decreases were noted between 1984 and 1995 (2.3%) and 1995 and 2008 (2.7%). The spatio-temporal wetland changes are attributed to complex intervening factors. The wetland changes are caused by factors such as rainfall amount in the catchment area, relief, rock type and slope steepness. Thus, it is suggested that the treatment of such ecosystems to reinstate their health requires a diagnosis of the root causes so that correct interventions are applied. The results of the study indicate that limiting human activity by fencing the wetland might be critical to a successful rehabilitation of the ecosystem.

One of the wetlands that experienced a significant decrease in size is the Magwenzi wetland. The Magwenzi wetland, in the Chivi District, measured 91099m^2 in 1972 and the figure dropped to 88 360m^2 in 1984, which is a decline of 3.1%. In 1995, the wetland size declined to 84880m^2, a drop of 4.1%, the measurements for 2008 showing that the wetland had decreased to 80 000m^2, which is a 6.1% loss of the wetland size. The extreme drought conditions experienced in the Chivi District in 1995 and 2005, shown by SPI value -1.60 and -1.20 respectively, explain the encroachment and cultivation of the observed crops in the Magwenzi wetland. Therefore, a consideration of change in wetland size due to agricultural activity or land use is one of the key inputs in designing a sustainable wetland rehabilitation model.

The Mutubuki wetland also experienced decline in size between 1972 and 2008. The wetland measured 70 845m^2 in 1972 and had a 4.8% decline to 67 600m^2 in 1984. The wetland decreased by 5.1% to 64 320m^2 by 1995, and shrank further in size from 64 320m^2 in 1995 to 60 000m^2 by 2008. This period witnessed the greatest reduction in wetland size amounting to about 7.2%. A complex set of physical factors such as rock type and soil type as well as human factors such as overgrazing and planting of alien species such as gum trees contributed to the changes in wetland size. Clearing alien species in light of rainfall variability is the current policy position of the EMA. However, it seems there is a lack of urgency in policy implementation in practical terms considering that some alien invasive species such as *Lantana camara* and Eucalptus have not been cleared to date.

The Zidya wetland measured 1 083 142m^2 in 1972 and declined slightly by 2.1% to 1 060 864m^2. In 1995 it dropped further to 1 036 000m^2. Finally by 2008, the Zidya wetland had lost 3.6% of its 1995 size to 1 000 000m^2. Wetlands in Zimbabwe are generally small in size; however, the Zidya wetland is the biggest, as shown in Figure 3.5 of the sampled wetland patches. The change in wetland size has to do with anthropogenic factors and rainfall variability. The prevailing socio-economic circumstances led people to cultivate wetlands as a livelihood strategy during dry episodes resulting in their shrinkage. Socio-economic development needs to be prioritised in designing wetland rehabilitation models for wetland sustainability to be achieved.

The Maturure wetland experienced the least decline in wetland size in the study area. The change was from 56 442m^2 in 1972 to 56 161m^2 in 1984. This is a decline of about 0.5%. The same wetland decreased by 0.8% from 56 161m^2 to 55 715m^2 over an eleven year period from 1984 to 1995. Maturure also lost 1.3% of its size when it declined from 55 715m^2 in 1995 to 55 000m^2 in 2008. The gorge like topography of the Maturure wetland and mountainous nature of its catchment could explain the slight decrease of wetland size. Maturure wetland occurs in a trough like valley encircled by mountains and hilly terrain from which recharge seepage lines ensure continuous supply of underground water.

The Manjinji pan measured 15 886 m^2 in 1972 and dropped to 15 698 m^2 by 1984, which is a 1.2% decline. The size of the wetland fell from 15 698 m^2 in 1984 to 15 420 m^2 by 1995, which is a 1.8% decline. The pan shrank in size by 2.8% after decreasing from 15 420 m^2 to 15 000 m^2 as at 2008. Although accounting for the decline of wetland size is rather complex, poverty-driven wetland cultivation practices are key drivers of the shrinkage.

3.5 Hypothesis Testing

In this study, the first hypothesis stated that *rainfall variability has no impact on wetland rehabilitation and recovery.* It cannot for certain be proved that there is a direct linear link between rainfall variability and wetland loss. It was proposed that there is no direct relationship between changes in mean annual rainfall and the amount of wetland loss, expressed in square metre units. Statistical computations from research findings illustrate that there is no relationship between changes in rainfall patterns and wetland loss (Table 3.6). From the regression analysis, the p value = 0.611>0.05, the hypothesis that rainfall variability has no significant impact on wetland rehabilitation and recovery was accepted. The conclusion, therefore, is that there is no direct relationship between changes in mean annual rainfall and the amount of wetland loss. However it needs to be pointed out that data on change in wetland size over time and rainfall dynamics can be used during implementation of rehabilitation activities such as afforestation whose success also depend on time of planting trees.

Statistical findings from the study suggest that other factors, account for the observed decline in wetland size. This implies that 99% of wetland loss in the study is attributed to other factors such as over-cultivation and overgrazing. The coefficient of determination is 0.010; therefore, only about 1.00% of the variation in the wetland loss is explained by mean annual rainfall variability. Hence, although wetland shrinkage is an on-going phenomenon, it cannot be attributed to rainfall variability alone. Table 3.6: Analysis of variance (ANOVA)

Model	Sum of Squares	Df	Mean Square	F	Sig.
Regression	34316333752.606	1	34316333752.606	65	0.611[b]
1 Residual	3363293092110.071	26	129357426619.618		
Total	3397609425862.678	27			

a. Dependent Variable: wetland loss

b. Predictors: (Constant), mean annual rainfall

Correlation analysis, [with the results shown in Table 3.7] was used to prove the validity of the statement that there is a relationship between changes in mean annual rainfall and the amount of wetland loss. The results from an analysis of variance (ANOVA) proved that there was no relationship, over the time period, between changes in rainfall patterns and wetland loss. The Pearson correlation analysis results reveal that there is no significant correlation between wetland loss and changes in rainfall patterns. The correlation coefficient for wetland loss and mean annual rainfall is -0.1. This value of r suggests a weak negative linear correlation. Therefore, it is strongly argued that wetland rehabilitation should be linked to socio-economic factors that account for wetland loss. According to Millennium Ecosystem Assessment (2005), direct and indirect human activity has considerably altered the rate of change of wetlands. The loss of wetlands has far outstripped the gains due to direct and indirect human activities in wetland ecosystems. The socio-economic influences affect both the wetland loss and rehabilitation.

Table 3.7: Correlation between wetland loss and annual rainfall

		wetland loss	mean annual rainfall
Pearson Correlation	wetland loss	1.000	-.100
	mean annual rainfall	-.100	1.000
Sig. (1-tailed)	wetland loss	.	.305
	mean annual rainfall	.305	.
N	wetland loss	28	28
	mean annual rainfall	28	28

Source: Research findings (2015)

Wetland patches were also subjected to a T-test analysis to determine the relationship between rainfall patterns and wetland size as part of the data triangulation process. The T-tests results reveal that there is no statistically significant relationship between rainfall patterns and change in wetland size. All the seven wetlands have a critical value of 4.303. The rejection criterion was; reject H_0: if $T > t_{\alpha/2}$. The fact that the critical value 4.303 is greater than all T values means that there is no relationship between wetland loss and rainfall changes for the Makanda, Mupunga, Magwenzi, Mutubuki, Maturure and Zidya wetlands together with the Manjinji Pan. The alternate hypothesis is therefore rejected and the null hypothesis accepted. Thus, there is no direct relationship between changes in mean annual rainfall and the amount of wetland loss and the findings point to the dominant role of other factors other than rainfall variability. It can, therefore, be concluded that spatio-temporal wetland loss is a product of multiple processes with rainfall variability as one of the minor drivers.

The rate at which wetlands decline in South Eastern Zimbabwe corresponds with trends observed in some parts of the country, especially those near the study area such as Driefontein, which have similar rainfall patterns. Driefontein has a designated Important Bird Area (IBA), but it has been ravaged by an on-going decline in the size of its wetlands.

A study by Fakarayi et al. (2015) showed that wetlands regressively declined in size from 3.503 ha in 1995 to a paltry 1.938 ha in 2010. At the same time the area under cultivation has progressively increased from 89 ha in 1995 to 4 244 ha in 2010. This implies that there is a correlation between wetland loss and drivers of change triggered by human activities, such as cultivation.

3.6 Summary

It can be concluded that since there is no relationship between rainfall and wetland loss the monitoring of rainfall data should be undertaken not as an end in itself but within the broader context of reconciling wetland production and adoption of an adaptive wetland rehabilitation model. It is vital to devise a wetland rehabilitation plan that enables management of water from the rivers and wetlands that the communities depend on. This allows for drought preparedness and subsequent prevention of wetland loss. All the seven wetland patches, consisting of one selected from each district in South Eastern Zimbabwe, showed a decline in wetland between 1972 and 2008. The research findings, however, show that the rates of change in wetland size differ from one wetland to another. Statistical analyses indicate that there is no relationship between rainfall variability and wetland loss. Therefore, causal factors of wetland loss overlap physical and human influences. The process of adaptive wetland rehabilitation in light of prevailing rainfall trends should not ignore the human factors that cause changes in wetland size.

The next chapter focuses on the socio-economic influences on wetland rehabilitation.

CHAPTER 4: SOCIO-ECONOMIC INFLUENCES ON REHABILITATION

4.1 Introduction

Multiple global crises of sustainability on economic, social, environmental, and governance issues have crippled the current development path (Lagarde, 2012; World

Bank, 2012). The transition to a green growth model, stemming from the concept of sustainable development, has been recognised as a ground-breaking path for a better future. The green growth model combines economic development, social welfare and environmental protection. A consideration of the green growth model in relation with wetlands shows that a careful use of wetlands should be at the centre of wetland rehabilitation in order to achieve sustainability. The principle of judicious use underscores the significance of the conservation and sustainable use of wetlands and resources for the benefit of humankind (Frenken and Mharapara, 2002). Catchment management practices should thus, be implemented in a manner that solves soil and water degradation problems but at the same time be socially and politically acceptable and economically feasible. The aim of conservation projects should be to both protect the environment and provide a solution to the community's problems.

An understanding of the socio-economic value of wetlands is crucial when deciding on conservation and development priorities related to land use (Lannas and Turpie, 2009). Good and working institutions are also needed to coordinate and effectively carry out the planning, implementation and monitoring of watershed management programme (Aglanu, 2014). Moreover, institutional and financial constraints are generally known to affect the formulation of conservation policies and contribute to the social and economic factors that continue to lead to wetland loss (Swart and Cohen, 2003; Ramsar Convention Secretariat, 2010). This calls for the assessment of catchment development and management approaches with a view to address biophysical, socio-economic, institutional, and policy issues (Aglanu, 2014). In any case, the contribution of both users and non-users of wetlands in conservation programmes ensures the achievement of better results.

There are a number of factors that influence wetland rehabilitation worldwide. These factors differ from developed to developing countries. The socio-economic and political circumstances of developed countries contrast those of developing countries (Morardet *et al.* 2010; Sieben *et al.* 2011). Developing countries such as Zimbabwe present unique socio-economic circumstances that have a bearing on rehabilitation projects. Therefore, establishing clear linkages between socio-economic factors and wetland rehabilitation among the riparian communities and non-riparian communities poses major challenges to wetland rehabilitation practice. The riparian communities have an influence on wetland rehabilitation practice. Riparian means an area located on the bank of a natural watercourse (such as a river) or wetlands in ecological terms. In other words riparian communities means they are living adjacent to the wetland. Wetland rehabilitation performance, however, depends on both the riparian communities and non-riparian communities. Non-riparian means an area located far away from the bank of a natural watercourse (such as a river) or wetland in ecological terms. In other words they are far away from the wetland.

4.2 Materials and Methods

A total of 159 interviewees were interviewed to gather data about the socio-economic influences on wetland rehabilitation. The basis for the decision on a sample size of 159 was representativeness and practical manageability of conducting the interviews. The research design used included interviews which were conducted between December 2013 and January 2015. Although interviews were conducted over a period of 13 months, the outcome was not inadvertently compromised due to consistency in use of an interview guide. Demographic, social and economic information was captured from interviewees who are living adjacent to wetlands (riparian) and far from wetlands (nonriparian). Demographic data included age, gender and family size. Social variables include marital status, level of education, source of drinking water, social norms and. Statistical methods such as the Pearson correlation analysis were employed to establish relationships between variables such as the size of wetland rehabilitated and level of funding.

Field observations were carried out to augment information from the guided interviews focusing on in-situ assessment of socio-economic interactions among wetland users such as types of crops grown and alternative livelihood strategies that have bearing on wetland rehabilitation and success thereof.

Stratified random sampling was used to select interviewees to interview and gather socio-economic data such as family size, crops grown and levels of incomes. Two categories, the one riparian and the other non-riparian, emerged (Table 4.1). Interview schedules were arranged with households that are riparian communities and nonriparian communities far beyond the wetland patches but whose area constitutes the catchment that contributes water for recharge. Each interview schedule indicates the district surveyed, ward and name of village. Two interview guides were used, one for riparian communities (Appendix 5) and the other for non-riparian communities (Appendix 6). The interviews assisted in gathering data, whose analysis would lead to findings on the socio-economic interactions that influence wetland rehabilitation.

4.3 Sampling Households for Interview

Household sampling for interviews was done in wards that have wetland rehabilitation projects. Interviews were conducted with riparian communities and non-riparian communities. Separate interview schedules were prepared for riparian communities and non-riparian communities. The majority of riparian communities are within a 10km radius, non-riparian communities are generally beyond the 10km radius. This is how the interviewees were classified in the demarcated area around each wetland rehabilitation project. Households were selected during fieldwork using base maps provided by the Surveyor General's office. A total of 15 438 households were assigned numbers and a table of random digits was used to pick households for the interviews. The sample was determined using the formula after Cochran (1977):

$$n = \frac{(t)^2 * (s)^2}{(d)_2} \quad \text{.. Equation 5.}$$

Where: n= is the required sample size, t=confidence level at (1.96), s=standard deviation in population=15 000, and d= margin of error 5% (7*0.05). Using the sample size determination formula shown in equation 5, the sample size was calculated thus:

$$n = \frac{(1.96)^2(10000)^2}{(7*0.05)_2}$$

n= 80 households

Table 4.1 provides information on sample size of each district and distribution in each of the seven districts in South-Eastern Zimbabwe where the research was conducted. From equation 5, it can be noted that a total of 80 heads households were interviewed. Almost a similar figure of 79 non-riparian community members was sampled for interview purposes giving a total of 159 interviewees. Within each household the head of the family, that is, husband or wife were interviewed because they are the decision makers on actions that impact on wetlands. However in instances of child headed or guardian headed families, the eldest family head was selected as the interviewee.

Table 4.1: Sampling of interviewees

Nature of Stratified Sampling Use			
Category of Respondent	Total Number	Percentage	Criteria Specification of Respondent
Riparian Community-Strata 1	80	50.3%	Riparian means an area located on the bank of a natural watercourse (such as a river) or wetlands in ecological terms
Non-Riparian CommunitiesStrata 2	79	49.7%	Non-Riparian means an area located far away from the bank of a natural watercourse (such as a river) wetlands in ecological terms
Total	159	100%	Sample Population

Interview data were processed and analysed using Microsoft Excel to reveal trends and patterns. The responses were pre-coded. Coding entailed the assignment of a corresponding numerical value to each answer on the interview guide. Every response to the close-ended questions was assigned to a proper category. Each listed response had to fit into only one of the categories. Prior to the capture of data in the computer using Excel, all the 159 interview schedules were checked for inconsistencies in data filling and completeness. Data capture was done by going through each interview guide and inserting each response into the assigned code. Data were analysed using percentages and frequencies and the results presented using pie charts, bar and line graphs.

4.4 Results and Discussion

4.4.1 Riparian communities' social influence on wetland rehabilitation.

Some of the social factors presented in this section that influence rehabilitation projects include age, marital status, gender, family size, levels of education and social taboos. A significant number of the interviewees, constituting 57.5% of the participants, were household heads. A household head means a person fending for the household and responsible for decision-making. For household heads the exclusion and inclusion criteria was who was responsible for decision making at household level. It was assumed that every household head had some knowledge about farming practices and the size of the wetland, farm, livestock and that of their households. The household heads are key interviewees because their activities and decisions impact significantly on wetlands through on-site and off-site activities including cultivation and deforestation. Moreover, they are key stockholders on wetland rehabilitation who need to be consulted as part of public participation approach. The other group of interviewees, which followed household heads, consisted of older children and these constituted 31% of the total participants. This was for child headed households. The household heads were the most preferred respondent because they make critical decisions for the households. This ultimately has an impact on the success of wetland rehabilitation projects initiated in the communities because of their involvement as participants. However, relatives (9%) or caretakers or maids (2, 5%) were interviewed in cases where household heads were not available.

A majority of the interviewees (26%) were 56 years and above, a result which concurs with findings of a study by Marambanyika, et al. (2012) that observed the average age of the peasant farmers areas as 57 years. Older people perform much better in rehabilitation participation and activities than younger age groups. Due to selective migration, more males than females move to urban areas in search of jobs. Children, women and old people remain in the rural areas due to labour migration into towns and cities. The 26-35 age-group, constituting 7, 5%, provided valuable data on the wetland. The 36-45 group

(24%) and 46-55 age categories (22, 5%) also gave their input during the survey. The other interviewees were those below 25 years (10%). The age factor influence wetland use and management considering issues of rural depopulation, labour shortage and aging of the rural population. Responses derived from the older generation >56 years were also useful in tapping into the memory book based on indigenous knowledge systems, for these also contribute to wetland rehabilitation.

The interview guide also contained marital status as one of the demographic characteristics. The interviews showed that a relatively higher proportion of the interviewees (56%) were married individuals. This was followed by widows (23%), divorcees constituting 11% and the single individuals (10%). Marital status affects wetland use and management because married community members tend to fend for their families and in the process tend to degrade natural resources such as soils, water, wetlands and woodlands as they spend more time on the land. However married riparian community members also play an important role in wetland rehabilitation through provision of labour during project implementation. It is for this reason that their views and preferences on wetland rehabilitation had to be taken on board.

In addition, the size of households, just as marital status, is an important aspect in wetland management and wetland rehabilitation. The greatest number of interviewees (50%) indicated that the household sizes range from 5–6 members. For rural communities this is not surprising considering that the national average family size is 4.6 (GoZ, 2012). Mapanda and Mavengahama (2013), in a similar study concurred with these findings by stating that average household size in the Masvingo Province was 5 people. Nevertheless, households with 3–4 members constitute 21%, while those with 7 and 8 members constituted 16%, and the households with more than 8 occupants constituted 4%. There are a few instances where households have less than 2 (9%). The significance of household size is that it influences intensification of wetland utilisation such as over-cultivation and provision of labour which are critical parameters in wetland modelling. It also determines the level of household participation in wetland rehabilitation activities, like piling loose rock units in wetland gullies, organised at village level. Therefore, the influence of household size on wetland utilisation intensity and provision of labour during implementation of rehabilitation initiatives by riparian communities are critical variables in designing model of wetland rehabilitation. Figure 4.1 shows the household size results.

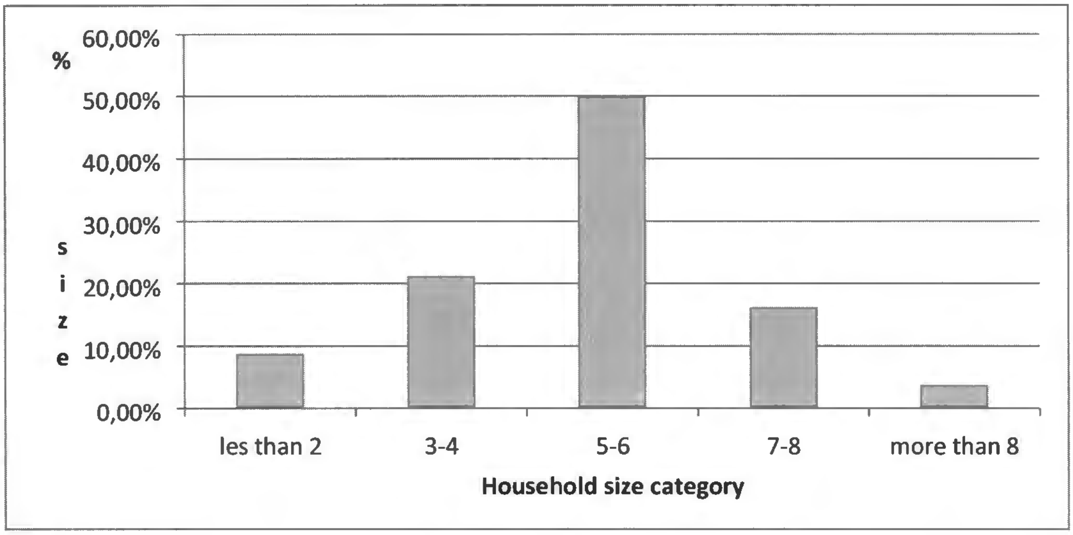


Figure 4.1: Household size

The interviewees' level of education is important with regard to wetland use and rehabilitation. Data from the interviews shows that most of the interviewees (55%) have attained secondary qualification, which is much higher than interviewees with primary school education constituting 14%. Diploma holders constitute 20% while graduate and post-graduate interviewees constitute 10% and 1% respectively. These figures are not surprising considering that Zimbabwe has one of the highest literacy rates in Africa. The educated members of the riparian communities such as teachers, agricultural extension workers and nurses have a better understanding of environmental issues and help raise awareness in wetland management. Furthermore, this high level of literacy should provide a strong driving force for the environmentalism in general and wetland rehabilitation practices in particular.

A majority of the homesteads (39%) are between distances of 100–200m from the wetland while 21% stay 201–300m from a wetland. The distance range of 301–400m had a 9%, with that of more than 400m having 11% and up to 20% of the household home-steads being located less than 100m from the wetland, which is a threat not only to the wetland itself but the rehabilitation efforts that can be implemented due to lack of a buffering zone.

A buffer zone is critical for re-instating the wetland structure and functions. Wetland buffer zones are required to afford wetland areas adequate protection from adjacent land uses that may adversely affect them. Proximity to wetlands has a greater influence on level of involvement and participation because the feeling of attachment is greater for riparian communities than non-riparian communities.

Most of the homesteads (34%) are within a distance of less than 50m from the cultivated land. Cultivation is done close to the homestead to maximise on the ash produce from the fireplace considering that a number of people are using firewood as a source of energy. Ash is important in that it acts as a fertilizer that improves soil fertility. In addition, 24% of the homesteads are 50-99 m from the cultivated land (fields), while 16% are within a distance of 100-149 m, with a small percentage (11%) of homesteads stationed between 150 m and 199 m, and 15% of the homesteads are on a distance of more than 200 m from the fields. Although wetlands are common property resources in Zimbabwe, proximity to wetlands creates a sense of natural ownership and entitlement by riparian communities and by extension use of the wetland. The reasons for staying close to wetlands could be water availability, soil fertility and in some extreme situations historical accident. However proximity to wetlands presents risks to riparian communities; including possibility of flooding, mosquitoes and malaria.

The interview also gathered data on distances between home steads and the nearest river. River water is important for activities that include cultivation. Furthermore, the unavailability of river water, due to the friction of distance exerts more pressure on wetlands. Friction of distance means that the greater the distance to the river the more costly (in terms of time and labour) it becomes to fetch or draw water. The results show that 26% of the interviewees live less than 1 km from the nearest river, while 41% of the interviewees travel for close to 2 km to access river water, with some 16% travelling for up to 3 km to reach a river, and 8% and 9% of the interviewees travelling for 4 km and 5 km, respectively, to access river water. The friction encountered from distances greater than 2 km while fetching river water has a critical impact on wetland utilisation. This is significant, considering that earlier results have shown that a majority of the homesteads (39%) are within the 100–200 m distances from the wetland.

A majority of the interviewees, 43%, get drinking water within a distance of less than 200 m. Farai *et al.* (2012) discovered that the average distance to the water source is about 90 metres. A higher number of interviewees constituting 38% walk a distance of 201–400 m to fetch water using wheelbarrows or by carrying 20 litre buckets on their heads. The sample also shows that 11% of the population travel a distance of 401–600 m, while 5% of the population travel a distance of 601–800 m, and 3% travel a distance of more than 800 m. These results support the finding by Chifamba (2013) that reveals that in some cases people carry water in tins on a wheelbarrow for more than 800 m. However, these findings are applicable during a normal rain season, for communities travel even longer distances after the drying up of some wells and boreholes during drought-stricken years. The depletion of underground resources affects households and deprives wetlands of a vital recharge base flow and ultimately, influences ecological sustainability and the feasibility of rehabilitation projects.

The interviews also gathered data on the sources of water for livestock. The data shows that boreholes constituting 37.5% were the largest, with water wells dug close to the homesteads constituting 22.5%, river water representing 20%, and springs 5%. Some of the boreholes, wells and springs are close to wetlands. Thus, the combined withdrawal of water from a borehole, water well, and spring, which is a total of 55% results in excessive water abstraction and exhaustion. This poses a negative impact to underground storage and subsequent recharge of wetland resources. The negative impact is in the sense that although most interviewees do not directly drive livestock to wetlands for water alone but pastures as well, boreholes are well replenished by wetlands. The surface storage from dams and rivers is, however, 35%. Statistics in Figure 4.2 show the source of water for livestock.

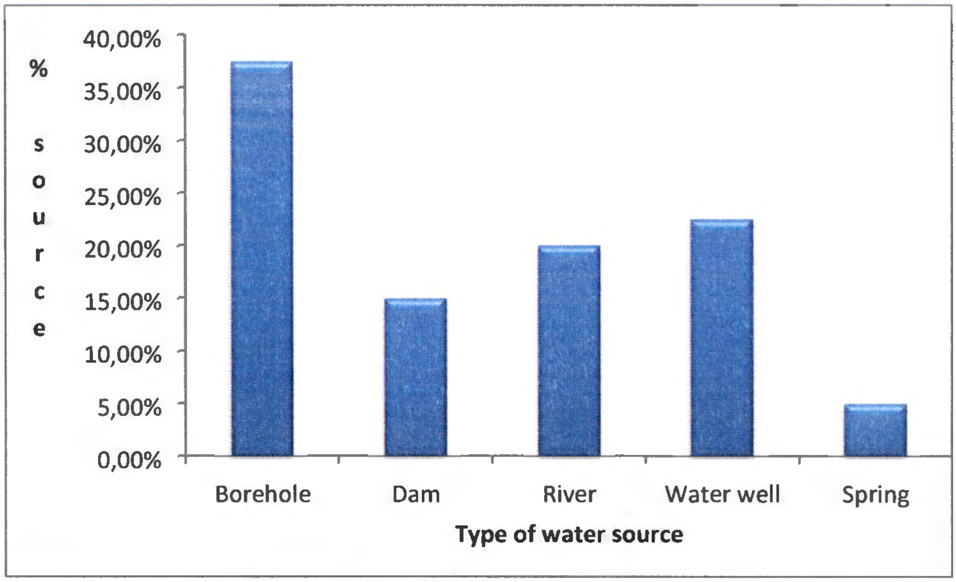


Figure 4.2: Source of water for livestock

Traditional customary law and statutory Acts are implemented to protect wetlands. Law enforcers implement the law. An overview of the rehabilitation projects discussed in chapter 5 shows that 40% of the rehabilitation projects have less than one law enforcer. This is usually the ―*headman's sergeant*‖ literally translated to mean ―*headman's police*‖. Moreover, 30% of the project sites have 2–4 wetland law enforcers, while 10% of the communities have between 5 and 6 wetland law enforcers, 6% have 7–8 and 5% have more than 8.

The interview findings reveal a number of taboos relating to human-wetland interactions. One of the beliefs is that intermittent fires in September and October signal the onset of the rain season. Indigenous Knowledge Systems passed through generations have enlightened communities about the fact that water in wetlands originates from mountains. This knowledge confirms a scientifically-held view from hydrology that water seeps by the processes of infiltration and percolation from uplands.

It reaches an impervious clay layer or impermeable rock stratum and moves through flow downslope underground and emerges in wetlands in the form of springs. The interviewed villagers also hold the belief that the application of manure dries the wetland.

Furthermore, the Bikita District's interviewees are of the belief that the Maturure and Tagwirei wetlands are guarded by a big snake (water berry snake); and those from the Zaka District hold the view that no one should ever cut trees around the Zishiri wetland. Some of these cultural norms can be used to reinforce principles of wetland rehabilitation to ensure their sustainability.

The interviewees also pointed out that menstruating woman are not allowed near wetland wells. Such a belief is meant to address issues relating to water pollution and thus ensure water quality. The cutting of fruit trees like *Parimari curatellifonia* is not allowed. Although this is meant to enhance food security, inadvertently vegetation diversity is widened. Furthermore, community by-laws do not allow the use of dirty clay pots with soot in wetland. Studies by Risiro *et al.* (2013) reinforce these indigenous knowledge systems, with people, for example, not allowed to kill aquatic animals such as frogs.

4.4.2 Economic influences on wetland rehabilitation

One of the commonly held debates in environmental science and policy is the view that poverty is a major cause of pollution. People's livelihoods are heavily reliant on the environment for resources and survival. Interviewees were requested to identify sources of income and they stated activities such as craftwork, cultivation, farming and informal work. A closer examination of these activities reveals that they are rooted within the primary sector of production such as agriculture and forestry. These are based on the environment in general and wetlands in particular. Most smallholder farming activities are done in the wetlands with rich alluvial silt-clay soils and reliable moisture and water supplies. Hence, poverty driven wetland activities ought to be factored into the design of wetland rehabilitation projects.

Other alternatives that alleviate poverty and reduce reliance on wetlands include informal trade at growth points such as Mpandawana, Ndanga and Nyika. Other interviewees rely on remittances from outside South-eastern Zimbabwe such as Harare, Bulawayo and other countries such as South Africa. Some of the interviewees also reported that they engage in informal trade such as the selling of *Uapaca kirkiana* and firewood at growth points. Although interviewees rely on these activities for survival, the *per capita* income is very low in the study area.

The interview schedule requested interviewees to indicate the amount of maize output. Maize was selected because it is the staple food crop in Zimbabwe. Most of the famers do not harvest much from their fields, the lowest figure in tonnes is 0.4 tonnes and the highest is 10 tonnes. Upland crop failure is responsible for this and this results in encroachment into marginal but fragile wetland patches. Most of the farmers yield close to 1.2 tonnes and the most successful get up to 10 tonnes of total maize harvest.

The interview results indicate that the mean financial income was $400, but some farmers have a paltry $100, and a few get $2 000. The amounts of financial gains from farming are also related to the type of crops that are grown, an issue that is discussed in the next section. Taruvinga (2009) in a study on economic wetland utilisation demonstrates that even some wetland cultivators are deriving low incomes from wetland production which has an influence on both wetland degradation and rehabilitation.

Most of the high water demand crops that are grown in wetlands include sugar cane, rice and banana. Other low water demand crops grown in the wetlands include maize, sweet potatoes, sugar beans and cow peas. The intensity of cropping in wetlands is also determined by the size of crop fields owned by the farmers. The greatest proportion of farms per household (44%) has land that is less than 4 ha, while households with a farm ranging from 5–6 ha constitute 38.5%, 10% have 7–8 ha farm size, least percentage of 4% have farms 9–10 ha, and those with more than 10 ha farm size constitute 4%. Resource insufficiency has translated into more hectares of wetland being put into agriculture. The size of farms influences the tendencies towards cultivation of marginal lands such as wetlands to increase agricultural production. The communal land tenure system and size of farms lead to wetland encroachment. Therefore, wetland rehabilitation should not deal with the symptoms of wetland degradation alone but the root causative factors as well. This helps to improve poor performance of rehabilitation projects in order to attain ecological sustainability.

Interviewees were also requested to indicate their general incomes. About 40% of these reported mean *per capita* income of less than \$100. The mean *per capita* income for those ranging from \$201 to \$300 is 23.5%, with those on \$301 to \$400 at 8%, while that above \$400 is 1% (Figure 4.3). These statistics have bearing on wetland use and rehabilitation, because the demand for natural resources in rural landscapes is strongly linked to household income (Shackleton and Shackleton, 2006). Even the results of this analysis show that the users of wetlands are generally poor and this drives wetland utilisation. For example, Lannas and Turpie (2010) valued the benefits that communities around Letseng-la-Letsie wetland (rural Lesotho) where a large proportion of the community realised a small proportion of their income from the wetland, and Mfuleni wetland (Cape Town, South Africa) where a small proportion of the community gained the a large proportion of their income from the wetland. These socio-economic circumstances need to be factored in when designing a sustainable wetland rehabilitation project.

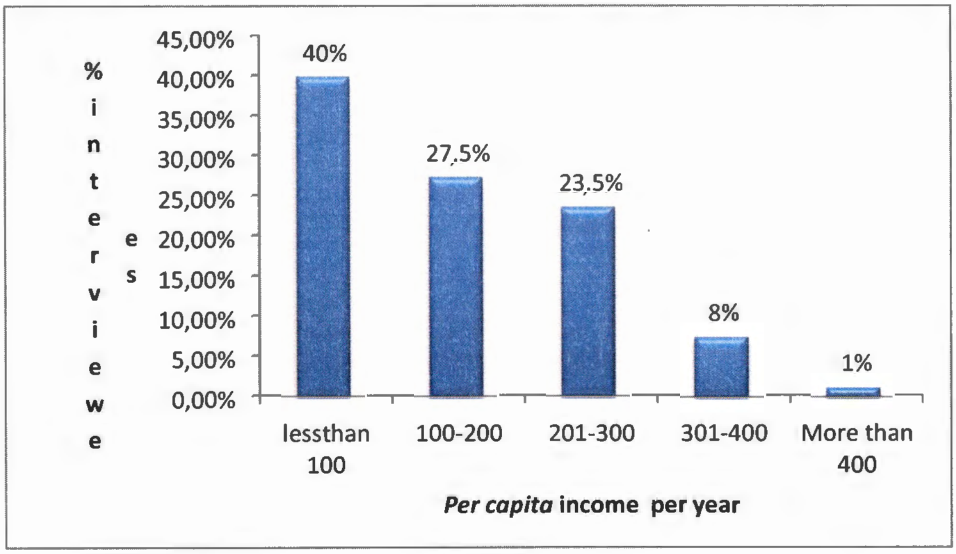


Figure 4.3: Mean per capita income

The interview also gathered data on size of farm plots used for horticultural activities like production of vegetables, fruit. A number of households (42.5%) have garden portions of <0.5 ha (Figure 4.4). The size of the wetland-based farm plots per household is proportionally too big considering that most of the wetlands in the study area are small.

This leaves a limited portion for wetland conservation. The wholesale utilisation of wetlands without conservation is a threat to their biotic integrity. Fencing becomes a necessary input for wetland modelling to protect vulnerable resources.

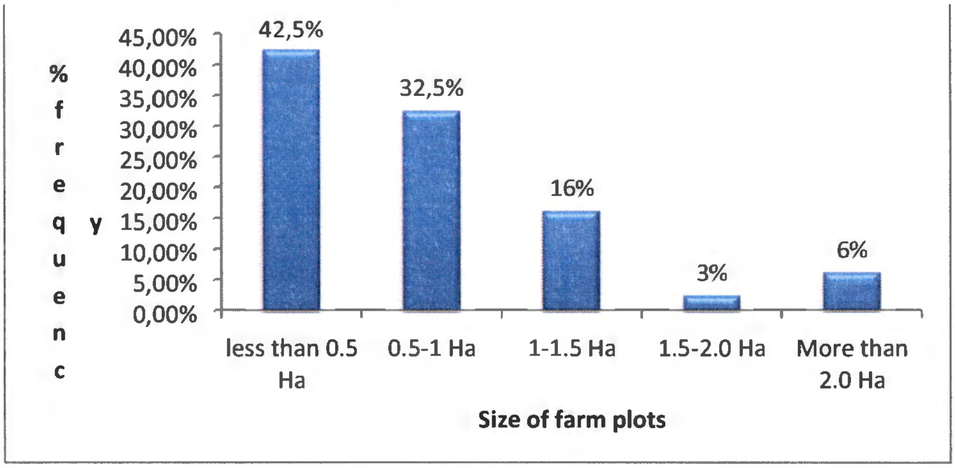


Figure 4.4: Size of garden portion per household (Ha)

At least 44% of households have a tropical livestock unit ranging from 11–20. There are a few households (23%) with less than 10 livestock units, while 29% of the households have livestock numbers ranging from 21 to 40, 4% have 31–40 and 1% have more than 40. Non-mechanised cultivation is widely applied and as such ox-drawn ploughs are used by 67% of the households. A further, 13% use hand hoes, while another 13% use ox-drawn hand hoes while manual methods are used by 1% of the homesteads. The use of appropriate technology for wetlands like the hoes and ox-drawn plough result in slow pace of wetland use. Appropriate technology can be defined as simple technology that takes adequate consideration of social, economic and environmental ramifications during its usage. However, inappropriate technologies for the wetland, like tractor-drawn plough have the negative impact of increasing the pace of wetland utilisation. Nevertheless, appropriate technology is important in wetland rehabilitation.

Most fenced wetlands do not provide for livestock watering facilities. A total of 47.5% of the interviewees indicated that cattle water troughs are not available nearby. These results also concur with observations conducted during the fieldwork, that only 25% of the fenced wetlands have watering facilities. Few sites, 12.5 %, have more than four watering facilities. Domestic, livestock and ecological water needs are often not adequately addressed in management measures (Aglanu, 2014). Thus, fencing wetlands on one hand without provision of watering troughs on the other hand presents challenges for wetland rehabilitation. Fencing wetlands without provision of alternative water sources to riparian communities leads to resentment, sabotage and the vandalisation of fences.

A number of alternative sources of income are available to the interviewees. The findings reveal that 24% rely on craftwork involving weaving bed mats using reeds and sedges. Up to 31% of the riparian communities rely on the informal sector or trading involving the selling of a variety of vegetables, fruits, wares at growth points and service centres. Access to cash is a serious challenge in rural areas, therefore informal work accounts for 17.5% of the interviewees' income (Figure 4.5). Informal working involves hustling by doing piece jobs and part-time jobs. Remittances from relatives working in urban centres and diaspora cash inflows contribute 17.5% as an alternative to wetland utilisation. Other sources of livelihood including honey harvesting, hunting, and the selling of *Uapaca kirkiana* help community members to eke out a living out of natural resources. According to Chifamba (2013), balancing conflicting interests between environmental protection and development are most acute in dynamic and complex ecosystems, such as wetlands. Wetland rehabilitation should also take into account the socio-economic circumstances of surrounding communities. Addressing socio-economic circumstances of the communities creates alternatives to wetland utilisation and avoids vandalisation of rehabilitation projects as people try to eke out a living. This helps to reestablish ecological sustainability.

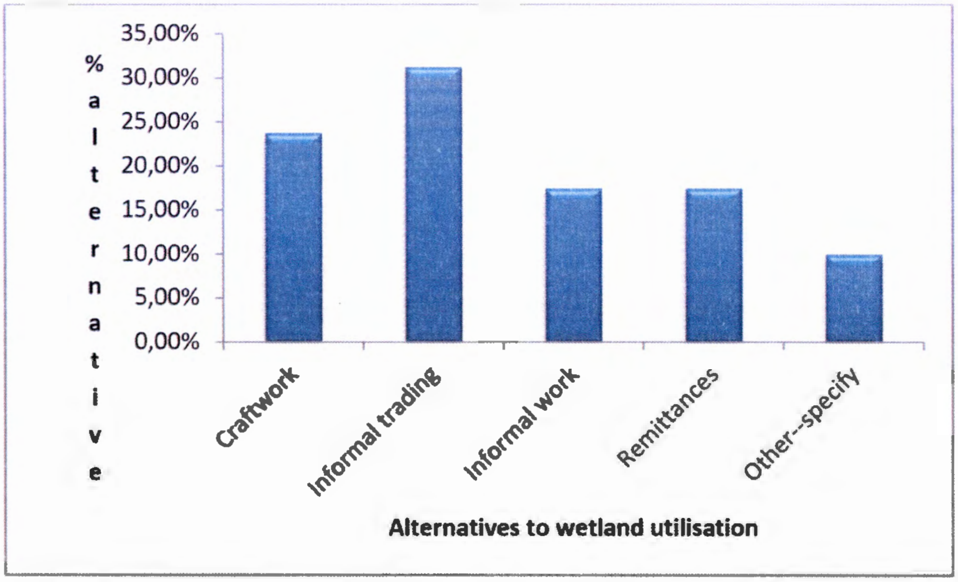


Figure 4.5: Alternative sources of income

The least cropping intensity for most wetlands underutilisation is characterised by cultivating one crop (15%) and an intermediate cropping intensity have two crops representing 32.5%. A similar percentage of 32.5% of the riparian communities grow three crops on the wetland. The cropping intensity of four and more than five crops is 16% and 4% respectively. Multi-cropping is actually more recommended in conservation agriculture or agro ecology. The number of crops planted on wetlands influences the extent of wetland deterioration and remedial action that needs to be implemented in any rehabilitation process. Therefore this requires corrective measures such as organic manuring which should be recommended in rehabilitation modelling.

The interviewees were asked to state their timing of burning crop residue in wetlands. The interview results also reveal that only 21% of the interviewees do not burn crop residue in wetlands at all. About 46% of the interviewees stated that they burn crop residue from previous harvests before October (onset of rainy season), while some stated that they burn in September. Wetland burning in August, that is two months before the onset of the rainy season was 21%. Burning wetlands at three and four months before onset of the rainy season was 9% and 3% respectively. Wetland burning is a common practice among rural farmers through a practice called —burning crop residuell. The aim is to reduce crop residue by clearing the land in preparation for the next cropping season. It also helps to re-fertilise soil with potash. The practice has been out-lawed by the EMA but continues unabated. The timing of burning crop residue is, however, critical to allow for accumulation of organic matter.

4.4.3 Hydro-ecological influences

The results reveal that most of the wetlands fall into the un-channelled valley bottom headwater category. These are the dambo wetland type and a majority of them are largely located in the communal lands and only one is located in commercial farming areas. Most of the wetland users (54%) indicated that the wetlands they use are permanent, whereas 41% of the interviewees stated that the wetlands are seasonal in nature. Episodic wetlands that release water during excessive rain events, as after *cyclone Eline* in the year 2000, constitute 4%. Shallow water wetlands, which are close to water bodies, with the best example being the Silveira Mission dam, represent 1%.

Although a majority of the wetlands sampled are permanent, it must be pointed out that they are mostly deteriorating by drying out during part of the year and increasingly becoming seasonal. A study by Chikodzi *et al.* (2012) concurs that the Mutubuki wetland used to be perennial and provided a reliable source of water for the community until 2007 when it dried up. The wetland now supplies water during the rainy season and a few months into the dry season before it dries up again. Seasonal wetlands are particularly fragile and more complex to rehabilitate because their recovery is slow and hampered by rainfall variability and other anthropogenic pressures in the area in the recent past. Therefore, most of the wetlands need rehabilitation so that they do not degenerate further.

The duration of discharge outflow from the wetland in 37.5% of the wetland rehabilitation projects is more than 8 months. The results also indicate that 17.5% of the projects have discharge flows ranging from 7-8 months, with 25% of the wetlands having outflows for 5-6 months, 14% discharge water contributing to surface overflow for 3-4 months, and 6% having flow for less than 2 months. The duration of water outflow from the wetlands is important for downstream users who rely on the wetland for water supplies for domestic and agriculture use. The duration of discharge outflow is important in designing wetland rehabilitation models that accommodate socio-economic needs of communities in which they are implemented.

Using historical memory, interviewees were asked to identify the duration of wetland hydro period. Hydro period in this study refers to the period of time during which soils, water bodies and sites are wet. Interview findings complement results of observation discussed in chapter 5 as part of the data triangulation process. Wetland hydro period is critical for vegetation growth and biodiversity in the wetlands. There were variations in the number of months, ranging from more than 8 months to less than 2 months, when the sampled wetlands are at field capacity (Figure 4.6). The duration of wetland hydro period is important in sustaining wetland plants and thus upholding their integrity. Chikodzi *et al.* (2012) and Chikodzi and Mutowo (2014) observed that Mutubuki wetland in Gutu district only flows for a few months after the rain season after which it dries up.

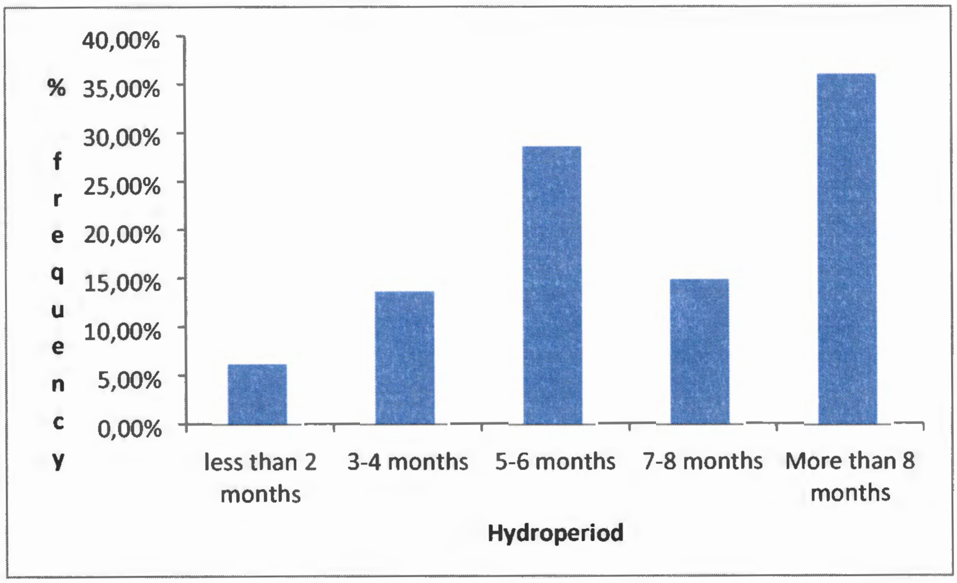


Figure 4.6: Wetland hydro period

Wetland rehabilitation projects where field observations were conducted are Chibvongodze, Kofoto, Mushangwe, Mutsambiwa, Makuvaza, Makanda, Mutubuki, Mukozhora, Zvemudzo, Sedeya-Mangisai, Chengwe, Ndarama, Maturure, Silveira

Mission, Tagwireyi, Machingambi, Mupunga, Zishiri, Masinire, Magwenzi, Samson and Manjinji Pan. Different rehabilitation interventions are implemented in these projects and are discussed in chapter 5. Rehabilitation projects require financial support. Most of the projects (39%) are funded by the EMA, while the community is responsible for funding 30% of the projects. The Rural District Council (RDC) through the District Development Fund (DDF) finances 16% of the projects and Non-Governmental Organisations (NGOs) are responsible for 9% of the initiatives whilst Government Agencies such as AREX fund 6% of the projects. However, the institutions responsible for funding rehabilitation projects are poorly resourced. Therefore, financial support should be improved in order to increase their sustainability.

Institutions responsible for managing rehabilitation projects are critical for their success. The EMA is responsible for managing 35% of the projects. This is followed by the communities which sustain 32.5 % of the projects, the Rural District Councils monitor 15%, NGOs manage 7.5% of the wetland rehabilitation projects and government agencies are responsible for 10% of the projects. Strong and powerful institutions are also needed in most countries to coordinate and effectively carry out the planning, implementation and monitoring of catchment management programmes (Aglanu, 2014).

The hydrological objectives involve installation of weirs to reinstate wetland wetness. A majority of the rehabilitation objectives are ecological (54%). About 12% of the rehabilitation objectives driving wetland repair are hydrological while those targeting livelihoods like food security constitute 24%. The objectives aiming at job creation account for 2.5% and the ones aimed at addressing cultural issues constitute 7.5%. In wetland rehabilitation modelling, goals that are hydrological need to be prioritised since wetland wetness is critical in achieving ecological integrity and sustainability.

Projects from the study area where motorised pumps have been installed represent 31% whereas 69% of the riparian communities do not use motorised pumps. The use of motorised pumps is a serious problem in wetlands since it contributes to the depletion of underground water leading to the drying up of the wetlands. For example, the excessive water abstraction at the Magwenzi wetland means that it takes an hour to fill a 20-litre bucket at Chibi Mission (Chapungu et al., 2013). However, the construction of a weir helps to re-establish and reinstate the wetness of the ecosystem. For example, the Kofoto wetland close to Gutu Mission has motorised pumps, but has been able to withstand excessive water abstraction because of numerous weirs upslope. In instances where motorised pumps are in use without weirs upslope, as is the case at Magwenzi, the drying of wetlands due to a reduced water table and exhaustion of water resource become a reality. Empirical evidence demonstrates that the depletion of underground water may shorten the period of field capacity of water and cause the drying of wetlands/springs. This can be made worse by increased populations as noted at the Chibi and Gutu Missions.

A majority of the interviewees agree that their memory book based knowledge informs them that wetland loss has occurred. About 84% of the interviewees confirmed that they had indeed witnessed wetland loss. A small proportion of the interviewees comprising 16% pointed out that they had not experienced wetland loss. Interviewees were requested to suggest reasons for wetland loss. The interview interviewees attributed the loss of wetland size to natural droughts. Other explanations given include the lowering of the water table because of overgrazing and activities such as wetland smallholder cultivation.

Riparian communities from Maturure Village in Bikita District appreciated the EMA efforts in protecting the wetland through the Maturure Wetland Protection Committee, which initiated rehabilitation measures. The committee has designated Maturure wetland a restricted area and cutting of trees within the wetlands buffer zones is not permitted. People's fear of taboos has resulted, in the existence of permanent seasonal water flows as people do not want to be seen violating their cultural norms. Thus, such a wetland service is likely to be realised sustainably going into the future.

Some questions on the interview guide sought to establish alternatives to wetland cultivation (Figure 4.7). A large proportion of interviewees (57%) suggested that upland irrigation using small scale dams can be an alternative to wetland cultivation. Other interviewees (18%) suggested dependence on remittances as a substitute to wetland cultivation. The use of public works programmes as a substitute to wetland cultivation was suggested by 14% of the interviewees. Public works is an activity involving the community members providing labour for public services such as road rehabilitation by filling potholes and wetland rehabilitation by clearing alien species. The other methods pointed out by 4% of those interviewed are craftwork also suggested by 7% of the interviewees.

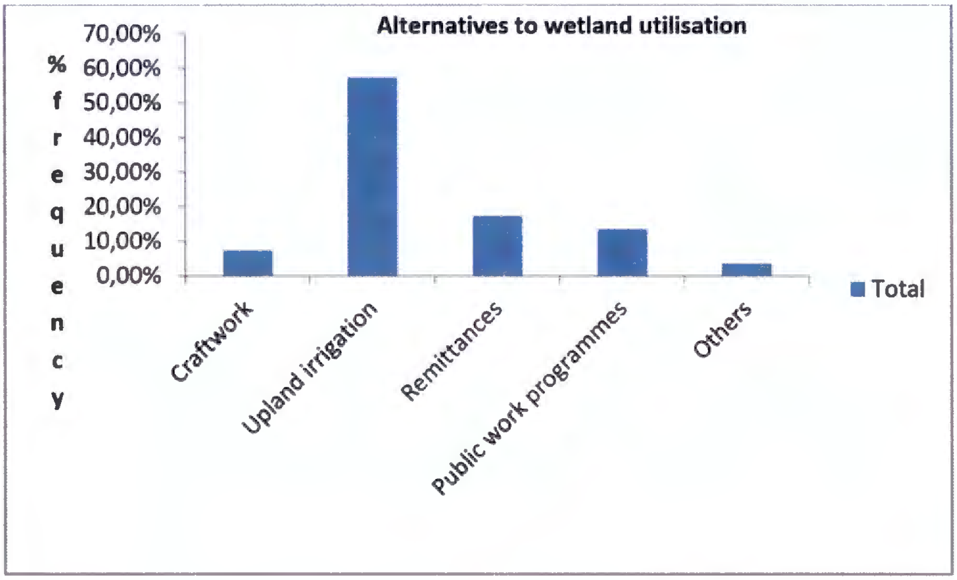


Figure 4.7. Alternatives to wetland utilisation

The researcher asked open-ended questions to riparian communities members to suggest solutions to problems of wetland degradation and loss. Interviewees suggested tree planting. The significance of afforestation is evident in the case of the Magwenzi wetland rehabilitation project, where afforestation has been facilitated by the Forestry Commission, with a cash injection from UNDP amounting to $32 000. Several techniques were suggested to prevent further wetland degradation and these include: gully reclamation, fencing, the clearing of *Lantana camara*, removal of gum trees from upland catchment areas and rolling out of environmental awareness campaigns in communities. These rehabilitative measures should be implemented together with payment for ecological services to yield high ecosystem goods and services. Payment for ecological service involves wetland users compensating for wetland use in cash, kind and or in labour. These are some of the variables that need to be factored into wetland rehabilitation modelling.

The level of preparedness to pay for ecological services is very high (60%) compared to a 40% who are not prepared. All wetland utilisation activities, including, cultivation, grazing and brick making should be expected to internalise the negative impacts of wetland production by paying for ecological services. The challenge here is to internalise the costs and benefits in such a way that all the stakeholders are part of a win-win scenario (Agnalu, 2014). This challenge is more acute in the study area. Riparian community members who use wetlands benefit from water, fertile soils, fish, reeds and other ecological goods and services need to pay for them using the user pays principle. Therefore, there is a need to move from a goodwill notion on wetland rehabilitation to a mandatory payment for ecological services on the basis of user pays principle in financing wetland rehabilitation projects.

A number of mechanisms were suggested with regard to the payment for ecological services. The suggested mechanisms include royalty from dams suggested by 28% of the interviewees the establishment of upland irrigation schemes (35%), public work programmes which have been suggested by (11%), food parcels were suggested by (5%) of the interviewees, while another 21% were for the idea of other mechanisms. Figure 4.8, displays these findings. Kaffashi *et al.* (2015) conclude in another study that the interviewees' socioeconomic variables, their income and employment have a direct and positive effect on the willingness to pay for ecological services.

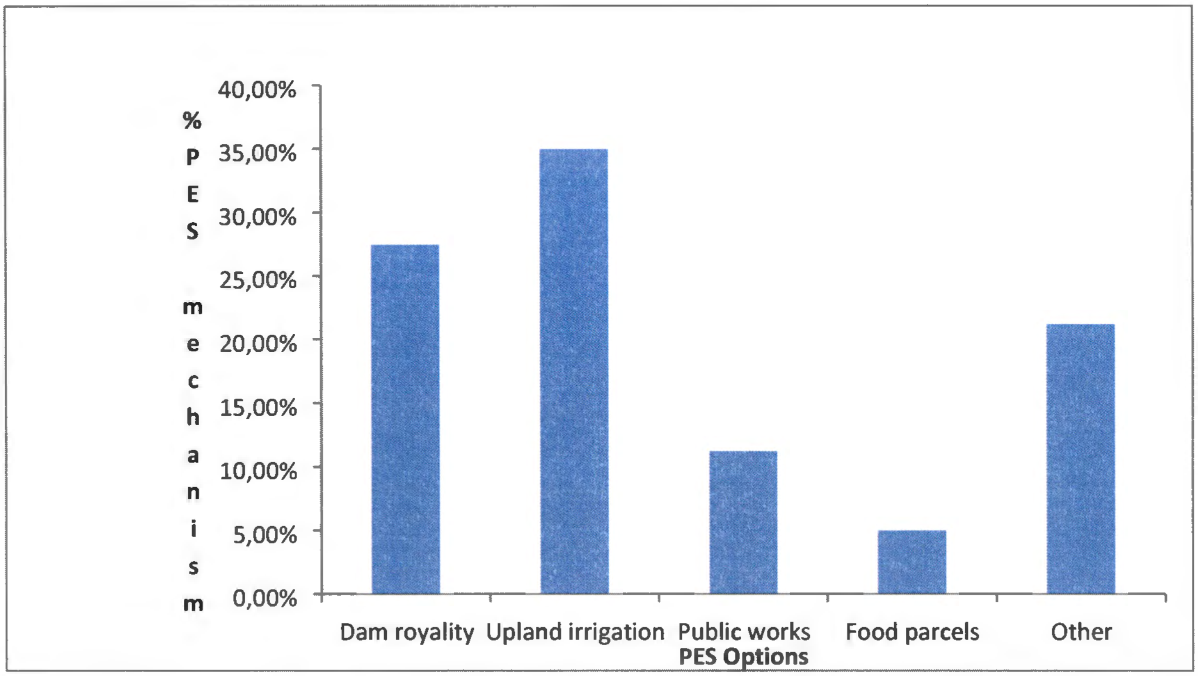


Figure 4.8: PES mechanisms

The interviewees who are totally against PES justified their position by citing factors including the scarcity of money and the unreliability of government programmes. Others indicated that should sources of income be available, the funds are abused and misappropriated by government officials or any implementing institutional body. Designing a wetland rehabilitation model requires that the riparian communities and users of wetlands play an active role in providing resources for intervention measures to be implemented.

4. 5 Non-riparian communities

4.5.1 Social influences of non-riparian communities

The realisation of the critical role of non-riparian communities on wetland rehabilitation is premised on the understanding that planned projects should start on a catchment scale and be cascaded down to specific sites. This also allows for a multi-stakeholder and multi-thronged approach in initiating projects for success and feasibility to be attained. This section, therefore, focuses on non-riparian communities which who are in the catchment area and indirectly influence rehabilitation to a certain extent. Dini (2008) advises that best international practices require wetland rehabilitation planning at the catchment level. At this level, both riparian and non-riparian community members matter in influencing wetland degradation and wetland rehabilitation models. The findings from the interview survey conducted with non-riparian communities are discussed below.

The results reveal that most non-riparian community members were male household heads; constituting 48%, while elderly children numbering up to 30%. In addition, if household heads were not available relatives were asked survey questions and constituted 14%, while the other interviewees such as domestic workers made up 8% of the interviewees. All these interviewees are aware of the factors responsible for wetland degradation and influences on wetland rehabilitation in the study area. An understanding of the socioeconomic value of wetlands is crucial when deciding on conservation and development priorities related to land use (Lannas and Turpie, 2009). Hence, that data provided by household heads is important in as much as the age of the interviewees, which is the focus of the next paragraph.

Information on the age of interviewees who are non-riparian is presented. A few interviewees constituting 13% were of the 16-25 age group, 12% of the interviewees who were youthful job seekers and economically active falling into the 26-35, and 20% falling in the 36-45 age group, 28% and the majority constituting the interviewees of age 46-55 group, whilst those above 56 years represented 27%. The age of interviewees is important in that it determines the length of residence of the interviewee in the study area and hence comprehension and knowledge of interactions that influence wetland rehabilitation modelling.

The educational level of the interviewees was also considered. A sizeable proportion amounting to 19% went up to primary school level, just as findings reveal that 50% of the non-riparian communities members have attained secondary school level, and 16% have acquired diplomas at tertiary education level. The sample reveals that 9% of the interviewees have acquired university degrees whilst a small fraction of 6% is in possession of a post-graduate qualification. The graph in Figure 4.9 presents the educational levels of the interviewees.

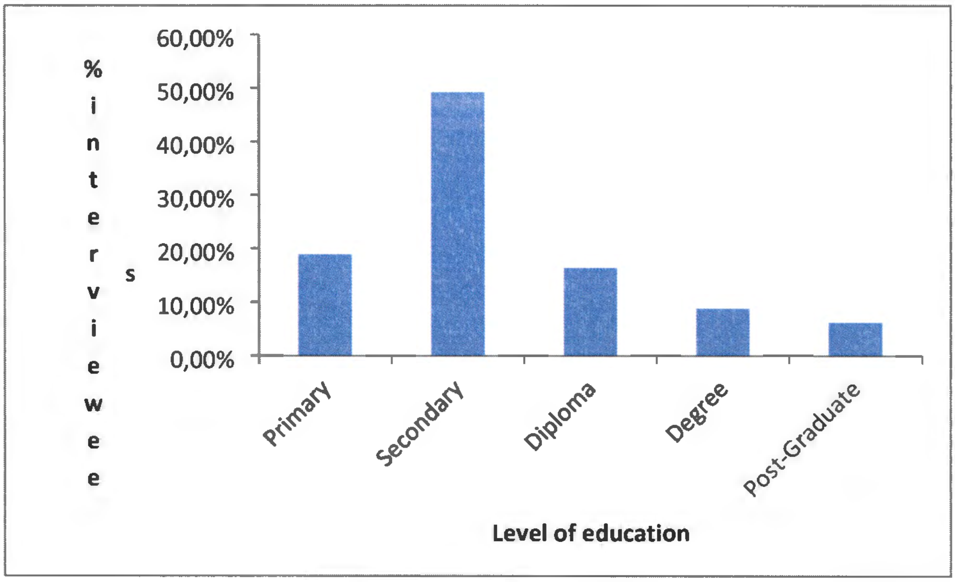


Figure 4.9: Educational level of non-riparian communities

The level of education of non-riparian community members has an influence on attitudes towards wetland rehabilitation. It should be noted, however, that an interview survey research by Kaffashi *et al.* (2015) shows that education has a positive and direct relationship with attitude factors. These in turn indirectly affect the willingness to pay and/or participate in wetland rehabilitation efforts. The subsequent section focuses on marital status of interviewees.

Among other demographic characteristics in the interview guide meant for non-riparian community, was the data on marital status whose results are shown in Figure 4.10. The greatest proportion of the interviewees, 56%, are married, while the single constitute 18%, the separated or divorced 15%, and a small percentage of 11% are widowed. The fact that the majority are married is significant, especially when considering that more mature interviewees, such as married couples, usually play a pivotal role in taking up communities environmental responsibilities. Other social factors influencing wetland rehabilitation are the attention of the subsequent paragraphs.

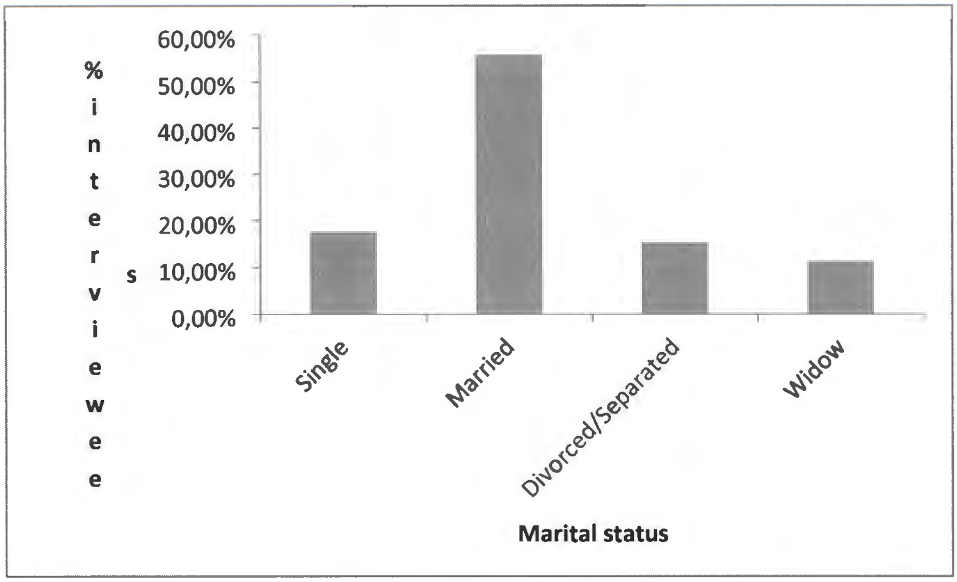


Figure 4.10. Marital status of the non-riparian communities

The study also gathered data on how far the non-riparian communities are situated in relation to wetland rehabilitation project sites. Table 4.2 captures the distances to the nearest wetland. At least 19% of the non-riparian communities are less than a kilometre from the wetland, with (27%) falling within the 2–3 kilometre range from the wetland. A further 19% of the interviewees are situated 3–3.99 km from the nearest wetland and 16% are more than 4 km away. The distance to wetlands has a huge bearing on ecological sustainability and project success. Therefore in wetland rehabilitation modelling adoption of an integrated watershed approach that considers the friction of distance in both wetland degradation and rehabilitation can help wetland recovery and attain wetland sustainability.

Rangeland management is critical in the rehabilitation of wetlands, especially from an ecosystem point of view. This is within the context of watershed management. It is important because it influences ecosystem health in which wetlands are situated. Interviewees were asked if their grazing areas have fenced sections or paddocks. About 10% agreed that grazing areas are fenced and a majority, constituting 90% said they were not. These results mirror the national picture where fencing is becoming a serious challenge not only on communal areas but commercial farming areas as well.

Table 4.2: Distance to the nearest wetland

Distance to the nearest wetland	Percentage
<1	19%
1-1.99 km	19%
2-2.99 km	27%
3-3.99 km	19%
>4 km	16%
Grand Total	100%

Madebwe and Madebwe (2005) argue that chiefs and headmen, with the help of the EMA, and the Ministry of Agriculture must designate properly managed paddocks in the newly resettled areas. This should be done in order to control livestock grazing density and reduce rangeland overgrazing. This should have a positive effect slowing the rate of land degradation in these areas but unfortunately full implementation is a problem.

Interviewees residing in areas characterised by lack of fenced grazing areas were asked to suggest the measures that can be put in place to manage rangelands. They suggested paddocking, use of fire guards and destocking. In addition, others came up with the idea of marking off boundaries for cultivation, rotational grazing and an adherence to carrying capacity. The construction of more dams for livestock watering and the production of lucerne grass came out as further and strong recommendations. Rotational grazing helps in reducing degradation in general and in reversing threats on the watershed that also influence wetland health on a broader scale. Nonetheless, it is clear that the role of non-riparian communities is important in ensuring project implementation and ecological sustainability. Non-riparian communities influence wetland modeling considering the part they play in processes like overgrazing and deforestation.

A number of rehabilitation intervention strategies were suggested during the interview. These include adherence to traditions and customs, fencing and use of informal village institutions. It was also pointed out that rehabilitation could be achieved through the optimal use of traditional authority, a reduction of stock size and limitation of extension of cultivation into rangeland. It must also be emphasised that they complement on-site rehabilitation efforts to recover wetland health. The introduction of sustainability criteria in the decision making process seeks to broaden the scope of the analysis beyond the wetland itself, temporally to incorporate interests of future generations and spatially to consider external effects on off-site stakeholders (Morardet *et al.* 2010).

Watering points for livestock within a wetland catchment are critical for wetland health and recovery. Figure 4.11 illustrates the watering points for livestock. Up to 43% of the non-riparian community members use borehole water, with 18% stating that they utilise dams, 10% use rivers, 23% rely on water drawn from wells, and the other 6% draw water from a spring. Although quantification of the number of dams, rivers and water wells and boreholes in the catchment was not part of the scope of this study, observations done indicate that there is a need to increase the number of water sources to reduce heavy reliance on fragile wetlands. The current distribution of watering points is a cause for concern and their presence helps in wetland rehabilitation. Ramsar (2010) asserts that the conservation of wetlands in least developed countries should be based on the principles of integrated water resources management (IWRM) since IWRM recognises the need to manage water resources at different scales, from local to basin, to ensure that local needs can be sustainably met. Sustainability is therefore critical to wetland rehabilitation and should therefore be incorporated in modelling efforts.

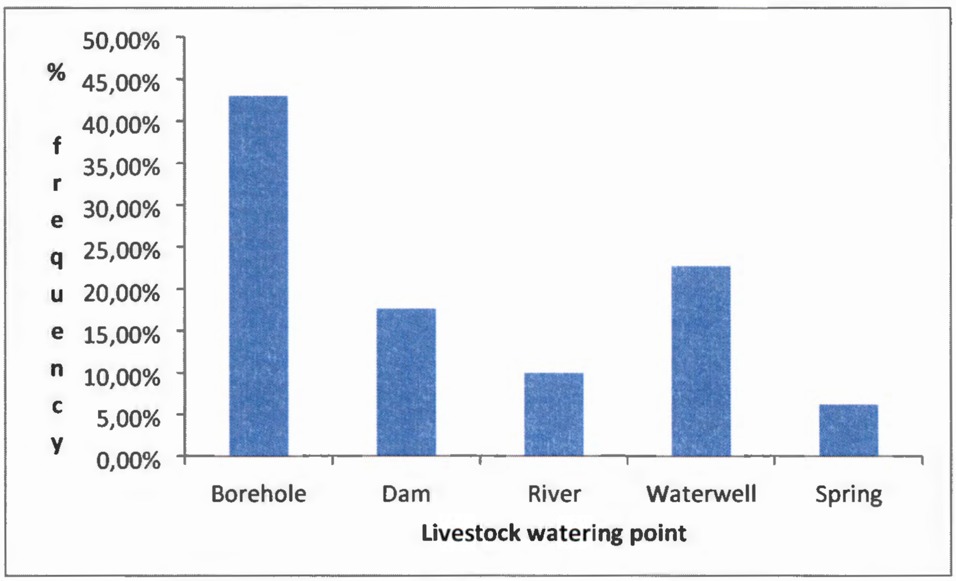


Figure 4.11: Watering points for livestock

Table 4.3 shows the study findings on the distance from grazing land to watering point. The distance between grazing areas and watering points is vital in making decisions on sources of water. The results reveal that 30% of the interviewees travel less than 1 km while 35% travel for close to 2 km to access water.

Table 4.3: Distance from grazing land to watering point

Distance from grazing land to watering point	Percentage
<1km	30%
1-1.99	35%
2-2.99	24%
3-3.99	8%
>4 km	3%
Grand Total	100 %

Furthermore, 24% of the interviewee‘s access water at a distance of 3 kilometres, while 8% travel a distance of four kilometres. The introduction of boreholes, dams and wells helps to reduce the distance to watering points. This in turn reduces dependence on wetlands thereby facilitating wetland enhancement and rehabilitation. These are key variables that address socio-economic needs but wetland sustainability as well as in wetland rehabilitation modelling.

4.5.2 Economic influences of non-riparian communities.

People‘s livelihoods are often heavily reliant on the environment for resources and survival. The interviewees were requested to identify sources of income and they highlighted activities that include craftwork, farming and informal work. These activities are primary sectors of production that rely on the environmental resources. Smallholder farming activities are done in the wetland catchment with unreliable water supplies. Poverty driven natural resource based activities becomes key in wetland rehabilitation modelling.

Table 4.4 shows the per capita income per family. The income is derived from such activities as farming, informal work, remittances from relatives in gainful employment and sale of natural resources such as firewood, reeds and crafts. Most of the people (45.5%) survive on less than $100 per month. This impact on wetland degradation and capacity to fund rehabilitation initiatives

Table 4.4: Income per capita

Income per capita	Percentage
less than 100	45.5%
100-200	29%
201-300	14%
301-400	2.5%
More than 400	9%
Grand Total	100%

The size of the land influences watershed-catchment management activities; subsequently, the wetlands because they are inextricably linked to livelihood issues that cannot be detached from wetland activities. The challenge on wetland rehabilitation is therefore to increase small scale irrigation projects which serve as substitutes to wetland cultivation and thereby counter the conversion of rehabilitated wetland to farming. Diversification ensures flexibility in resources and income generation. This is vital for the ability of communities to adapt to the adverse effects of climate change and thus avoid options like encroachment into wetland. Given the intimate link between poverty, livelihood and water security, this implies that the interface of rehabilitation and management objectives becomes strongly developmental in nature and encompasses both social and ecological objectives (Pollard *et al.*, 2005).

The study also gathered data on the size of arable land available per family. The results show that 3% of the interviewees have arable land that is less than one hectare, while 33% have two hectares. Up to 30% have three hectares, 20% have four hectares and 14% have five hectares of arable land. The size of arable land is at a critical levels in districts such as Chivi, which has a population density of about 43.9 people/km^2 and some wards such as Ngundu whose estimated density is at 61.8 people/km^2 (Mutekwa and Kusangaya, 2006). Furthermore, the size of arable land per capita arable land that is less than 0.5 ha is 23%, while 58% of the interviewees have per a capita arable land of 0.5-1ha, 10% have 1–1.5 ha per capita arable land, 5% 1.5–2 ha and 4% of the interviewees have a per capita arable land that is more than 2 ha each. In another study Farai et al. (2012) found that for mainland cropping the majority of the farmers used land portions varying from 1 – 2 hectares (62 %), 22 % use less than 1 hectare of land whilst 16 % use more than 2 hectares of land. The size of per capita arable land helps to analyse the impact of population pressure on both the land and wetland. These are critical factors that need to form key inputs into the design of a sustainable and viable wetland rehabilitation model in South-Eastern Zimbabwe.

The non-riparian communities interviewees were asked to state their source of water for cultivation activities. A variety of water sources for cultivation activities are used by interviewees. Figure 4.12 presents the sources of water for cultivation activities. The figures shows that 24% of the interviewees' use borehole water for cultivation, while 16% use dams, 23% use rivers and 33% use water drawn from wells for cultivation.

Another 20% of the water for cultivation purposes comes from rivers, and vleis with other sources, such as gutters contributing 4%. It is suggested that expanding sources of water for cultivation and or horticultural activities should be done within the broader scheme of IWRM that advances the objectives of wetland rehabilitation. Broadening of these sources could also encompass a switch to rain water harvesting options that can alleviate pressure on wetlands and thereby rehabilitate them.

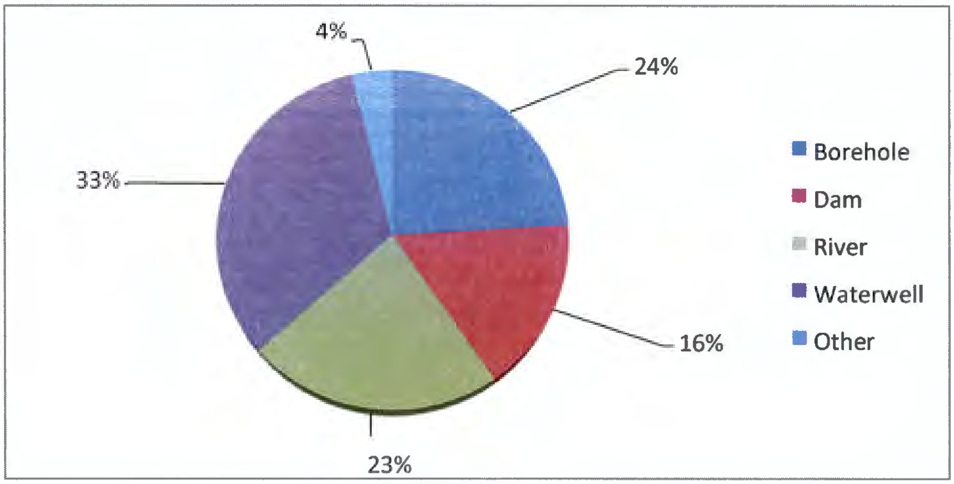


Figure 4.12. Source water for cultivation activities

A survey of the interviewees' total number of livestock units was made. The results, as shown in Figure 4.13, shows that 33% of the interviewees have a total stock of cattle, goats, sheep, pigs and donkeys falling within the 21–30 range, while 30% have domestic animals ranging from 31 to 40, 6% have more than 41 and 28% of the interviewees have livestock ranging from 11 to 30, as well as 3% of the interviewees who have less than 10 livestock units. The number of livestock units has a bearing on catchment carrying capacity and rehabilitation thereof. The next section pays attention to influences that have a bearing on rehabilitation prospects in South-Eastern Zimbabwe.

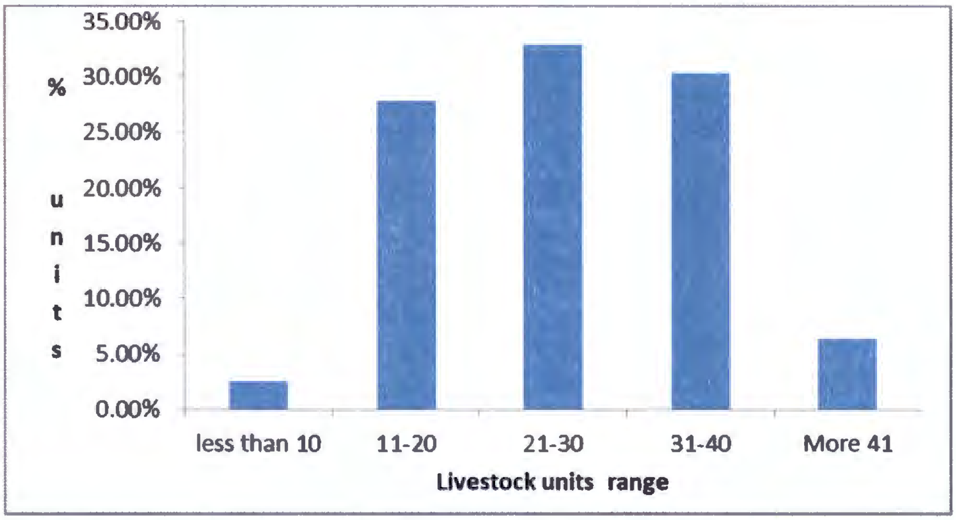


Figure 4.13. Total livestock units of non-riparian communities

4.5.3 Off-site (Catchment) wetland rehabilitation

The interviews reveal that rehabilitation using vegetative live fencing of farm land in the catchment area in the form of sisal constitutes 22%; hedge 30%; and bull 24%. The results further show that wire fencing is also used by 20% of the interviewees and other methods like poles constitute 4%. Dead vegetative methods of fencing like bulrush are destructive and contribute to deforestation and loss of biodiversity. Live fencing, however, helps in enhancing of biological diversity, and accelerates water infiltration into the underground zone and recharge wetland ecosystems. According Marambanyika *et al.* (2012) fencing with dry branches of acacia species is contributing to the degradation of communal land through increased deforestation. The deforestation of catchment areas increases soil crusting thereby reducing infiltration, it also increases surface runoff and reduces groundwater recharge, (Zinhiva *et al.*, 2014). Agnalu (2014) confirms this observation by highlighting that catchment management practices should be implemented in a manner that solves soil and water degradation problems. Figure 4.14 illustrates the type and prevalent fencing material.

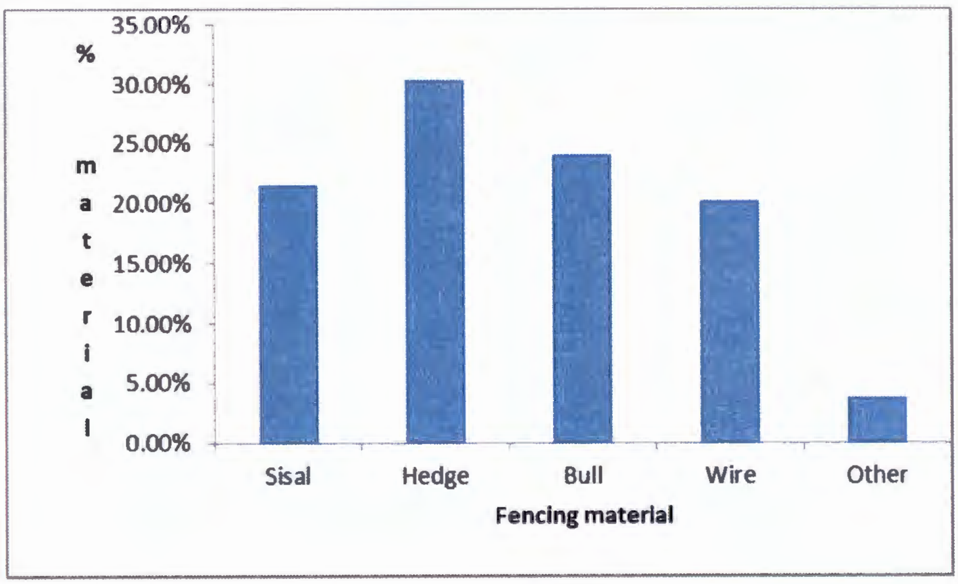


Figure 4.14. Fencing material in use by non-riparian

Contour ridging and spacing of contour ridges in wetland catchment areas helps to prevent soil erosion and facilitate water entry into the ground as groundwater. Contour ridges are small earthen ridges, 15 to 20 cm high, with an upslope furrow which accommodates runoff from a catchment strip between the ridges. Most of the interviewees were those who answered affirmatively when asked if they are prepared to construct contour ridges. The construction of contour ridges is a colonial and Rhodesian government legacy where ridges were initiated as part of conservation agriculture. Contour ridging might have been introduced by the colonialists, but it remains an effective strategy for controlling erosion. Nonetheless, ridges must be designed in conformity to slope gradient. Other methods in use include terracing. However, these rehabilitation methods, such as contour ridges, sometimes rapture and require immediate rehabilitation themselves. Effective construction of contour ridges in the upland areas is catchment management activities that impact positively on wetland recovery downslope.

The findings also revealed that only 21.5% of the interviewees adhere to set rangeland management practices. About 78.5% acknowledged that they do not adhere to rangeland management rules. This is a problem in communities where wetlands are reserved for grazing only in dry winter months when pastures are limited. Rangeland management influences wetland health and rehabilitation, hence activities such as trampling and vandalisation of fenced wetlands impact on rangeland management. The observation here is that the rules that would have been conventionally and collectively agreed to in an attempt at strengthening adherence to rangeland management at a village are more effective than national statutes, for a bottom-up approach is socially binding. Rules that bar the cutting of foliage branches, initiation of veld fires and expansion of cultivation into grazing areas are best agreed upon through community institutions that are supported by traditional authority.

Women play a fundamental role in environmental management in general and specifically with regard to wetland rehabilitation. During the study, interviewees were asked to express their opinion on women's participation in environmental issues. Some of the expressed views are that, women should take the centre stage as they interact with environmental issues, almost on a daily basis as they fend for their families. Women participate in socially organised events like beer parties, public works programmes, and ‗rainmaking' ceremonies (Ndlovu and Manjeru, 2014). A rain making ceremony, which is a traditional ceremony used to supplicate to the ancestral spirits to bless the communities with rainfall can also be practised to sustain the wetlands. This confirms the centrality of women in community events, and a centrality that can be extended to taking responsibilities in environmental stewardship. The other interviewees pointed out that, ―Zimbabwe is a free country where all people including women are free to participate in communities events that even used to undertaken by men‖. Although women are very effective, they are at times handicapped by household chores at home. At times women participation is limited by the patriarchal nature of families, thus they often perform subservient roles to men, which are not limited to environmental matters.

The interview results reveal that interviewees are aware of wetland recovery interventions that can reinstate wetland health. A number of remedies were pointed out. These include fencing, the clearing of *Lantana camara* and gum trees, and gully reclamation. Other interventions highlighted include planting indigenous trees to stabilise gullies. Finally, the interviewees suggested the creation of a strong institutional capacity by empowering village heads, strict application of environmental law that restricts wetland usage and the adoption of payment for ecological services to strengthen wetland rehabilitation projects.

4.6 Summary

This chapter described and analysed the socio-economic factors that influence wetland rehabilitation. It has been observed that social circumstances such as age, gender and household size of the interviewees can enhance wetland rehabilitation to some extent. Economic circumstances, including crop outputs, rainfall variability induced wetland utilisation and income levels, hinder wetland rehabilitation. Other challenges to wetland sustainability include funding constraints and lack of livelihood alternatives. These have been shown to have a constraining effect on efforts to accelerate and expand the scope of rehabilitation projects. The chapter ended with a discussion on off-site wetland rehabilitation measures that need to be incorporated to complement on-site intervention measures and maximise a sustainable ecological approach in wetland rehabilitation.

CHAPTER 5: PERFORMANCE LIMITATIONS OF REHABILITATION PROJECTS

5.1 Introduction

This chapter assesses the current state of wetland rehabilitation projects and the performance limitations of on-going rehabilitation structures in the study area. The researcher went on fieldwork to observe and assess the rehabilitation projects. An observation schedule was drawn and variables observed were entered in fieldwork note book *in-situ*. The chapter discusses the current state of rehabilitation projects and performance limitations of current wetland rehabilitation projects on a theme by theme basis. These issues are critical in engineering a paradigm shift to a sustainable and approach to wetland rehabilitation.

5.2 Materials and Methods

5.2.1 Study area and sampling

The number of wetland rehabilitation projects for each district in the study area was provided by the Environmental Management Agency (EMA). It was estimated that there were 69 projects in the province and the number increases each year as new projects are initiated. Figure 5.1 shows the number of rehabilitation project sites in each district that were observed in this study. This sample was selected using the stratified random sampling method. It shows that the Gutu District has the largest number of observed rehabilitation projects with a sample. The wetlands in each district were selected using a table of random number. As a result, 22 wetland rehabilitation projects were selected. The decision to use a sample of 22 wetland rehabilitation projects was based on the fact that it is representative enough of the population considering that this is almost a third of total projects initiated in the Province. The rehabilitation projects are initiated by government agencies and non-governmental organisations such as Oxfam and UNDPGEF.

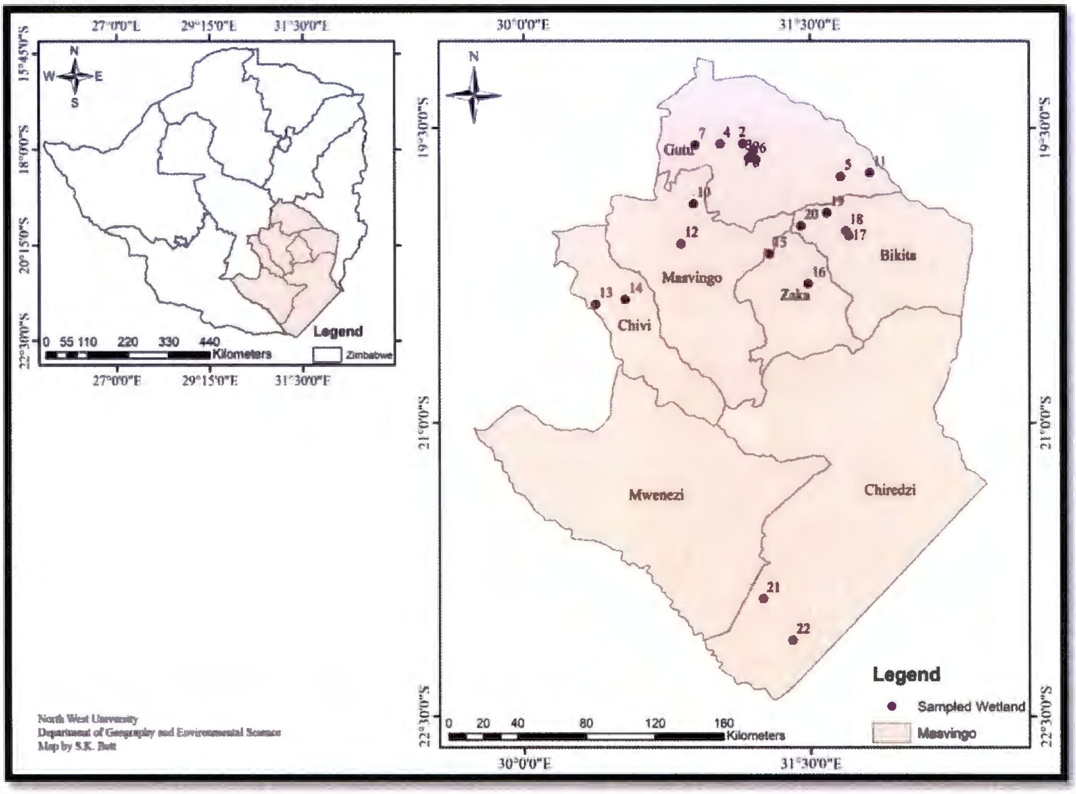


Figure 5.1: Distribution of wetland rehabilitation projects in the study area.

Table 5.1 provides information on the sample size of the rehabilitation projects in the seven districts. The table also shows the degree and cause of disturbance at each site and the main rehabilitation activities implemented. A sample size of 30% of the population was used to observe different variables specified in appendices 2 and 3.

5.2.2 Key informant interview

Interviews were conducted with the Projects Officer of the Environmental Management Agency of Zimbabwe based at the Masvingo provincial office. The interview was conducted face-to-face and it took place over two days and was followed-up with an email response. The Projects officer was a critical informant who influenced the design of wetland rehabilitation modelling considering the experience gained over the years on the ground during implementation of wetland rehabilitation projects.

Table 5.1: Summary description of 22 wetland rehabilitation projects

Wetland project name and number appearing on figure 5.1	**District**	**GPS**	**Size in (Ha)**	**Degree and cause of disturbance**	**Main rehabilitation intervention activities initiated.**
Makanda (1)	Gutu	19,61632S/31,20473E	1.4	Low degradation due to overgrazing and cultivation	Fencing, re-vegetation, clearing invasive species, cultural
Mushangwe (2)	Gutu	19,57945S/30,37952E	7	Low degradation because of small holder cultivation and cultivation	Re-vegetation, removal of nutrition cropping plots
Makuvaza (3)	Gutu	19,64552S/31,18863E	4	Moderate degradation due to overgrazing and cultivation	Re-vegetation, clearing invasive alien species
Mukozhora (4)	Gutu	19,57945S/3037952E	1.9	Low degradation due to cultivation	Cultural/IKS and conservation agriculture
Mutubuki (5)	Gutu	19,74464S/31,662E	3.6	Severe degradation invasive species, rainfall variability and cultivation	Fencing, re-vegetation and social fencing
Kofoto (6)	Gutu	19,65985S/31,21707E	1.5	Severe degradation due to overgrazing and excessive water abstraction	Weirs and re-vegetation
Zvemudzo (7)	Gutu	19,58664S/30,89831E	3.8	Low degradation due to deforestation	Re-vegetation and removal of nutrition cropping plots
Mutsambiwa (8)	Gutu	19,65223S/31,17998E	5	Severe degradation due to overgrazing and deforestation	Re-vegetation and clearing invasive species
Chibvongodze (9)	Gutu	19,65223S/31,17998E	4	Low degradation due to rainfall variability, cultivation and overgrazing	Fencing
Sendeya-Mangisai (10)	Masving o	278966S/7799852E	1.5	Low degradation caused by cultivation and overgrazing	Fencing
Chengwe (11)	Masving o	19,72661S/31,81165E	5	Moderate degradation due to cattle tracks, gully's, overgrazing and deforestation	Fencing, stone pitching
Ndarama (12)	Masving o	20,08835622S/30,824 28470E	1.2	Low degradation due urbanisation, urban agriculture and	Fencing, Re-vegetation
Masinire (13)	Chivi	20,39735S/30,37505E	8	Moderate degradation	Fencing and revegetation
Magwenzi (14)	Chivi	20,37274S/30,53067E	5	Low degradation due to small holder cultivation, overgrazing, invasive species	Relocation of nutrition cropping plots Fencing, revegetation
Mupunga (15)	Zaka	20,1402S/31,28823E	3,5	Moderate degradation due to cultivation, overgrazing and human settlements	Fencing, clearing invasive species
Zishiri (16)	Zaka	20,29197S/31,49E	2	Moderate degradation due to human settlements and rainfall variability	Relocation of nutrition cropping plots, Cultural/IKS
Maturure (17)	Bikita	364294S/7782783E	5.5	Low degradation due to small holder cultivation	Fencing/relocation of nutrition cropping plots, IKS/Cultural
Silveira Mission (18)	Bikita	20°1'21.24"S/31°41'13 .92"E	1.3	Low degradation due to excessive abstraction	Fencing, fanya juus, weirs, revegetation, weirs

Machingambi (19)	Bikita	19,9305S/31,58732E	6	High degradation due to cattle trampling, overgrazing and deforestation	Installation of stone checks-stone pitching relocation of nutrition cropping plots
Tarwireyi (20)	Bikita	19,99787S/31,45262E	4.5	High degradation due to small holder cultivation, cultivation and overgrazing	Relocation of nutrition cropping plots, Revegetation
Samson (21)	Chiredzi	21,89979S/31,25084E	1.4	Low degradation due rainfall variability and agriculture	Re-vegetation and sustainable agriculture
Manjinji (22)	Chiredzi	22,11082S/31,40655E	0.9	Low degradation due to rainfall variability and population pressure	Cultural/IKS

Source: *(EMA, 2009) and ** author

5.2.3 Observations

Observations (See Appendices 3 and 4) were conducted in the study area. An observation is when a researcher collects information by interacting with the environment in a more naturalistic setting without using predetermined ideas, measurement or responses. This technique was found suitable because of its flexibility and strong validity of findings (Gadzirayi *et al.*, 2006). The observation method is flexible and reliable because the researcher is in direct contact with the phenomenon being investigated. Much of the research, including field observations, was conducted between December 2013 and January 2015. The observations were done during winter and summer, which are seasons when wetland wetness fluctuates; and in that way a balanced picture of the performance of rehabilitation projects was obtained. The field observations were complemented with guided interviews so that observed information could be recorded while conducting interviews at the same time. This approach is best suited for attempts at corroborating data provided by interviewees and what field observations show.

An observation schedule (see appendix 3) was used to gather information about the rehabilitation projects that influence wetland ecosystem functions, structure and processes. The observation schedule contained particulars such as date of observation; the wetland's patch geographic location (latitude and longitude); wetland's name; and type of wetland that is, whether it is a dambo, swamp or a pan. Appendix 3 and 4 illustrate these. The researcher took photographs of the study area's observed rehabilitation projects showing the efforts at re-establishing wetland processes and functions. A photographic galery helped to capture the current state and performance of rehabilitation projects. From the sampled rehabilitation projects, an observation guide as alluded to earlier on was used to collect data. The final raw data was screened, its outliers dealt with using relevant literature, and missing values checked and tested for normal distribution before analysis.

5.3 Results and Discussion: Current State of Rehabilitation Projects

5.3.1 Ecology

The observation guide required the fieldwork survey to check on the extent of the wetland buffer zone. A buffer zone is a lateral strip of undisturbed land extending from the edge or boundary of the wetland that protects the wetland from pollution or degradation. The results show that in most cases the width of wetland buffer zone from is less than 100 m wide. More than 77% or 17 (n=22) of the communities maintained a buffer zone of less than 100 m away The observations concur with earlier studies by Ndlovu and Manjeru (2014), which showed that the width is about 50 m. Only 9% of the wetlands have a buffering zone that is more than 100 m wide. Narrow buffer strips do not comply with the legislative requirement of a 100 m flood-line.

Wetland buffers are required to afford wetland areas adequate protection from adjacent land uses that may adversely affect them. Therefore, most wetlands do not have wide buffer zone against degradation from human activities. According to Ogato (2013), policies and strategies that promote the establishment of buffer zones beyond the delineated boundaries of wetlands should be developed and properly implemented. At Maturure rehabilitation project in Bikita district, the enforcement of the buffer zone involved the actual activity of relocation of vegetable small holdings from the core of the wetland to an upland consolidated nutrition plots that uses borehole water. However some community members return to the core of the wetland after relocation. Therefore, most of the rehabilitation projects targeted maintenance of a 100 m buffer zone adjacent to the wetland but with limited success due to lack of compliance and enforcement.

The area under rehabilitation in slightly over half of cases was 20% of a particular wetland. A total of 55% of the surveyed wetlands have 20% of the entire wetland size under rehabilitation. Slightly more than a quarter of the wetland rehabilitation sites, 26%, recorded 21–40% of wetlands being under rehabilitation. The remainder is illustrated in Figure 5.2. Such observations also concur with information from the interview held with the Environmental Projects Officer, where it was indicated that only 20% of the entire wetland mass in the Masvingo Province was under rehabilitation. Not even a single wetland project was capable of rehabilitating more than 80% of the wetland area.

Rehabilitation can succeed if it involves a significant proportion of the wetlands in question. This is particularly critical for wetlands in Zimbabwe, which despite their socioeconomic and ecological importance, are vulnerable and small in size.

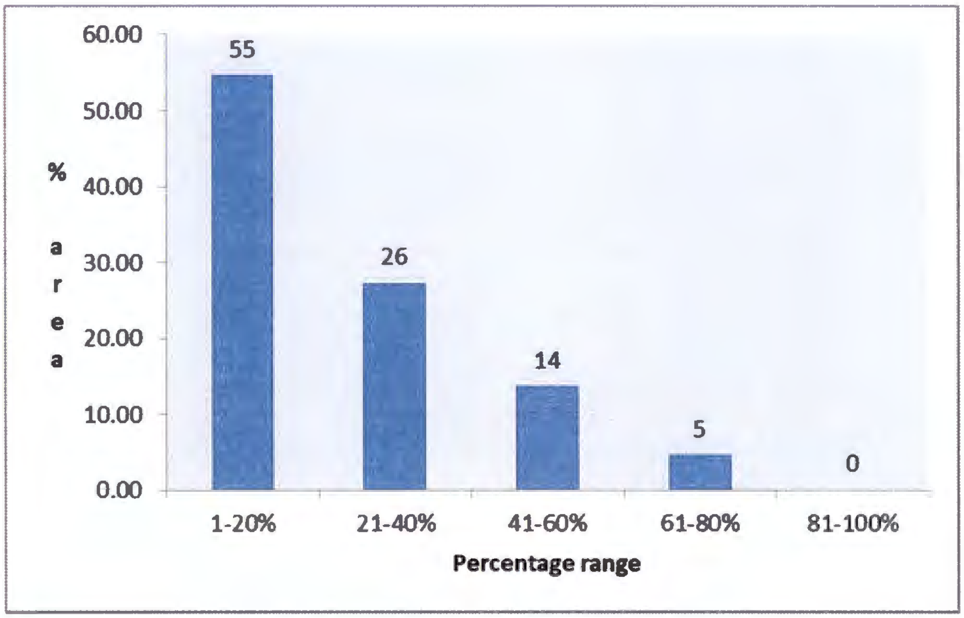


Figure 5.2: Area under rehabilitation

A majority of wetland sites, 13 (59%) have less than one hectare of wetland under rehabilitation. Further results from the field observations are that: five (23%) sites have two hectares under rehabilitation; three (14%) rehabilitation sites have more than three hectares of wetland under rehabilitation; and one (5%) site has close to four hectares under remediation and on the way to full recovery of wetland structure and functions. Therefore, a reinstatement of the associated ecosystem goods and services improves the health of both the wetland and the communities

Planting indigenous aquatic plants was one of the remedial re-vegetation measures implemented at the rehabilitation project sites. The observation assessments showed that the rehabilitation biodiversity indicator species, such as water berry *(Cordatum syzgyium)*, are significantly dominant species, comprising 30% in sampled projects. Cut grass, (*Leersia hexandra)* constitute 26% and Sedges, (*Cyperus species)* were also quite prevalent (19%). Localised extinction and relicts are visible for reeds, (*Phragmites species*) (19%) and bulrushes, (*Typha capensis)* (4%). Most of these species have been degraded by invasive alien species such *Lantana camara* and overgrazing by livestock. To some extent there is a need for the diversification of the species composition in wetlands. The rehabilitation interventions need to address this acute loss in biological diversity.

The size of the area of re-vegetated wetland is significantly limited in sites under-going rehabilitation. There were a few, six (27%), wetland rehabilitation sites with one (5%) being re-vegetated, whilst no re-vegetation has commenced at 15 (68%) of the sites. Re-vegetation assists in reinstating the ecological integrity of the wetland itself and in establishing the hydrological and geomorphological structures and functions of fragile wetland ecosystems. The afforestation with exotic species like gum trees has proven to be a wrong approach given that they worsen wetland degradation. Gum trees are counter-productive to wetland recovery because their high water consumption results in depletion of underground water resources. It is the contention of this research that indigenous tree species should be planted and maintained in wetlands. This will help to enhance their hydrological recharge, wetness, erosion control, flood regulation and biological integrity, and richness and evenness.

Observations revealed that eight (36%) wetland rehabilitation project sites have 1-20% bare wetland soil as a percentage of total wetland. Bare wetland soil describes a condition whereby wetland soil is not covered with grass. The bare wetland soil is caused by multiple factors such as overgrazing and drought-induced receding water level. Bare wetland at three (14%) sites stood at 21-40%. Bare wetland soil, as a percentage of total wetland, helps to determine the state of current wetland rehabilitation projects. The proportion of bareness on the wetland helps to determine the biological integrity of that system among other indices. The fencing off of a majority of the rehabilitation projects resulted in most of the wetlands not having bare soil patches. Bare surfaces expose the soil to erosive forces and cannot keep moisture for long periods. Wetlands need vegetation cover to help bind soil aggregates, reduce raindrop terminal velocity, and facilitate infiltration and percolation of rainwater into the underground zone, as well to provide an ideal habitat for different flora and fauna. It is for this reason that greater caution on soil disturbance is taken and bare soil should be avoided.

Fencing of wetlands has been one the major rehabilitation activities at the project sites meant to recover the organic matter in the wetland soil. The level of organic matter content in the soil was also measured. Soil samples at two (9%) sites showed that organic matter, as a percentage of the soil, is less than 20%. The organic matter at five (23%) of the sites, is 21-40%, at the other eight (36%) sites it is 41-60% organic matter, while six (27%) rehabilitation projects have soil samples that have 61-80% organic matter content. Finally, one (5%) site's organic matter content is 81-100%. The results from observations show that some of the wetland sites have a low percentage of organic matter per unit volume of soil. This finding is surprising considering that wetlands are generally known for their high organic matter content.

Organic matter is derived from the decay of plant matter particularly in winter in Zimbabwe where aerobic conditions prevail and are followed by anaerobic conditions in mid-summer when water logging is predominant at wetland eco-tones. The amount of organic matter has declined considerably in patches predominantly under cultivation with no fencing. These significant results, point to the need for communal farmers to employ conservation agricultural practices, such as the application of livestock manure and compost. Society should move from using inorganic fertilizers that contribute to eutrophication, soil toxicity, invasion and the proliferation of alien species, such as algae and water hyacinth. Organic fertilizers such as cow dung manure, humus and compost enrich the soil without negative impacts such as eutrophication.

The fieldwork results show that the length of gullies in the wetlands is increasing. The gullies are initiated from the natural processes such as tropical summer rainfall flash floods. The gully at the Mupunga site is 100 m long. In addition the Chibvongodze wetland gully (5%) in the Gutu District measured more than 150 m and that at the Machingambi wetland site (5%) in the Bikita District has one gully whose length measured in excess of 200 m. The presence of gullies is indicative of the ineffectiveness of the process of reinstating the hydrological, ecological and geomorphological condition of the ecosystem. Thus, the lack of geotextiles engineering structures to plug the gullies at a wetland site such as Mupunga, in Zaka District, despite the fencing of the wetland core, and the fact that the gully at Mupunga site extends for more than 100 m and forms the stream headwaters, shows that gullies have the potential to drain and degrade the wetland itself as well as contribute to drying, desiccation and loss of ecosystem structure and functions. Therefore, the observed rehabilitation projects experiencing gullyfication are poor in geomorphological and ecological performance.

5.3.2 Agro-ecology

The mapping of distance between the wetland and the housing units relied on the nearest housing unit to the wetland (typical of nearest neighbour analysis in settlement geography). The sample comprised the nearest 22 farmers living within or in the proximity of the wetland patches. EMA stipulates that housing units should be at least 100 metres from wetlands. It was observed that in most cases that the distance between dwellings and the wetland rehabilitation projects in 14 (64%) of the 22 was 100 metres. Therefore the distance variable was mapped and surveyed on the nearest 22 farmers to the wetland patches. The distance measured at five (22%) wetland sites was within the 100–200 metre range to the housing unit. Other findings reveal 201–300 metre distance measured at two (9%) sites, with a distance of 301–400 metre measured between one wetland rehabilitation project, constituting 5% of the observed wetlands, and the dwellings. There is no wetland project site that is more than 500 metres from human dwellings. These findings are not surprising considering the fact that population density in the study area, the Zaka District, for example, is 65 people/km^2 (Muzenda 2013), which is more than double the country average population density of 32 people/km^2 (Population Reference Bureau 2009). Figure 5.3 shows percentage of dwellings in relation to distance from the wetland.

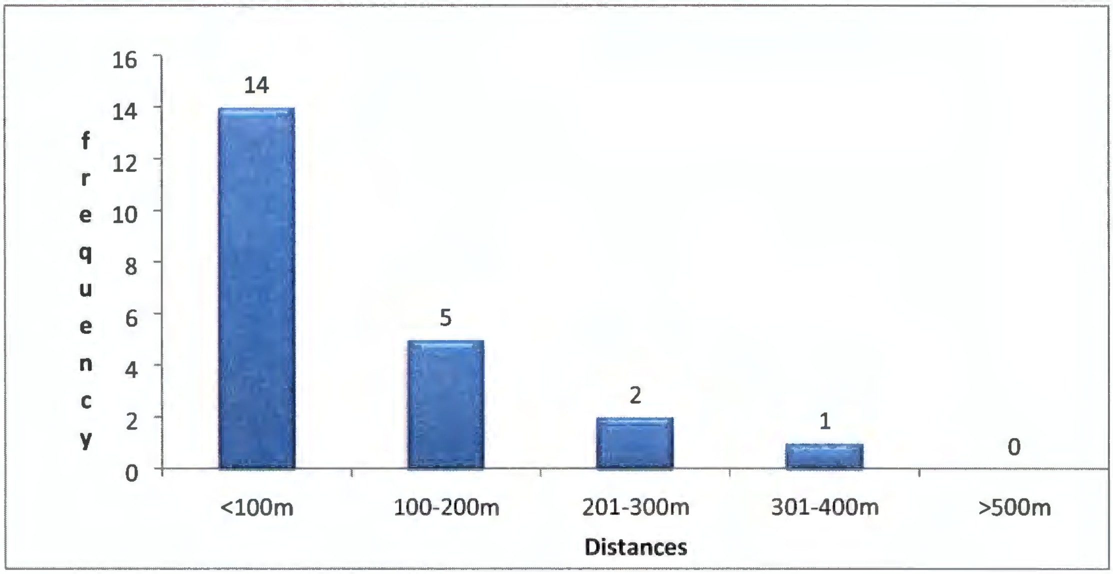


Figure 5.3: Distance of the nearest housing unit from wetland

The observed distance between wetland rehabilitation projects and dwellings create stressors and pressures on ecological conditions for wetland health and inhibit recovery from degradation. Morardet and Koukou-Tchamba (2005) point out that increasing human pressure on wetlands leads to a potential degradation of their ecological functions. The distance from dwellings to the wetland influences the width of the buffer zone because the stretch of undisturbed portions on wetland margins should allow it to recover from deterioration. Narrow buffer zones have the net effect of diminishing the potential for wetland re-establishment and attainment of close to pristine condition.

The results from observations indicate that a sizeable proportion of wetland patches, five (23%), are impacted by agroforestry and on-farm conservation eco-agricultural systems. There are no wetland rehabilitation agronomic practices at four (18%) wetland sites and mono-cropping is practised. The study also reveals that multi-cropping and intercropping are common at six (27%) on-farm rehabilitation interventions. Organic farming is observed at three (14%) sites and thus limited in practice due to increased usage of inorganic fertilizers. Double cropping, which is evident at four (18%) sites, is to some extent limited. Environmentally friendly agronomic practices are a fundamental building block for successful wetland rehabilitation. However, it is being noted that these rehabilitation measures are more driven food security consideration than pure wetland rehabilitation driven initiatives. Organic farming is limited by shortage of compost manure, while double cropping has been caused by rainfall variability since wetland cultivation is preferred ahead of upland crop cultivation. Only a limited number of households apply cow dung manure. Cow dung usage is also low because of traditional belief that cow dung manure has a wetland drying effect.

The study findings reveal that 17 (77%) project sites from the assessed 22 wetland sites do not have cattle watering points. Only three (14%) sites have a watering point each for livestock while two (9%) project sites have two watering points. Although 14 wetland rehabilitation projects have fences and other protective measures, little has been done to offer alternative watering points for livestock. The lack of watering points exposes wetlands to unregulated usage by cattle headers, as shown in Figure 5.4. The findings in Figure 5.4 corroborate an earlier assessment of the Chebvute wetland in Zvishavane, where, as noted by Marambanyika *et al.* (2012), 36% of plot holders revealed that one challenge of rehabilitation was fence vandalisation that resulted in domestic animals accessing the wetland. Provision of watering points such as adequate number of earth dams and weirs can go a long way to address this challenge. The number of stock watering facilities near fenced wetlands is a significant component determining the success of repairing damaged ecosystems. Nonetheless, it is evident that wetland protection without wetland production is unsustainable because resources such as wetlands need to be put to beneficial use but at the same taken care of.

Adaptive rehabilitation is important during the implementation phase. Integrative animal husbandry activities that create stock watering facilities together with fencing are a requirement for effective rehabilitation. The solution lies in adapting to the current climate change, which is characterised by erratic, unreliable and below-average rainfall trends. Stock watering points make agro-ecological sense in Zimbabwe's agro-based economy where livestock rearing is both an economic livelihood and of socio-religious significance. Environmental rehabilitation and conservation interventions by both governmental and non-governmental organisations alike are focusing mainly on installing biophysical measures or structures and paying less attention to the socioeconomic and institutional side of the problem (Balana 2010). Findings from this study suggest that there is a need for fencing and a concomitant installation of livestock watering points. Wetland degradation usually emanates from unchecked animal trampling and treading which initiate soil compaction and ultimately soil erosion and gully formation. Figure 5.4 reveals that gates are opened to access wetland goods such as water and pastures due to lack of alternatives.

Livestock grazing challenge Gates opened for greener pastures

Figure 5.4: Gates opened to access wetland resources due to lack of alternatives

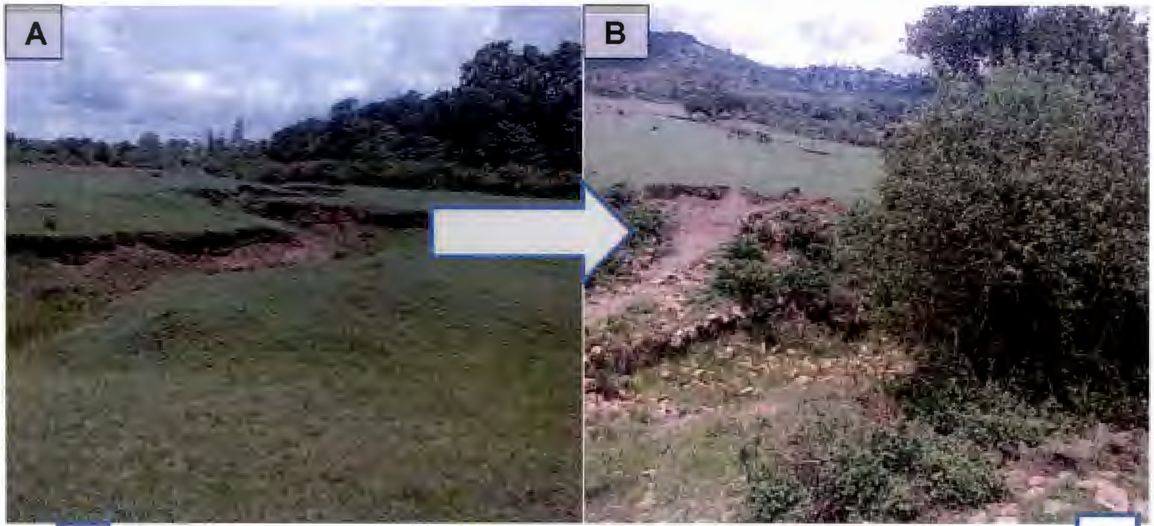
Direct field observations at three (14%) project sites show that cultivation is done without using ridges which results in the wasting of water. The frequent ridge height in wetland nutrition cropping plots at 10 (45%) sites is less than 20 cm, while ridge heights ranging from 21–30cm exist at five (23%) rehabilitation sites, of 31–39cm at two (9%) sites and ridge heights greater than 40cm are available at two (9%) other sites. Conservation agriculture requires that there must be raised ridges in wetlands to minimise wastage of water when flood irrigation is used for watering plants. In addition, appropriate bed height with raised side ridges prevents the escape of water from the wetlands. Thus, on-farm rehabilitation strategies are based on social visioning initiatives which are not strongly evident in the study area, resulting in poor hydrological performance of wetland recovery.

5.3.3 Rehabilitation engineering structures

Most of the rehabilitation project sites (64%) are fenced. Wetland rehabilitation interventions such as geotextiles were observed at a few sites, six (27%), such as the Machingambi and Silveira Mission Dam wetlands. Afforestation, as a form of wetland rehabilitation intervention, and other remediation initiatives were observed at nine (41%) sites. However, it was noted that most of the afforestation efforts entailed haphazard clustering of gum trees without systematic planting of indigenous plant species. Vegetative live fencing was used at two (10%) project sites at Maturure and Tarwireyi in the Bikita District. The sites, Makanda in the Gutu District, Chefuta in the Zaka District and Manjinji Pan in the Chiredzi District, constituting three (8%) of the observed total wetlands, utilise cultural methods, such as banning the usage of detergents for bathing and washing at springs that pollute water sources, which are rooted in Indigenous Knowledge Systems, to maintain wetland integrity.

The use of geotextiles for rehabilitation is not widespread use because they are available on six sites (17%). Some rehabilitation projects, such as Mupunga in the Zaka District, can perform better with geotextiles. This is because geotextiles can also be placed on the gully to trap sediments and to prevent the gully walls from collapsing. Geotextiles also assist in repairing gullies. A big gully that is threatening to incise into the Ndanga-Roy highway was observed and plugging the gully with gabion blocks can rehabilitate it. The sights from photographs A, B, C and D (Figure 5.5 illustrate the situation in the Bikita District. The current rehabilitation status is represented by photos (A, B and D) and the ideal rehabilitation engineering structure is shown in photo C.

There are no erosion stone checks at 13 (59%) rehabilitation sites because of technical and capacity failure. There are, however, five (23%) wetland rehabilitation projects that have erosion stone checks. Loose erosion stone checks with rocks fetched from nearby mountains stabilise the gully by breaking the flow of water and trapping sediments. They are available at a few sites partly because geo-textiling in whatever form is labour intensive and requires expertise to install durable structures. However, it should be noted that loose rock structures can complement other available biological rehabilitation initiatives in stabilising gully banks threatened by erosion.



Me[illegible]ering gully and erosion stone checks at Machingambi site

Gabions

Gully at Machingambi site unchecked

Figure 5.5. **A, B, C** and **D**. Erosion stone checks and gabions compared

Geotextiles and other bio-engineering structures are effective in stabilising erosion gullies in wetlands. They are effective when strengthened by concrete reinforcement and mesh wire net, as shown in Figure 5.5 C. Gully filling is a remediation intervention that can be used to reinstate wetland hydrology (Hamudikuwanda *et al.*, 2001, Riddell, 2010; Riddell, 2011 and Riddell, 2012). Furthermore, gully reclamation is a sustainable wetland protection intervention (Muzenda, 2013).

The results also show that some few wetlands are fenced for grazing management purposes. There is no rangeland grazing management paddocks which were installed at about 16 (70%) wetland rehabilitation sites. These paddocks are in no way wetland rehabilitation fences *sensu stricto* but are just like other paddocks in rangelands. Observations at 3 (13%) sites reveal that up to 25% of the wetland is paddocked, while two sites constituting 9% of the total count have 26-50% of the total area under paddocks and another two (9%) have more than 51-75% installed with paddocks. Nonetheless, no single wetland has more than 75% of the area paddocked. Paddocking wetlands is critical in striking a balance between ecosystem preservation and livestock grazing. Fencing for paddocking and wetland protection best protect and rehabilitate wetlands for the future. It must be highlighted that building social fences concomitantly with technical fences is the better approach. Technical fences are expert driven and costly but subject to vandalism, while social fences are communities driven, cheap and attract and enjoy communities buy-in. Technical fences are made from wire whilst social fences are social contracts banning certain environmental damaging practices.

5.3.4 State of rehabilitation

The report in this section is based on an oral and email interview conducted with the Projects Officer responsible for wetland rehabilitation in the Masvingo Province. The Project Officer is an ecologist based at the Environmental Management Agency (EMA) and was interviewed between October 2014 and February 2015. The total provincial size of wetland under rehabilitation is 165.13 ha, which is about 23% of the total 716.325 ha of wetlands in the province. A majority of these wetlands are not health ecosystems and are thus disturbed. The level of wetland degradation existing in the Masvingo Province caused largely by anthropogenic drivers such as overgrazing and over-cultivation suggests that more still needs to be done to increase the size of wetlands under rehabilitation. The Projects Officer also affirmed that the proportion of wetland area that is under rehabilitation in the province is low.

The existing rehabilitation gap demonstrates the current state and performance limitation of the country's rehabilitation efforts are inadequate. The wetland rehabilitation gaps indicate that interventions are inadequate. The on-going intervention measures are influenced by the level of funding in Zimbabwe by the government and donor agencies. The global financial crisis has led to reduced investment in wetland protection and conservation measures (Millennium Ecosystem Assessment, 2005; Ogato, 2013). Sieben *et al*. (2011) reinforce this view in their observation that there are limited funds to support wetland rehabilitation. The limited success of rehabilitation demonstrates human response to a problem and exposes the weaknesses of the existing rehabilitation designs. The ideal situation is to reduce the proportion of nonrehabilitated but degraded wetlands to minimal levels.

The current technical rehabilitation plans that are being implemented should start with the mapping of all wetlands by EMA because Zimbabwe has a poor wetland inventory. EMA is currently undertaking baseline surveys to come up with a scientific and comprehensive wetland inventory. Hence, the compilation of a wetland inventory should be coupled together with wetland rehabilitation and this will inform the cost for rehabilitating severely degraded ecosystems in an attempt to re-establish their ecological functions. Wetland mapping and characterisation by EMA field officers into categories such as pristine, degraded and severely degraded informs model designing and prioritisation in wetland rehabilitation.

Mapping and fencing off of wetlands are important in ecosystem repair. According to the Projects Officer, the exact proportion of the total area in the province that is fenced is 23%. Fencing has helped to keep livestock out of the wetlands and allow grass to grow. Most of the unprotected wetlands dry up due to livestock trampling, tracking, compaction and deforestation. Fencing therefore becomes a necessity. There is, therefore, a need for fenced wetlands which encourages the protection of wetland structure, functions and integrity. These should be the tenets of designing a wetland rehabilitation model. Nevertheless, the fencing plans should conform to the wetland judicious use strategies advocated by the Ramsar Convention.

Some wetlands experience excessive degradation due to steep slopes, especially those greater than 25°. Figure 5.6 illustrates a ―*fanya-juu*‖ or terrace at Silveira Mission rehabilitation project in Bikita. Construction of fanya-juus upstream of a wetland catchment to facilitate wetland recharge and control erosion has been an on-going programme in South-eastern Zimbabwe's Districts of Zaka and Bikita. ―Fanya juus‖ in the study area achieved soil stability and reduce soil erosion which limits land degradation in the catchment area. Catchment degradation leads to wetland loss directly when people and livestock invade marginal areas such as wetlands in search of arable and grazing areas, so inherently catchment preservation helps to improve wetland vitality. This is consistent with the findings from a study by Branca et al. (2011) which notes that the building of excavated terraces (bench/fanya juus) in the Ulugurus Mountains in Tanzania has improved soil stability. However, the construction of ―fanya juu‖ requires environmental engineering knowledge and expertise to achieve a sustainable wetland recovery programme.

Wetland rehabilitation is a cost that demands foregoing certain livelihood options. Nutrition cropping plots and orchards in communal areas often use open wells and that has a bearing on wetland wetness, especially when considering that Zimbabwe has limited resources to promote nutrition cropping plots under upland irrigation schemes. Nutrition cropping plots and orchards deplete underground water through excessive water abstraction.

Figure 5.6: Rehabilitation using terraces and fencing in Bikita

Nonetheless, the impact of ground water withdrawal on water balance in wetlands is characterised by the following parameters:

P + SI + GI = E + SO + GO (Hayal, 2012); **Equation 2**

Where P represents precipitation, SI-surface water inputs, GI-groundwater inputs, E-evapotranspiration, SO-surface water output, and GO-groundwater output.

Therefore, any alternatives to wetland use must quantify amounts of water that are likely to be extracted (outputs) in order to introduce matching water conservation measures. Some of the alternatives to offset wetland use in areas where rehabilitation strategies are implemented include upland nutrition cropping plots fed by water from dams. It also emerged, from the interview with the Projects Officer, that those communities during their interface interactions with EMA field officers stated that they prefer the establishment of nutrition cropping plots and orchards near protected wetlands. Nutrition cropping plots fed by water from small scale dams deter communities from wetland based cultivation. This suggests that creation of consolidated horticultural plots allows communities to realise immediate benefits of wetland rehabilitation. The strategy, which is meant to encourage wetlands protection, assists in achieving the goal of socioeconomic development and ecological sustainability. Therefore fencing off to encourage the rehabilitation of the wetland together with an establishment of community nutrition cropping plots helps to achieve immediate survival needs of the community and wetland vitality. The nature and character of rehabilitation can be summarised as direct and indirect. Direct rehabilitation activities include stone piling in gullies, fencing, avoiding overgrazing and relocation of small holder nutrition cropping plots. Indirect activities include establishment of nutrition cropping plots and creation of income generating projects to minimise poverty and ultimately wetland over-exploitation.

5.4 Performance limitations of projects

5.4.1 Technical limitations

The results reveal that a number of rehabilitation projects have more than three rehabilitation objectives. Most of the objectives are related to the hydrology 8 (36%), n=22, ecology 8 (36%) and food security 6 (28%). Wetlands rehabilitation projects have a hydrological goal to recover wetland wetness. Projects with an ecological aim target enhancement of vegetation and biodiversity. Food security related rehabilitation projects not only focus on the wetland sustainability but also pay attention to socio-economic needs of the community. Attempts at ensuring food security resulted in the establishment of cultivation plots at the Mutubuki, Magwenzi, Maturure, Makanda and Mupunga wetland rehabilitation sites (Figure 5.7 D). Kotze, (2013) states that wetlands are managed for a variety of objectives, such as maintaining indigenous vegetation and optimising the assimilation of nutrients. The nature of rehabilitation goals set for a project is important for monitoring and evaluation purposes. It is, therefore, important for the goals to be set before a project's implementation. Some of the rehabilitation objectives appear in Figure 5.7

An assessment of wetland health is one of the rehabilitation performance indicators of the success of the project. Wetland health is measured using geomorphological, hydrological and vegetation criteria (Macfalane et al. 2008). This study did not use the Wet-Health (Macfalane et al 2008) scoring system in its entirety but used the measurement of gully density (geomorphological criteria) to evaluate rehabilitation performance and determine its limitations. Gully density was used to measure gully length per given area in km/km^2 helps ascertain the geomorphological condition of the wetland.

Job creation- Mupunga

Ecological and Food security-Maturure

Figure 5.7: A presentation of rehabilitation objectives

There are 14 wetland sites representing 64% that did not have gullies, and five (23%) sites recorded a density of 1–50 m/m^2. A density of 51–100 m/m^2 was recorded at one (5%) site, while an approximately 101–150 m/m^2 was measured at another one (5%) site as well as more than >150 m/m^2 recorded at another one (5%) site. A collection of photographs representing rehabilitation objectives and techniques observed during fieldwork surveys are presented in Figure 5.7. The observation confirmed interview results conducted with the projects officer who shows that hydrological, ecological and food security goals of rehabilitation are at the forefront of attempts to achieve wetland sustainability.

The results reveal that in six [(27%) n=22] of the observed wetland rehabilitation projects sites an area of about 1-20% was fenced, with the remainder of the wetlands exposed to degradation. Approximately 21–40% of the wetland at three sites (14%) is a fence-protected zone; 41–60% of the area at two (9%) project sites is protected with a fence. Only one (5%) has an area of 61–80% of the wetland that is fenced. The findings also reveal that two (9%) sites had 81–100% of their area fenced off. The other wetland rehabilitation sites eight (36%) are not fenced. The purpose of fencing was to protect the wetland from livestock grazing, trampling, cultivation and other destructive activities. The conservation of wetlands using fencing, as exemplified at the Mupunga wetland in Danda Village of Ward 3 in Zaka, repairs degraded ecosystems (Muzenda, 2013). The protection and rehabilitation of the core wetland preserves and perpetuates the supply of wetland goods and services, such as water, grass and reeds. The other benefits derived from rehabilitation include the growth of sedges, habitats for birds and aquatic fauna.

Off-site catchment rehabilitation is an initiative meant to complement and reinforce onsite wetland remediation efforts. Nonetheless, no visible rangeland rehabilitation is noticeable within the vicinity of eight (36%), n=22 project sites. The eucalyptus tree species are visible at the other seven (32%) sites. Unfortunately, there were limited interventions seeking to initiate grass at three (14%) sites, gabion blocks at two (9%) and paddocks at two (9%) sites, and yet measures that increase fodder production, control erosion and reduce overgrazing assist in treating the root causes of wetland destruction than heal the symptoms. Wetland rehabilitation modelling needs to take these symptoms into account.

The study area had a varying picture of wetland re-vegetation projects. There were no plants on slopes of more than 25° at seven (32%) of the sites, n=22, while sisal and vertivar grass have been used for re-vegetation at eight (36%) of the project sites. The researcher observed the presence of sisal at Maturure wetland in the Bikita District from the sampled wetland projects. Indigenous re-vegetation was also used as a strategy at four (18%) sites. However, the Eucalyptus species were used to repair degradation at three (14%) sites. It was also observed that the wetland periphery is experiencing deforestation and requires immediate afforestation. Yet, no other forms of re-vegetation on slopes at an inclination of more than 25° were observed. Slopes of more than 25° are susceptible to flash floods and soil erosion which limits the catchment recharge capacity.

Observations on the use of indigenous trees for conservation were also made. The use of indigenous trees for rehabilitation was, however, noted at seven (32%) of the observed sites, but the trees cover up to 20% of the wetland area. It was further recorded at eight (36%) of the sites that indigenous trees only cover 21–40% of the steeper slopes, while four (18%) project sites' wetlands have 40-60% and three (14%) of the sites have 61–80% coverage with indigenous trees. There was no site with indigenous cover of 81–100% that was recorded. The existence of indigenous vegetation on steep slopes, such as close to Mupunga, Zishiri, Makanda and Maturure wetlands, facilitates the slopes' water recharge and discharge.

The performance and effectiveness of fencing to reinstate the health of a wetland depends on the number of strands on the barbed wire fencing. The number of strands and their spacing determine their ability to prevent livestock from entry which creates footpath that initiate gully formation. The findings also reveal that seven (32%) of the site fences have five strands, with five (23%) sites having four strands only. Notably two (9%) sites had three strands. However, it was discovered that the lack of mesh wire, save for the Silveira Mission rehabilitation project and the Maturure wetland in Bikita, was a weakness in most cases. Wire mesh is very important for the lower parts of the defence against small stock that includes goats and sheep.

The observation schedule also sought to check on the presence of herbaceous plants, such as reeds, on the wetlands under study. Herbaceous plants are plants that have no persistent woody stem above ground. Examples of herbaceous plants includes grassses. They are important as pioneer species in plant succession and revegetation of degraded ecosystems. No herbaceous plants and trees were recorded at about seven (31%) sites. A total of 11 sites and 50% of the total sites were observed as having up to 25% of herbaceous plants on shallow banks/gentle slopes. At three (14%) sites the percentage of herbaceous plants was 26–50%, while only one (5%) site had 51–75% covered with herbaceous plants on shallow banks and gentle slopes. The presence of herbaceous plants is important in guarding against erosion, enabling hydrological recharge and also points to a level of ecosystem biological integrity.

5.4.2 Infrastructural limitations

It was observed that a number of wetlands in this study do not have motorised pumps that can contribute to excessive abstraction and eventual drying up the ecosystem wetlands. It was noted that 16 (73%) of the 22 wetlands observed do not have motorised pumps. However, the presence of one or two motorised pumps to supply water to nearby users was observed at Zishiri, Silveira Mission, Magwenzi, Kofoto wetland rehabilitation projects. The availability of electricity and large population at Business Centres, Mission High Schools and Mission Hospitals necessitated the installation of electric pumps at the above-noted study sites. The presence of such pumps, although desirable contributes to excessive abstraction, which depletes groundwater base flows that sustain wetlands. In addition, motorised pumps withdraw water much faster than the rate of wetland recharge, which exacerbates the wetlands‘ drying up and defeats or limits the achievement of rehabilitation goals. Although EMA does regulate the amount of abstraction, the licencing and quota system, few people adhere to the regulation

South East Zimbabwe has a water scarcity problem. Rehabilitation interventions need to take this situation into account and not only reinstate wetland wetness but make water resource available to the communities as well. Weirs have been constructed at six (16%) n=26, of such sites, while ponds are available at five (19%) sampling points, canals at

(19%) wetland patches, raised beds at seven (27%) and mulching recorded at three (12%) sites. A number of weirs are evident around both the Kofoto and Silveira wetlands. However, trampling is retarding efforts to re-instate the wetness of that fragile resource. Nevertheless, water harvesting rehabilitation structures, such as weirs, which help to counter rainfall variability in the face of climate change and enhance successful rehabilitation, can be introduced here. The weirs counter challenges of rainfall dynamics by harvesting storing for future use which reduces over-reliance on wetlands.

5.4.3. Financial limitations

Rehabilitation efforts are costly and require huge sums of money. Zimbabwe is one of the countries that has had less progress in key action areas such as sustainable resource conservation financing (Mwendera, 2010). The source of funding for the initiatives is thus a critical element, which is why the researcher investigated the nature of funding at the various rehabilitation projects during the fieldwork. A majority of the rehabilitation projects are funded to the value of US$1 000, although some are heavily funded. The results from the observation assessments show that 15 (68%) of the projects were funded to about US$1 000 on the basis of costing the available infrastructure. The other two (9%) projects' capital expenditure amounted to US$5 000 (Makanda and Sendeya Mangisai), and a further three (14%) were valued at US$5 000–US$15 000 (Maturure, Manjinji Pan and Mupunga) and the final two (9%), Mutubuki and Magwenzi, were financed for between US$20 000–US$35 000.

Nevertheless, the state of rehabilitation infrastructure at some of the observed sites does not mirror the amount channelled towards them by multi-lateral institutions. Kaffashi et al. (2015), observe that stakeholders can help better the conservation of wetlands by affecting or encouraging international funding in wetland rehabilitation. In any case the contribution of both locals and non-riparian communities in conservation programmes is likely to bring better results.

A majority of the projects, amounting to 9 (41%) of the sites observed are funded by the communities. The Environmental Management Agency is responsible for financing 7 (32%) of the on-going rehabilitation projects in South Eastern Zimbabwe. EMA usually works in partnership with non-governmental organisations, which are a source of funding for three (14%) of the projects, while the government is responsible for two (9%) of the projects. One rehabilitation project (5%), namely Machingambi in Bikita, is not funded at all. This project is only a project in the sense that the communities harness labour to fill a gully with loose rock packs to stabilise it. There was a pile of loose rock packs intended to stabilise a gully at Machingambi (Figure 5.5 B). However, the rudimentary nature of the environmental engineering initiative at Machingambi failed to stabilise the gully such that another gully is developing within the gully; hence erosion has not been arrested.

5.4.4. Managerial limitations

The performance of wetland remediation efforts depend on the source of skills applied to wetland rehabilitation. Environmental engineering skills are critical in the implementation of rehabilitation plans. Assessments conducted during the fieldwork reveal that community-based basic expertise 10 (40%) is all that is available to execute and run the rehabilitation project. Community members apply simple and basic skills obtained from experiences in road rehabilitation to repair wetland gullies. As a result, there are poor and loose erosion stone checks piled in a gully at Machingambi in Bikita District, which were meant to stabilise a network of gullies. In addition, the typical fence at Makanda project in Gutu is not durable and hence will not last long. Environmental engineers applied their skills to about six (24%) installations, while civil engineers supplied skills at about three (12%) project sites, especially in the installation of weirs at Kofoto in the Gutu District, resulting in better conditions leading to the re-establishment of the wetness of the ecosystem. Agricultural extension services (Agritex) officers were also involved in two (8%) initiatives, while Indigenous knowledge Systems were applied at wetlands such as the Manjinji Pan in the Chiredzi District and the Zishiri wetland in the Zaka District. Wetlands are complex systems but their management is sometimes fragmented amongst numerous authorities and departments. These have differing levels or types of expertise as well as diverse and sometimes conflicting interests and agenda (Coiacetto, 1996), hence calling for a coordinated effort in their management.

Each rehabilitation project was rated on a scale of 1-10 to ascertain its performance using the suitability of environmental engineering structures intervention criteria. Direct field observations indicate that five (23%) of the sites scored two out of 10, while 8 (36%) rehabilitation sites score four out of 10. This implies that a combined total of 13 (59%) sites out of the 22 sites scored less than 5 out of 10. Nonetheless, four sites representing 18% scored 6 out of 10, and 5 (23%) of the sites scored a satisfactory 8 out of 10. No project rehabilitation project scored 10 out of 10. This poses serious challenges for the overall performance of rehabilitation initiatives being undertaken in the study area.

5.4.5 Community limitations

Most of the homesteads are situated at 100 metres away from the wetlands. Not even a single wetland project site is more than 500 metres from a homestead. The observed situations create inhibiting social conditions for wetland health and recovery from degradation. The distance between a wetland and a homestead is a strong factor determining the failure or success of such projects considering such issues as the extent of the buffer zone.

Interviewees also made comments on the level of water use for domestic purposes. Interviewees estimated that a range of 0–20% abstraction of water at about seven (32%) of the wetland sites is used for domestic usage. Furthermore, the amount of water withdrawal at six (27%) wetland rehabilitation sites for home usage amounts to 21–40%, while at four (18%) sites water abstraction for domestic use is at 41–60%, three (14%) sites had water abstraction for domestic use sitting at 61–80%, and two (9%) sites having the amount of water abstraction for domestic use falling within the 81– 100% range. Instances where water abstraction for domestic use is too high suggest that there is a need to provide alternative sources of water for human consumption. Wetland rehabilitation planning needs to take into account many different aspects of the wetland and its context (Sieben, 2011). The provision of alternative sources of water to wetlands is commendable. It is, however, emphasised that the performance of wetland rehabilitation projects depends on other factors besides volumes of water demand and the abstraction from that resource.

5.4.6. Rehabilitation performance

The interview held with the Projects Officer focuses on the state of current rehabilitation projects and their performance limitation(s). The interview findings reveal that the EMA is working in conjunction with the AREX in the implementation of rehabilitation projects. Partnerships are important in creating capacity in wetland remediation. However, there are problems with the involvement of the AREX in wetland rehabilitation because this institution is responsible for ensuring food security and as such the AREX tends to promote utilisation and piecemeal rehabilitation. In addition, the AREX tends to take a top-down, technocratic, prescriptive and centrist approach, which is opposed to a participatory and more democratic bottom-up strategy suited to wetland rehabilitation. The EMA also works closely with traditional leaders in enforcing environmental legislation. The major weakness of traditional leaders in law enforcement lies in a lack of knowledge about the requirements of the Environmental Management Act chapter 20: 47. The Act requires that one must get permission for wetland utilisation from the responsible Minister. It also stipulates the implementation of mandatory Environmental Impact Assessments before wetland utilisation for agricultural purposes. Finally, traditional leaders' power is limited here in that they can create social fences but lack the authority to enforce laws.

The interview also highlighted that Rural District Councils are also involved in land allocation and are thus key partners in wetland management. The communal tenure system of land ownership structure influences use of wetlands. Communal ownership as opposed to private ownership creates a lack of responsibility for rehabilitating degraded wetlands. The model of wetland rehabilitation should therefore acknowledge these challenges.

Other instruments and tools involved in the rehabilitation projects are Local Environmental Action Plans (LEAPs). LEAPs stipulate the involvement of environmental committees in communities and environmental subcommittees but these are often not effective. It was also pointed out that some of the Non-Governmental Organisations (NGO), such as Oxfam, Christian Care and Plan International, were engaged in wetland repair in

Masvingo. NGO's are key participants because they bring with them the much needed expertise and financial resource base that ensure success of such projects.
Some of the NGO's provide capital that is used to buy fencing materials and initiate consolidated nutrition cropping plots which are comprehensive components of wetland rehabilitation. What also emerged from the findings is that NGO's also introduce populist approaches, such as nutrition cropping plots in their Public-Private Partnerships which rather than reinstate a wetland's wetness and ecological status ended up exacerbating wetland degradation. Nutrition cropping plots run by NGO utilise underground water from boreholes which negatively affect nearby wetlands.

The interview also shed light on government departments involved in wetland rehabilitation. Government ministries and agencies involved in wetland management play a key role in successful wetland rehabilitation. The Ministry of Agriculture through its agent, the AREX, is vital in project monitoring, especially in addressing issues relating to wetland cropping. The Department of Mechanisation assists in pegging contour ridges and determines their spacing. This is an important factor in catchment water recharge and erosion control. The Forestry Commission is a key player in woodlot establishment and management. The commission deals with loss of biodiversity not only in wetlands but on uplands and river catchments as well. There are also some IGOs (Inter Governmental Organisations) involved in wetland management, which are in the agricultural and land reform ministries and environment and climate change departments.

Another question that was posed to the Projects officer during the interview was on measures that need to be taken to improve wetland rehabilitation projects. It was suggested that there is a need for capacity building, which is crucial in community based natural resource management efforts for resources such as wetlands. Various measures are usually put in place to build capacity. Some of the measures implemented to enhance capacity building in the communities for successful rehabilitation include the training of local communities and government departments staff that interact with farmers. The training of community law enforcement agents, such as traditional leaders is therefore necessary for the achievement of ecosystem sustainability.

It was also suggested by the Projects officer that training of local farmers on wetland rehabilitation can also improve rehabilitation efforts. The direct training of farmers can thus empower them on on-farm wetland remediation measures. On-farm wetland rehabilitation is the only way to restore wetland health considering that wetland protection without preservation is counter-productive and unsustainable. Finally, it was also highlighted that a multipronged approach to raise awareness through print and electronic media can be taken at exhibitions such as agricultural shows and through road shows.

Challenges relating to wetland rehabilitation were also outlined by the Project Officer. There is a lack of commitment from other key government departments, such as local government and rural district councils, in upholding environmental stewardship. The Project Officer echoed the sentiments expressed in literature such as that of Kaffashi et al. (2015) that the most serious among the myriad of challenges is limited funding of wetland rehabilitation. The other linked problems are pressure on land due to overpopulation, which results in the cultivation of wetlands. Furthermore, the prevalence of poverty means that communities over-rely on natural resources for livelihoods which therefore demand that alternative subsistence alternatives have to be put in place to save wetlands.

From interview results with the Projects Officer it was found that there is need to improve wetland health through increased funding towards wetland rehabilitation projects. Wetland health can also be improved through the diversification of livelihood options. For example instead of wetland based cultivation production communities should practice dam water fed upland irrigation. So relocation of nutrition cropping plots to nearer dams helps to recover wetland vitality. Diversification and other alternatives to reliance on wetland resources are part of the solution to wetland threats. The performance can also be increased by law enforcement on wetland protection, such as the implementation of the EMA act's requirement for a buffer zone of 100 metres to avoid stream bank cultivation. The fact that a majority of the wetlands in Zimbabwe are of a riverine nature suggests that it would be prudent that this legislative restriction is adhered to. There is thus a need to improve awareness of key stakeholders on sustainable wetland practices, for example AREX officers and farmers, since they are more on the ground and in touch with wetland conditions. Figure 5.8 shows rehabilitation using mesh-wire fencing at Maturure in Bikita.

Figure 5.8: Fencing using mesh wire at Maturure in Bikita.

5.5. Hypothesis Testing

The study sought to test the null hypothesis that, *financial investment in wetland rehabilitation does not lead to wetland recovery.* The alternate hypothesis was, *financial investment in wetland rehabilitation does lead to wetland recovery.* . Correlation analysis was used to test the hypothesis that, *financial investment in wetland rehabilitation does lead to wetland recovery.* One wetland rehabilitation project was randomly selected from each district. Data that were generated from the field and official documents as shown in Table 5.2 was used to for the purpose of conducting various tests. It shows the influence of funding on the size under wetland rehabilitation since the inception of the projects, which covers more than 20 years.

Table 5.2: Influence of funding on the size under wetland rehabilitation

Name of Wetland	Size of Wetland (Ha)	Size under rehabilitation (Ha)	Size under rehabilitation as a %	Capital Expenditure in US$ on project
Masvingo Projects	716	165	23%	$72 000
Magwenzi	8	5	63%	$33 000

Mutubuki	5.9	3	51%	$21 000
Maturure	5.5	5.5	100%	$7 000
Mupunga	7	3.5	50%	$15 000
Sendeya-Mangisai	1.9	1.5	79%	$5 000
Manjinji Pan	1.5	0.9	60%	$12 000
Makanda	1.9	1.4	74%	$2 000

The hypothesis *financial investment in wetland rehabilitation is not leading to wetland recovery,* was calculated thus, H_0: p = 0; H_1: p≠ at α = 0, 05; R = 0, 90749; N = 8; Test statistic: T= $\frac{\sqrt{n-2}\ R}{\sqrt{1-R^2}}$; $=\frac{\sqrt{8-2}\times 0{,}90749}{\sqrt{1-0{,}90749^2}}$; = 12,962; Critical value = 2,447; Reject

H_0: if $|T|$>Tα/2; n-2. Since T = 12,962, and the critical value is = 2,447, then the H_0 is rejected. With the rejection of the alternate hypothesis the conclusion that p≠ 0, which is the size of wetland rehabilitated is related to the amount of financial investment allocated are correlated. Therefore, the null hypothesis is accepted and it can be concluded that the amount of money in US dollars allocated per year per project has a statistically significant impact on the total size of area of the rehabilitated wetland. These results focusing on the wetland projects show that with enough funding wetland rehabilitation can be successful. The results showing the Pearson correlation, analysis of variance and correlation appear in Table 5.3. The results are based on Table 5.2 by comparing the amount of money spent on rehabilitation and the size of area of the wetland rehabilitated as a proportion of total wetland size.

Table 5.3: Correlations analysis between financial investment and rehabilitation size

		Capital expenditure in US$ on project	Size under rehabilitation expressed in square kilometres
Pearson Correlation	Capital expenditure in US$ on project	1.000	.907
	Size under rehabilitation expressed in square metres	.907	1.000
Sig. (1-tailed)	Capital expenditure in US$ on project	.	.001
	Size under rehabilitation expressed in square metres	.001	.
N	Capital expenditure in US$ on project	8	8
	Size under rehabilitation expressed in square metres	8	8

Table 5.4 illustrates that there is a strong relationship between the level of financial investment and the wetland recovery. It is also evident here that the more money committed and channelled towards rehabilitation projects, the greater the size that is under rehabilitation. The converse is also true.

Table 5.4: Analysis of variance (ANOVA) between funding and rehabilitation size

Model		Sum of Squares	Df	Mean Square	F	Sig.
1	Regression	3026405376.362	1	3026405376.362	28.002	.002[b]
	Residual	648469623.638	6	108078270.606		
	Total	3674875000.000	7			

a. Dependent Variable: capital expenditure in US$ on project

b. Predictors: (Constant), size under rehabilitation expressed in square kilometres

An analysis of variance was used to determine the relationship between financial investment and the size of the rehabilitated wetland. The analysis of variance (ANOVA) between financial investment and rehabilitation size in Table 5.2: was used to draw up Table 5.5 which shows a strong correlation between the two variables.

Table 5.5: Coefficients[a] funding and rehabilitation size

Model		Unstandardized Coefficients		Standardized Coefficients	T	Sig.	95.0% Confidence Interval for B	
		B	Std. Error	Beta			Lower Bound	Upper Bound
1	(Constant)	12448.691	4005.673		3.108	.021	2647.163	22250.220
	Size under rehabilitation expressed in square metres	362.812	68.563	.907	5.292	.002	195.045	530.579

a. Dependent Variable: capital expenditure in US$ per project

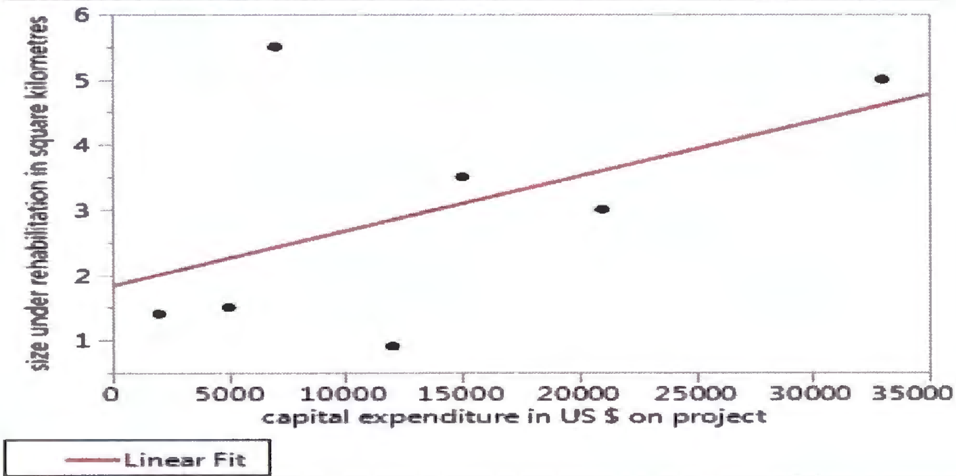
The correlation coefficient for financial investment and size under rehabilitation is +0.907 in Table 5.5. This value of r suggests a strong positive linear correlation since the value is positive and close to 1. This means that the data points are clustered closely about a positively sloping regression line. The coefficient of determination is 0.824; therefore, 82.4% of the variation in the capital expenditure data is explained by the size under rehabilitation. The regression equation appears to be very useful for making predictions since the value of r^2 is close to 1.

The regression equation from above is:

Capital expenditure = 12448.691 + 362.812 size under rehabilitation

The regression analysis shows that the p value 0.02 is less than 0.05, hence the null hypothesis that is, *financial investment in wetland rehabilitation does not lead to wetland recovery* is rejected, while the alternative hypothesis is accepted and the conclusion made is that the amount of money in US dollars allocated per year per project (financial investment) has a statistically significant impact on the total size of rehabilitated wetland expressed in square metres. The statistical results reveal that it was 95% confident that the slope of the true regression line is somewhere between 195.045 and 530.579. In other words, there is a 95% confidence level that for every kilometre of the size of wetland under rehabilitation, the average amount of money allocated per year in US dollars increases somewhere between $195 045 and $53 057

Bivariate Fit of size under rehabilitation in square kilometres By capital expenditure in US $ on project



Linear Fit

size under rehabilitation in square kilometres = 1.8305152 + 8.4067e-5*capital expenditure in US $ on project

Summary of Fit

RSquare	0.246537
RSquare Adj	0.095844
Root Mean Square Error	1.723601
Mean of Response	2.971429
Observations (or Sum Wgts)	7

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio
Model	1	4.860291	4.86029	1.6360
Error	5	14.853995	2.97080	Prob > F
C. Total	6	19.714286		0.2570

Parameter Estimates

Term	Estimate	Std Error	t Ratio	Prob>|t|
Intercept	1.8305152	1.104554	1.66	0.1584
capital expenditure in US $ on project	8.4067e-5	6.573e-5	1.28	0.2570

Figure 5.9. Bivariate fit of wetland size and capital expenditure

The JMP Software was also used to analyse the relationship between size of wetland rehabilitated and level of funding. The JMP output in Figure 5.9 shows that the R squared value is 0.82354, which implies that 82% of the variability is explained by the model and confirms further that the amount of money allocated per year per project (financial investment) has a statistical impact on the total size of rehabilitated wetland. The β_1, i.e. intercept, is equal to 0.0022699, whose p-value = 0.0018 < 0, 05, hence H_0 is rejected, thus indicating the parameter significance of the estimate. This then means that the amount of money allocated per year per project (financial investment) has an impact on the total size of the rehabilitated wetland.

Table 5.6 shows the projects that have been funded in Zimbabwe from 1993 to 2010. These projects cover thematic areas such as biodiversity conservation, climate change, international waters, land degradation, and management of persistent organic pollutants.

Table 5.6: Funds allocated in each operational phase and funded projects

Operational Phase	Projects funded under each thematic area							Total grant allocated under each phase
	BD	CC	IW	LD	POP'S	Multifocal	Total Projects	Total Grant Allocated
1. Pilot phase (1993 – 1995) and Operational phase 1 (1996 – 1998)	23 71.88 %	3 9.38%	3 9.38%	0 0%	0 0%	3 9.38%	32 100%	878.266.69
2.Operational phase 2 (Feb 1999 to Feb 2006)	20 51.28 %	9 23.08 %	2 5.13%	4 10.26%	1 2.56%	3 7.69%	39 100%	1.355.464.99
3.Operational phase 3 (2005-2007)	17 56.67 %	3 3.00%	2 6.67%	3 3.00%	2 6.67%	3 3.00%	30 100%	800 000
4.Operational phase 4 (J2008-2010)	7 18.92 %	3 8.11%	0 0.00%	12 32.43%	6 16.22 %	9 24.32%	37 100%	1.200.000.00
TOTAL	67	18	7	19	9	18	138	4.383.794.67

KEY: BD –Biodiversity, CC - Climate Change, IW - International Waters, LD - Land Degradation, POPs Persistent Organic Pollutants

The projects have been funded by multi-lateral institutions. Although a high number of biodiversity conservation projects and wetlands have been supported, this does not necessarily mean that large amounts of funds were channelled towards wetland rehabilitation. There are various projects in environmental management and science, which all compete for financial support from similar sources. For example a total amount of US$800 000 was allocated during operational phase three but in phase four the amount jumped to US$1, 200 000. It is suggested that rehabilitation projects generate their own returns so that project sustainability is achieved.

The linear trend line (figure 5.10) shows that the funding for environmental conservation projects is on the general increase and rehabilitation planners need to maximise on that through careful planning and lobbying for funds.

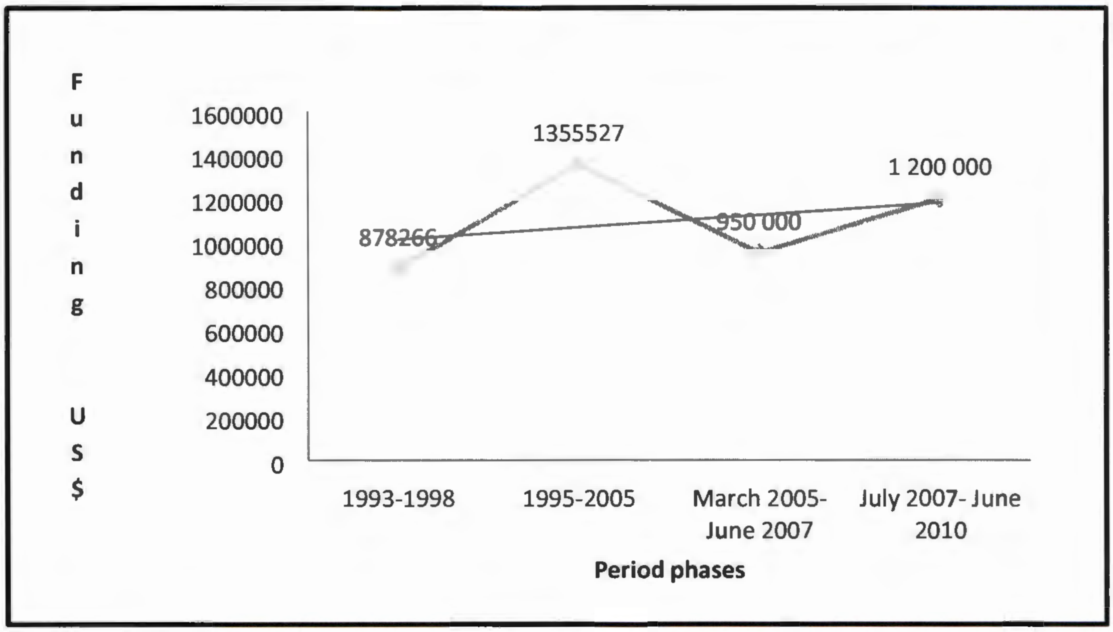


Figure 5.10: Funding of conservation by SGP-GEF in US$

There is a wide variation in percentage allocation between the environmental areas of interest because donor funds come with strings attached to them. Although funds for environmental funding in figure 5.10 are on the rise, it seems that more money needs to be channelled towards operational costs as opposed to administrative expenditure. It is vital to state that without community participation, it is practically impossible to achieve sustainability. Successful rehabilitation may require long-term engagement, sensitisation and capacity building at all levels of the community. Individual responsibility becomes a key feature. These are the key parameters that underpin wetland rehabilitation modelling discussed in chapter 6.

The best performing rehabilitation projects should allow for ecological objectives to be realised together with community's socio-economic goals. Compromising on the livelihood needs of people will render rehabilitation goals unachievable. According to Chifamba (2013), the trade-off between environmental protection and development is most acute in dynamic and complex ecosystems such as wetlands. It is for this reason that a holistic approach to wetland governance, which puts the environment and people's needs first, is essential to confront the changes posed by wetland degradation. It is feasible to achieve wetland rehabilitation and production by adopting a holistic approach to the seemingly intricate environment-human interface. However, it needs to be pointed out from the discussed hypothesis that, availability of capital is critical to attaining some of the goals. In a nutshell relocation and resettlement reduces overcrowding and wetland degradation. Adherence to riparian zone requirement and grazing ban requirement enhances wetland integrity and vitality. Re-vegetation and reafforestation not only re-instate the biological diversity of the ecosystem but the health of the wetland itself. Last but not least without the necessary engineering works such as gabion blocks and fences rehabilitation does not succeed and these parameters need to be captured in wetland rehabilitation.

5.6 Summary

This chapter discussed the two objectives of this research, which are the current state of wetland rehabilitation projects and performance limitation of current rehabilitation. It also discussed the findings from observations recorded in the field and from an interview conducted with the projects officer of the EMA of the Masvingo Province in Zimbabwe. Both technical, managerial, financial and community circumstances contribute to the current poor state of wetland rehabilitation in Zimbabwe. The results revealed that a paradigm shift is required to re-establish wetland structure, wetland function and wetland biological integrity. Finally, it is evident in the chapter that results from hypothesis testing demonstrated that there is a close link or significant relationship between the level of financial funding and the size of land under rehabilitation. The next chapter focuses on the design of a wetland rehabilitation model and the results of tests conducted to test its applicability.

CHAPTER 6: MODEL DESIGN AND TESTING

6. 1 Introduction

The development of a mathematical model is the first step in using models to solve problems of a scientific nature. The model developed in this study aims at addressing wetland loss and degradation in Zimbabwe and other parts of the world with similar situations. The design of wetland rehabilitation models in Southern Africa in general and in Zimbabwe in particular is in its infancy. This is especially the case with large catchment areas that encompass on-site and off-site rehabilitation plans. Although the study area is relatively small, the resultant model can be reliably applied to large scale catchments. There is therefore a need for models that can work on both site specific and catchment scales (Acreman et al. 2007). The model is constructed from the inputs arising from interviews conducted heads of households in riparian and non-riparian communities. The other data source was responses made by the EMA Project Officers and the records from field observations of the assessment of rehabilitation projects.

6.2 Materials and Methods

6.2.1 Desktop survey

Prior to field investigations being undertaken on modelling wetland rehabilitation projects, the concept was surveyed at a desktop level using *Google Scholar* search engines. A desktop survey helped to review literature on wetland rehabilitation in different parts of the world. Publications in the database therefore make reference to original field data from projects promoting the adoption of sustainable wetland rehabilitation practices in a specific area and implemented by local institutions. These results informed the key components in model development.

6.2.2 Interviews

In this study a total of 159 interviewees constituted the sample size drawn (n=159) from riparian community and non-riparian communities members. Structured interviews were conducted with the 159 interviewees described earlier in chapter 4.

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6.2.3 Observation

The observation research method was used as another tool during the data collection phase and involved the researcher making observations in the study area. Photographs were taken of some rehabilitation structures such as fences which informed the researcher in wetland rehabilitation modelling. This aided memory recalling during the thesis write-up.

6.3 Key research findings

The following key findings generated from this research are used to construct a wetland sustainability model.

Objective 1

1. Long-term rainfall data from 1980-2015 shows that Masvingo province experiences extreme rainfall variability within a single rainfall season.
2. Wetland loss is an on-going phenomenon and unless urgent rehabilitation efforts are taken to reverse the trends, the wetlands can become totally lost.
3. A weak link exists between wetland loss and changing rainfall patterns in SouthEastern Zimbabwe because natural systems have a tendency of self-correction following natural disturbance, but there is a direct relationship between recharge and wetland vitality.

Objective 2

4. Socio-economic factors, such as education level, family, crop output and income levels, impact on both wetland degradation and wetland rehabilitation.
5. Income gains from direct wetland utilization and wetland utilization off-sets are low and need to be maximized by initiating and increasing number of consolidated nutrition cropping plots.
6. The level of preparedness to pay for ecological services is high and the community is willing to invest in wetland rehabilitation.
7. Institutions and communities responsible for wetland rehabilitation such as EMA, AREX, RDC's, and NGO's are weak and fragmented.

Objective 3

8. The extent of wetland rehabilitation is not adequately documented.
9. Engineering project structures are poor, piece meal, vandalised, basic and simple.
10. Wetland rehabilitation only covers 23% of the possible degraded wetlands that should be rehabilitated.

Objective 4

11. The rehabilitation programmes are not adequately financed.
12. Results from hypothesis testing show a statistically significant relationship between the level of financial investment and wetland recovery.

Objective 5

13. A sustainable wetland rehabilitation model is feasible for Zimbabwe.

6.4 Aim of the model

The aim of the model is to re-establish lost wetland structure and functions and enhance the socio-economic wellbeing of communities in a wetland catchment.

6.5 Model Assumptions

The model assumptions were derived from research findings of this study. The assumptions are listed as follows:

1. South-Eastern Zimbabwe receives low rainfall.
2. Wetland loss is an on-going phenomenon but reversible by rehabilitation.
3. Wetland resources are an integral and indispensable component of the rural economy that require a balance to be struck between production and conservation in the scheme of resource use.
4. The management of water in the wetland catchment is key to achieving wetland sustainability by balancing socio-economic development and wetland ecosystem needs.
5. Communities value their wetlands and are willing to participate in green and blue economies.
6. Zimbabwe needs a model that streamlines financial allocation in wetland management projects.

6.6 Model Inputs

The key variables of the model, which are based on major findings of the study, are;

- net wetland utilisation income,
- wetland fencing efficiency index,
- lifespan coefficient of intervention structures,
- institution power matrix on rehabilitation decision making,
- management weight matrix on rehabilitation projects, and
- Mean funding % of total expected rehabilitation expenditure.

Each parameter has a set of actions that need to be implemented by responsible actors to achieve desired outcomes. The desired outcome is ecological sustainability. This is the ability of the wetland to continuously supply ecosystem goods and services, and the enhancement of the surrounding community's economic viability.

6.6.1 Net wetland utilisation income

The target goal and parameter of the model is based on viable projects. This entails communities should be involved in installing irrigation projects together with fencing to achieve sustainability. Rehabilitation is not only fencing and removal of smallholder nutrition cropping plots but also involves the concomitant partial downstream or downslope cultivation to address socio-economic needs of riparian communities. Wetlands are, undoubtedly, an integral component of the production base for rural communities in least developed countries, and in that respect contribute significantly to their livelihoods (Ogato, 2013). It is from this observation that one can postulate that rehabilitation programmes can perform better if a certain threshold income level is attainable by riparian communities that use wetlands (x_1). The benchmark value that can help realise wetland sustainability in this study is US$600. To get the x_1 value the following measurable parameters are factored into:

1. Wetland resources harvested and sold to the market.
2. Financial value, in US$ terms, of food equivalent not bought due to consumption of wetland produced food.
3. Income value, in US$ terms, of produce from upland irrigation nutrition cropping plots sold to the market or option value.

The use of wetland utilisation off-sets, such as upland irrigation, deters wetland invasion and conversion thereby achieving both production and preservation. Wetland avoidance can also be expressed in monetary values as explained in point number three above.

6.6.2 Wetland fencing efficiency index

The wetland fencing parameters that determine wetland vitality and project viability because it is a physical barrier against livestock are listed as follows:

1. Number of strands in barbed wire fencing based on type of livestock.
2. Height of mesh wire fencing based on livestock.
3. Planting live fencing.
4. Community policing (social fences).

The use of 6 strands spaced at 30 cm intervals can be put at 100%, 5 strands at 80%, 4 stands at 60%, while the use of mesh wire, together with barbed wire, assists in deterring small stock, such as goats and sheep, from entering the wetlands. The height of the mesh wire fencing is critical when one considers that cattle can jump over the fence into the wetland. A wetland fencing efficiency index of at least 60% is considered ideal for sustainable and feasible wetland rehabilitation. The observations from the field suggest a strong factoring in this model earmarking 50%, that is, x_2 of a wetland perimeter for complete fencing or preservation whilst the other half can be subjected to sustainable usage. Wetland fencing efficiency index considers the quality and quantity of fencing to yield x_2. The same efficiency index can be tailor-made to planting live fences and raise awareness and sensitise on community policing (social fences).

Although fencing is a limited view of wetland management because it results in ecosystem fragmentation and interferes with other ecosystem services such as habitat and source of food for wildlife, it protects it from livestock driven deterioration.

6.6.3 Lifespan coefficient matrix of intervention structures

The durability expressed in years of engineering works (K2) is vital in rehabilitation. The value of K2 can be determined by the following set of parameters:

1. Number of years the structures such as geotextiles and weirs are expected to last.
2. Frequency of replacing worn out material used for rehabilitation.

Wetland rehabilitation mechanical interventions are measures put on-site and off-site by environmental engineers, extension officers, community groups and farmers to reestablish wetland ecological health. A pre-rehabilitation wetland health assessment determines the form of remedial action that should be installed. Measures that encourage wetland recharge and wetland water retention are highly recommended for installation. Upland weirs recharge pits and afforestation initiatives enhance recharge whilst fencing promotes water retention by arresting trampling, overgrazing and erosion. The interventions employed should aim to improve the system and allow the system to persist after corrective interventions are implemented (Pollard et al. 2004). Such actions, according to the rehabilitation goals, are aimed at reinstating the wetland structure and functions.

6.6.4 Management weight matrix on rehabilitation projects

The management weight efficiency index expressed as a % is used as a measure of the weight of management (m_w) used for rehabilitation. The tools designed are important for project implementation, monitoring and evaluation. The management weight matrix listed as follows are used during project implementation, monitoring and evaluation:

1. Active participation.
2. Technical knowledge.
3. Community policies.
4. Policy frameworks.
5. Strategic plans.

The limitation of the model is failure to predict the complex dynamic behavioural change of rehabilitation management tools. It can be concluded, from the findings that sustainable management of wetlands as a common pool resource is very much linked to the characteristics of the actors and the way they interact with nature through their devised set of institutions (Mombo et al., 2013). A major problem, as revealed by 36% of plot holders, was that of fence vandalisation resulting in domestic animals accessing the wetland (Marambanyika et al. 2012).

6.6.5. Institutions power matrix of decision making

The power can be expressed as a % of ability to make binding decisions. The power matrix ranges from 0–100%. The ability of institutions to make decisions can be measured quantitatively by assessing the score out of 10 of, for example, community based rules and regulations implanted. If 7 community based rules and regulations and out of 10 decisions are put into practice then those institutions will score 70%. Community based rules and regulations should also be specific of actions mandate and compliance for rehabilitation to perform better. The percentage value can be interpreted as follows:

1. A range of 0–30% denotes weak institutions.
2. A range of 31–60% shows moderate institutions.
3. A range between 61–100% strong institutions.

Institutions responsible for wetland rehabilitation make significant decisions seeking to achieve wetland health and sustainability. Project Officers, state actors, traditional leaders and community members, who occupy a central role of the success/failure of the rehabilitation process, have dynamic behavioural factors that impact on the performance of rehabilitation projects. Without community participation, it is practically impossible to achieve sustainable results. This may require long-term engagement, sensitisation and capacity building at all levels of the community. Individual responsibility becomes a feature.

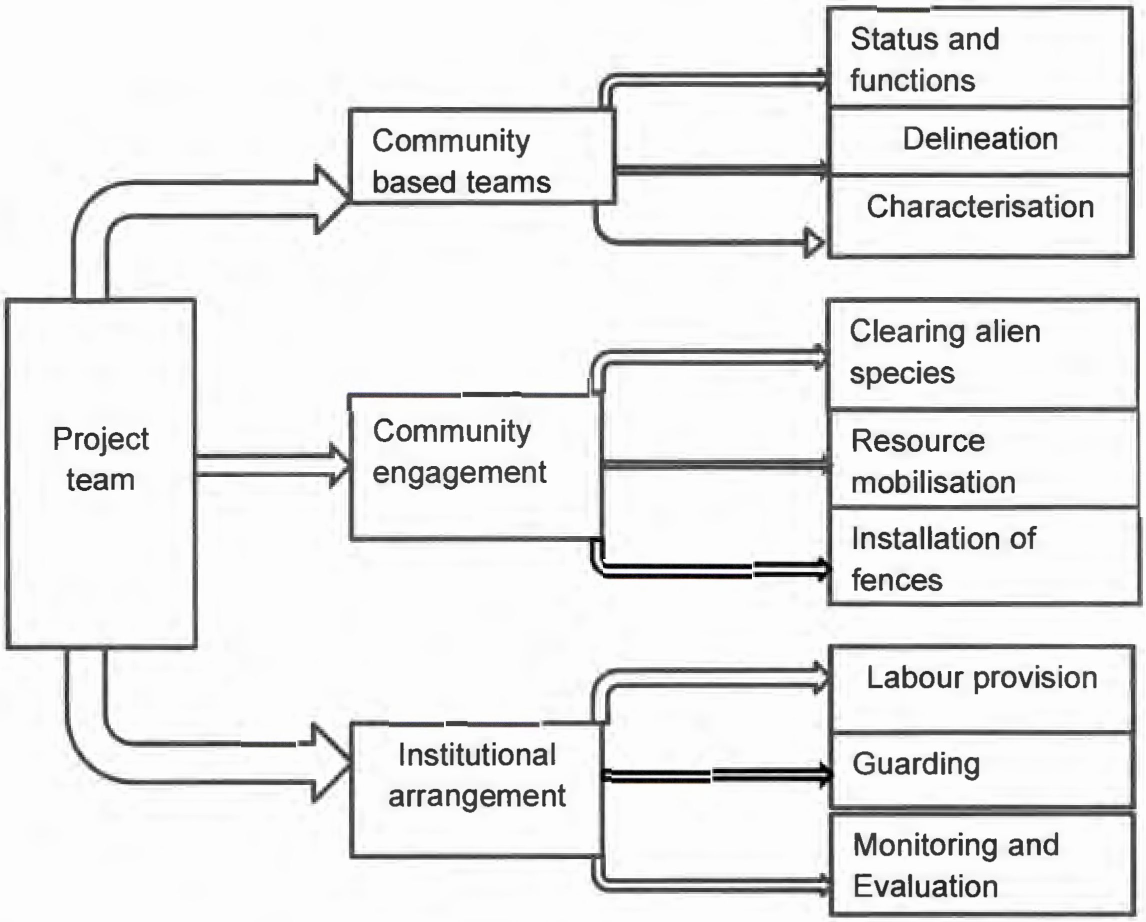

Figure 6.1: Structure and functions of wetland rehabilitation institutions

An incorporation of local institutions, customary practices and knowledge systems is vital in the management process (Armitage, 2005). The identification of rehabilitation sites, implementation of rehabilitation plans, and the monitoring and evaluation of rehabilitation projects, is run using an organogram as shown in Figure 6.1.

6.6.6. Mean % financing of expected expenditure on rehabilitation

Wetland rehabilitation sustainability can be achieved with a certain threshold of funding expressed as a % of expected rehabilitation expenditure. A calculation of the project total cost assists in expressing the amount that is available as a percentage. The breakeven percentage for project viability is set at 65%. This means that projects that exceed that mark pass the test of time for full wetland recovery. Financial funding plays a critical role in putting resources together and enables the purchase of often expensive materials during project planning. Multilateral institutions, according to research findings (Hove et al. 2013), like UNDP which have played a leading role in some successful rehabilitation interventions should continue and expand financial resource mobilisation. However, it should be pointed out that donor driven projects are most often not sustainable and therefore need community financial support. An affordable, lasting and cost effective payment for ecological services mechanism can be put in place at grassroots level to cater for project maintenance costs. Some of the profit realised from the sale of crops from wetlands such as bananas, sugar cane and vegetables should be reinvested into the maintenance of the wetland, by for example, buying fence materials and financing agroforestry activities instead of relying on donors (Marambanyika et al., 2012). All wetland related utilisation activities, including, cultivation; grazing and brick making should be expected to internalise wetland production externalities by paying for ecological services. After paying, local institutions such as AREX and EMA should take responsibility for rehabilitation. Activities such as water abstraction, brick making, grass harvesting, and grazing on wetlands should be considered and fund wetland rehabilitation.

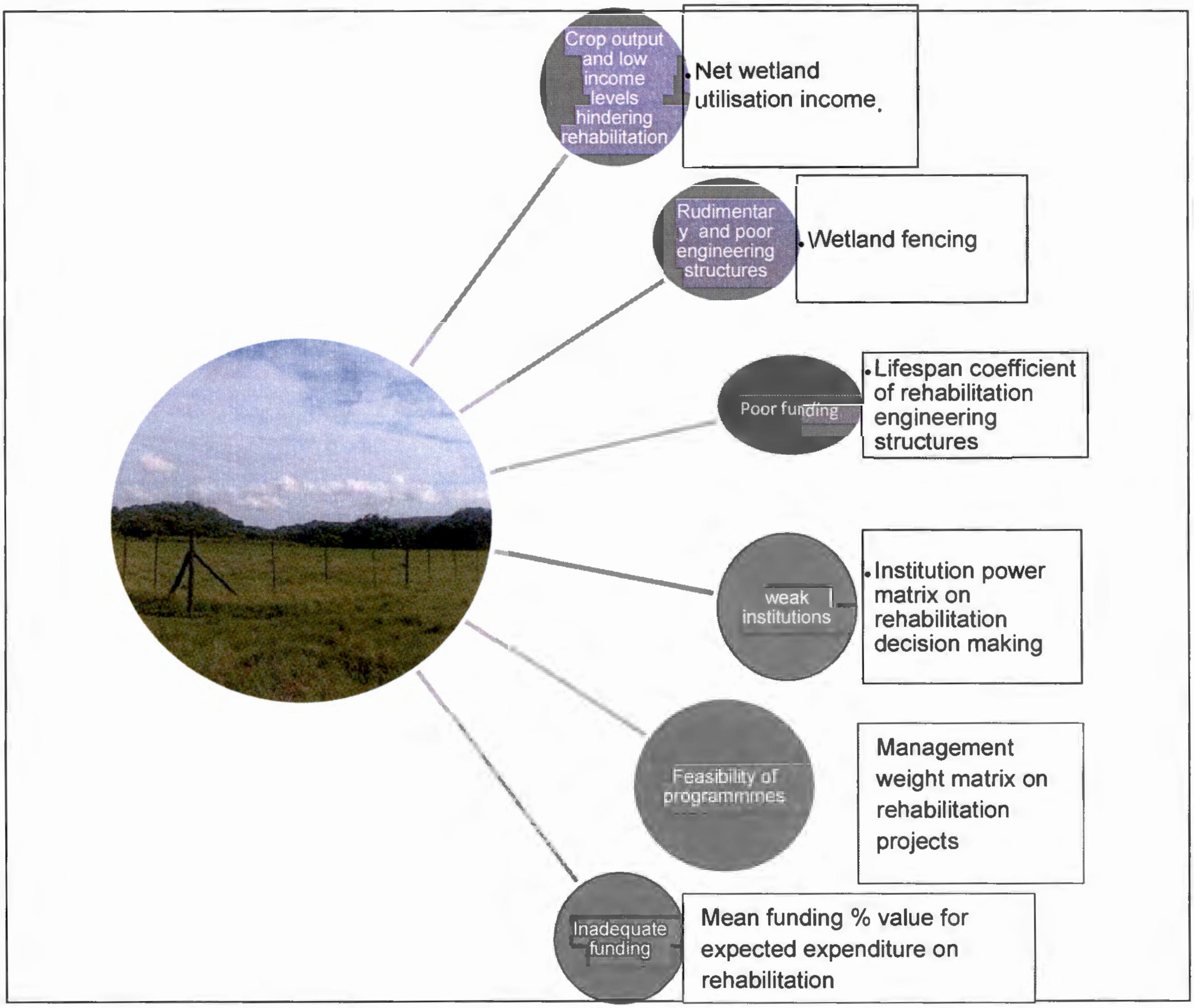

Figure 6.2: Research findings that inform model components

Financing sustainable wetland rehabilitation projects is an acute problem in Zimbabwe. Nyagumbo (2012) attests that poor policy implementation and strategies, and lack of funding, were some of the major weaknesses in Zimbabwe's water management policies. The state lacks logistical and funding arrangements to effectively manage wetlands, (Murombedzi, 1995). The financing of water resources projects by both the government of Zimbabwe and the international donor communities has decreased since 2002. A further challenge is that many water sector agencies are not adequately prepared to cater for the increased funding. Recommendations concerning implementation assistance from the Ramsar Secretariat indicate that a majority of nations, including Zimbabwe, need financial and technical support. The decline in funding is shown in Table 6.1.

Table 6.1: Total Grants Allocated by GEF to Zimbabwe

Operational Phase	**Period**	**Total Allocated (USD)**
Pilot and operational Phase 1	1993-1998	878 300
Operational Phase 2	1995-2005	1 355 500
Operational Phase 3 year 1	March2005-February 2006	400 000
Operational Phase 3 year 2	March 2006- June 2007	550 000
Operational Phase 4 year 1	July 2007- June 2008	400 000
Operational Phase 4 year 2	July 2008- June 2009	400 000
Operational Phase 4 year 3	July 2009- June 2010	400 000
TOTAL		**4 383 800**

Source: UNDP (2011)

6. 7 Model design

The key components used in designing this model are expressed in mathematical terms and are explained in the section on glossary of input measures.

6.7.1 Glossary of input measures

A set of input measures are specified for the proposed model.

Y=Index of achieving a sustainable wetland rehabilitation project. This refers to wetland vitality index that is measurable and quantifiable.

x_1=Net wetland utilisation income. This refers to income that communities derive from wetlands through direct wetland goods sales or fore-going purchase of certain products owing to goods and services obtained from such ecosystems. This income is expressed US$.

x=Fencing efficiency index. The strength value of treated poles and perimeter wire either barbed or mesh wire used to buffer the wetland from livestock grazing and trampling in order to allow for wetland repair and recovery. This supports wetland integrity by recovering its vitality.

k_e=Lifespan coefficient of rehabilitation engineering structures. Life span coefficient is the total time in years that each rehabilitation structure can endure under the same conditions, without the occurrence of flaking in 90% of the system. The rehabilitation structures refer to fences, gabion blocks and weirs.

p_{Φ}=Institution power matrix on rehabilitation decision making. This denotes the % level of power that is vested in people to make binding decisions on wetland rehabilitation.

m_W=Management weight matrix on rehabilitation projects refers to management tools such as institutionalised rules and regulations that are put in place for effective rehabilitation practices expressed as an efficiency index.

f= Mean funding % value of total expected rehabilitation expenditure denotes monetary value of project funding and investment.

6.7.2 Steps in Model formulation

The model is a predictive multiple linear regression model for wetland rehabilitation. Selection of input variables in the formulation of the model was based on processes and factors influencing current performance of wetland rehabilitation projects. These processes and factors were generated from research findings listed in section 6.2. The model was developed in three steps. The first stage proposes the idea that wetland production should be combined with wetland preservation in order to attain optimum wetland production.

This is represented by equation

$Y_1 = B_0+B_1X_1+ B_2X_2 + B_3X_3 + B_4X_4 + e$

$Y_1 = B_0 + \sum B_i X_i + e$ .... Equation 3

Where: $_1\approx$ Utilisation index **X_1**=Fencing

efficiency index

X_2=Production income.

X_3=Cultural value index

X_4=Aesthetic value index

B_0, B_1, B_2, B_3, B_4 are constants

B_1 = Slope **e**= error term

The combined effect of partial wetland utilisation and preservation of a portion creates a win-win situation for both the wetland economy and wetland ecology. The flow diagram that follows explains this equation.

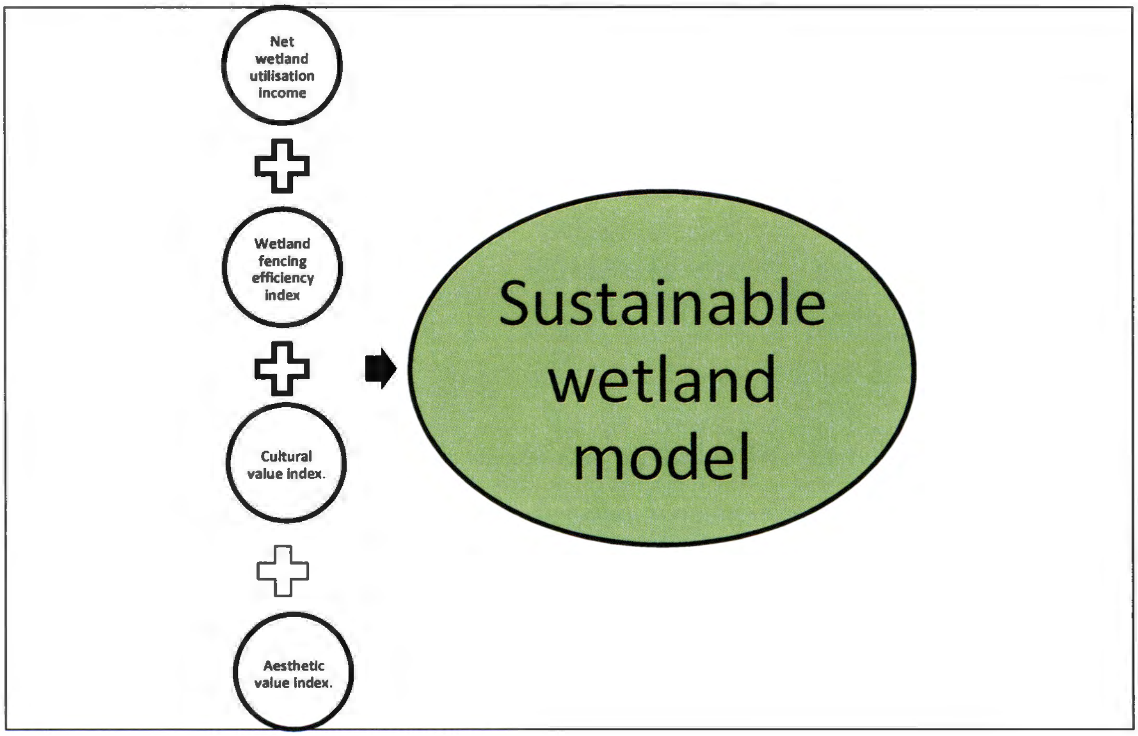

Figure 6.3. Equation that balances wetland production and preservation

Equation 3 is based on the premise that wetland rehabilitation is underpinned by environmental engineering expertise, institution power matrix on rehabilitation decision making, management weight matrix on rehabilitation projects, and the funding of rehabilitation expenditure squared. These key inputs are illustrated by equation 4:

$Y_2=k_e*p_\Phi*m_W*f$ .... Equation 4

Where:

Y_2= Index of achieving a sustainable wetland rehabilitation project

k_e=Environmental engineering coefficient index p_Φ=Institution

power matrix on rehabilitation decision making index

m_W=Management weight matrix on rehabilitation projects index f

= Mean funding % of total expected rehabilitation expenditure

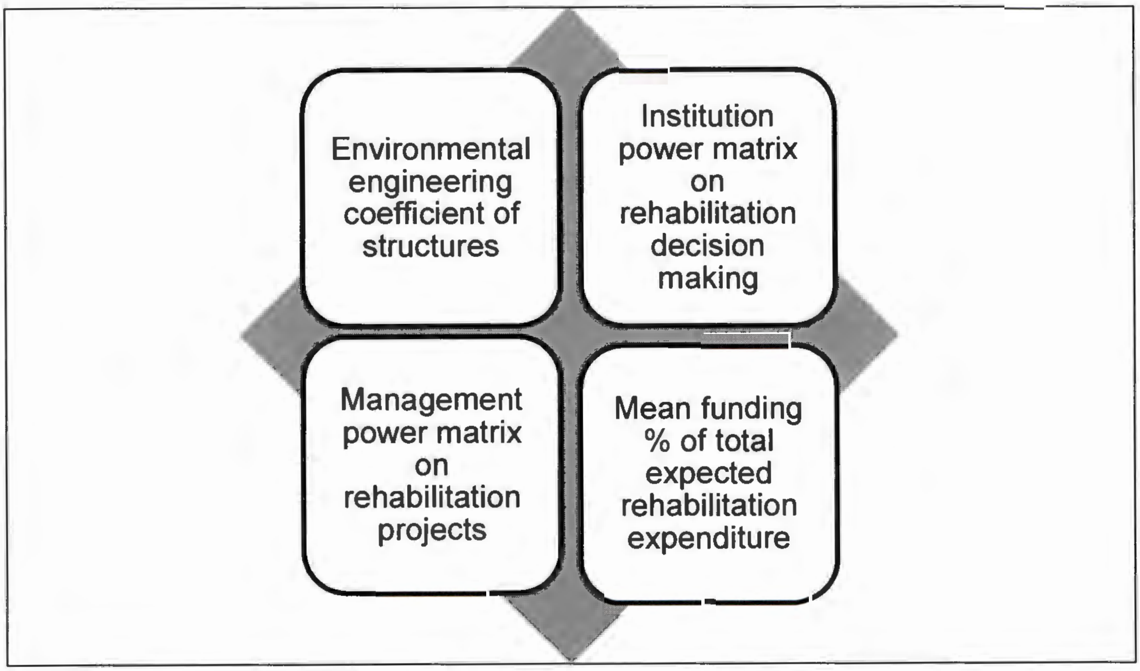

Figure 6.4: Key inputs in achieving wetland sustainability

Finally, a fusion of equation 3 and equation 4 leads to the establishment of equation 5.

$Y_3 = Y1 = B_0+\sum B_iX_i+ B_5 (k_e*p_\Phi* m_W* f)+ e$.............................Equation 5

Where:

Y_3= Index of achieving a sustainable wetland rehabilitation project.

Other terms are as defined in equations 3 and 4

The equation implies that sustainable wetland rehabilitation can be realised if optimum wetland production is promoted and entrenched. Optimum wetland production, in this model, refers to a measure of the maximum ecological potential of a wetland under continuous use with respect to the quantity and diversity of ecosystem services that it can render. The financial capacitation of projects increases the performance of projects to the power of two.

6.7.3 Model inputs, processes and outputs

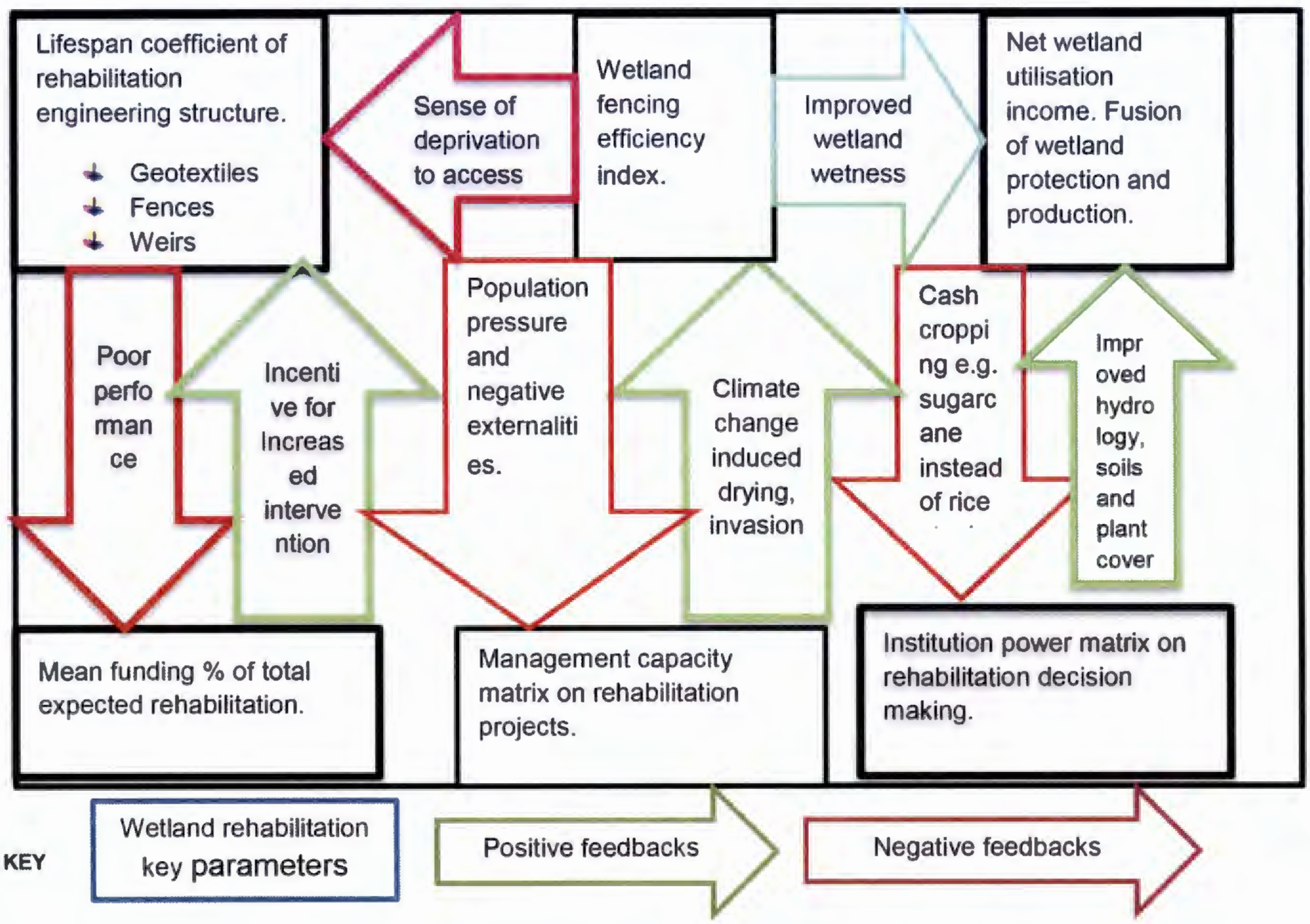

Figure 6.5: Wetland sustainability model.

The model offers a template from which wetland rehabilitation projects can be developed and thereby improve wetland health and performance in providing ecosystem goods and services. Finally, an improvement of wetland structure and functions depends on a solid and sound wetland rehabilitation strategy. Wetland productivity and functionality will be based on wetland hydrology. This must necessarily incorporate catchment management and integrated watershed management. The model in Figure 6.5 is called Wetland Sustainability Model (WESUMO).

Figure 6.5 is a diagrammatic representation of WESUMO. The key parameter variables of the model which are intervening operations are wetland rehabilitation engineering structures, wetland fencing, increasing net wetland utilisation income, increasing wetland rehabilitation funding, management capacity building and strengthening rehabilitation institutions. These intervening operations are key to achieving wetland vitality. Each parameter has a set of actions that need to be implemented to achieve the desired outcomes.

Wetland rehabilitation mechanical interventions are measures put on-site and off-site by environmental engineers, extension officers, community groups and farmers to reestablish wetland ecological health and character. The interventions need a long-term lifespan coefficient. Upland weirs, fences and geotextiles, recharge pits and afforestation initiatives enhance recharge. A pre-rehabilitation wetland health assessment determines the form of remedial action to be installed. Measures that encourage wetland recharge and wetland water retention are highly recommended in any sustainable wetland rehabilitation model. The interventions employed should aim to improve the system and allow the system to persist after correct interventions (Pollard et al., 2004). Such actions, according to the rehabilitation model for wetland productivity and functionality depend on wetland hydrology. This, as a matter of necessity, incorporates catchment management and integrated watershed management.

Wetland fencing efficiency is critical in rehabilitation modelling. Fencing efficiency index helps to formulate a consistent and stable measure such as number and spacing of strands. Erecting fences promotes water retention by arresting trampling, overgrazing and erosion. Protecting a wetland addresses threats coming from overgrazing, trampling and development of tracks. Although, fencing of wetlands results in a sense of deprivation and exclusion, it nourishes the wetland ecosystem by reinstating wetness. The best wetland protection practice against livestock grazing and trampling in wetland rehabilitation is fencing.

Net wetland utilisation income can be brought by partial cultivation and off-set activities such as upland consolidated nutrition cropping plots. Economic alternatives to wetland cultivation include initiation and rehabilitation of irrigation schemes. Judicious wetland utilisation and rehabilitation are key parameters of this model. Riparian communities directly benefitting from wetlands for, cultivation and grazing need not only the removal of smallholder agricultural plots but also concomitant fencing and installation of irrigation projects to derive a certain level of income. Wetlands are, undoubtedly, an integral component of the production base for rural communities in least developed countries, and in that respect contribute significantly to their livelihoods (Ogato, 2013). Compensatory initiatives like upland irrigation deter wetland invasion and conversion thereby achieving both production and preservation. Socio-economic factors play an important and sometimes supportive role in wetland rehabilitation. Therefore an understanding of economic activities such as small holder cultivation becomes an integral variable in wetland rehabilitation modelling.

Funding plays a critical role in putting resources together so that materials that are often expensive are bought during project planning. Multilateral institutions, according to research findings like UNDP which have played a leading role in some successful rehabilitation interventions should continue and expand financial resource mobilization. However donor driven funded projects are often short-term and not sustainable. Anything that will depend on bilateral external funding will not be sustainable. At grassroots level affordable, lasting and cost effective payment for ecological services mechanism can be put in place especially to cater for project maintenance costs. After paying for environmental services by local and traditional institutions use the funds for wetland rehabilitation.

Capacitation of rehabilitators is another critical element in the model. Capacity building initially should start with environmental awareness campaigns to attract communities buy-in and create a strong labour base. Public participation and involvement is attained in instances where local institutions' ward-based politicians and traditional leaders are heavily mobilized. Community based natural resource management (CBNRM) is regarded as the best approach to encourage effective resource management with the full participation of resource users in decision-making activities and the incorporation of local institutions, customary practices and knowledge systems in the management process (Armitage, 2005). The reason for engaging communities in wetland rehabilitation is that they are directly affected by degradation and benefit from wetland rehabilitation.

Institutions are key intervening operation drivers in wetland rehabilitation. Institutions such as AREX, ward councillors and tradition institutions are critical in project implementation. Fragmented and uncoordinated mode of wetlands ecosystems management by institutions act as an albatross in sustainable wetland rehabilitation. Institutions help in community engagement, awareness, sensitisation and involvement in project planning, implementation and monitoring. Institutional arrangements and active participation plays a role in supporting rehabilitation such as provision of labour in clearing alien species such as *Lantana camara* and *Eucalyptus* species and stone pitching. Muzenda (2013) observed that non-state organisations are embarking on small projects such as wetland protection such as the Mupunga wetland in Danda of Ward 3 in Zaka. Good and working institutions are also needed in most countries to coordinate and effectively carry out the planning, implementation and monitoring of watershed management programmes, (Aglanu 2014).

6.8 Model Testing

The model is based on the systems thinking paradigm which is useful for the purposes of environmental decision-making. A wetland rehabilitation model (WESUMO) was evaluated to test its applicability and performance. Seven rehabilitation sites implemented the new rehabilitation model. Model testing was done in partnership with the Environmental Management Agency in Masvingo Province which is the institutional authority responsible for rehabilitation projects. This involved putting up structures such as improved fencing, stone erosion checks and planting indigenous trees. The testing of the model ran from October 2014–October 2016 in order to give a two year cycle and ascertain the results. After implementation, the model performance was evaluated on the basis of its ability to re-establish wetland health based on a rapid assessment method. The rapid assessment method used the score rating system on criteria based on wetland health indicators such as hydrology, geomorphology, vegetation, biodiversity, ecology and economy. The score rating scale ranged from 1–10, with 1 being the lowest or worst score and 10 being the highest or best score.

Table 6.2: Project model testing sites in Masvingo Province

Wetland Rehabilitation Project Name	Wetland Size	Size under Rehabilitation	District	Ward	Coordinates
Makanda	1.9	1.4	Gutu	8	19,61632S/31,20473E
Mupunga	7	1.5	Zaka	3	20,1402S/31,28823E
Mutubuki	6	4	Gutu	36	19,74464S/31,662E
Magwenzi	5	3	Chivi	15	20,37274S/30,53067E
Maturure	5.5	5.5	Bikita	15	364294S/7782783E
Sedeya-Mangisai	1.9	1.5	Masvingo	1	278966S/7799852E
Manjinji Pan	1.5	0.9	Chiredzi	15	22,11082S/31,40655E

The methodology entailed implementing the major pillars of the model. The pillars are fencing degraded wetlands, increasing the lifespan of rehabilitation engineering structures, increasing wetland utilisation related income, strengthening institutions responsible for rehabilitation and mobilising financial resources. These pillars (Table 6.4) show that a wetland rehabilitation plan is derived from a wetland rehabilitation model. The model is conceptual in nature and needs to be translated into practical reality. The performance success of the project was measured both qualitatively and quantitatively. This involved observing and measuring elements of the hydrology, geomorphology, pedology and vegetation condition of the wetland following rehabilitation. The economic contribution of the wetland to community's wellbeing was also measured, as reflected in Table 6.4. The wetland rehabilitation projects were subjected to model testing. In addition, the major activities undertaken with regard to the model parameters include, wetland fencing, optimum wetland production to increase net incomes, initiating rehabilitation intervention measures, strengthening institutions responsible for rehabilitation, developing management tools and enhancing wetland rehabilitation financial sustainability. Table 6.3 is derived from the model in Figure 6.5.

Table 6.3: Wetland rehabilitation testing plan

ACTION/METHODOLOGY	RESPONSIBILITY	TIME FRAME	PERFORMANCE INDICATORS/DELIVERABLES
Fencing wetlands - Fencing off wetlands	Engineers, EMA officers Ward Councillor	April-May 2015	- Potential gains from wetland rehabilitation, determined e.g. hydrological flow periods, groundwater level, soil moisture.
Increasing lifespan coefficient of rehabilitation engineering structures - Filling gully's with gabion blocks and upslope weirs - Cutting lantana camara and re-vegetating with Off-site wetland afforestation	Communities	April 2015-March 2016	- Wetland required meeting obligations and outcomes, identified.
Net wetland utilisation income. - Downslope partial wetland consolidated nutrition cultivation. - Upland dam fed agricultural irrigation and poverty alleviation strategies.	EMA, Traditional leaders, Ward Councillor AREX	June-July 2015	- Key issues of landowners and farmers, such as food stock, cash stock and .well-being indicator identified. - Nutrition cropping plots and orchards downstream of fenced wetlands.
Institution power matrix - Environmental awareness. - Involvement of NGO sector with expertise, co-operating partners like agricultural extension services.	Traditional Leadership Environment Committees	April-July 2015	- Appropriate legislative instruments. - Environment Committees. - Harmonised stakeholder policies.
Management weight matrix on rehabilitation projects - Harnessing local institutions and local traditional in wetland rehabilitation. - Incorporating collective community's informal arrangements.	AREX Officers, EMA Officers	April 2015-October 2016	- Cross cutting issues. - Additional expertise appointed as appropriate implementers.
Financial mobilisation - Mobilising rehabilitation funding. - Indispensability of multi-lateral institutions. - Initiating PES mechanism including, compensation to farmers for opportunity costs of rehabilitating wetlands.	NGO, EMA, UNDP, UNEP	April 2015-October 2016	- Cost implications and allocations determined. - Improved institutional connectivity and capacity. - Improved durable rehabilitation structures such as fences and gabion blocks.

The testing was conducted by implementing the wetland rehabilitation plan in Table 6.3 derived from the model. The desired objectives of initiating rehabilitation structures have not largely changed save for a few limited sites due to financial limitations and a shortage of environmental engineers to install sound structures.

6.9. Empirical Results for Model Testing and Implications.

The results presented in this section were obtained through the use of the rapid assessment method. The rapid assessment method is a fast track system of assessing the performance of a wetland over a specific period. An assessment of wetland health, which is measured using the geomorphological, hydrological and vegetation criteria (Macfalane, 2008), is one of the rehabilitation performance indicators of the success of the project. The physical attributes of hydrological scores, and geomorphic, vegetation and health scores were obtained from direct observations during fieldwork surveys. Rated scores on ecological importance and sensitivity were also obtained during fieldwork. The other scores on the economic contribution to the communities were gathered using interviews which were corroborated with field observations and literature review. The hydro score was obtained by measuring the level of wetness, temporary, seasonal or permanent wetness. Monitoring took place during the initial implementation stages of the rehabilitation project as well as the operational phase. Scaled measurements were used to determine the seasonal, frequency, and quality of water. Geomorphic score was determined by accurate measurement of distance in meters advanced by a head cut erosion site and depth in meters of gullies. All the scores range from 1–10

Using a rating scale of 1–10, the vegetation score measured the level of biodiversity by assessing the habitat diversity, species diversity, unique species, rare and endangered species. Again alien plant re-emergence monitoring and removal was included to determine the vegetation score. The health category score was evaluated by scoring a number of attributes connected to the geomorphology, hydrology and vegetation, and devising an overall score which gives a rating of environmental condition. The ecological importance and sensitivity score was derived by routine seasonal sampling, with sampling being undertaken on a quarterly basis to cover seasonal variability. The recovery of the ecological resources such as fish and other aquatic organisms helps to the test the level of success of rehabilitation projects.

Economic contribution of wetland rehabilitation projects to the community was done by assessing the integration of wetland rehabilitation and utilization to balance wetland conservation and economic growth. For example, in sites where garden removal was done concomitant establishment of consolidated nutrition cropping plots has to be visible and viable. Other attributes such grazing of wetlands by livestock, harvesting of wetland plants for crafts show the economic contribution of wetland rehabilitation projects to the community. Scoring based on socio- economic characteristics of the community from 1-10 also helped to assess the success of the WESUMO.

The score values in Table 6.4 are the test results. Hydrological flow periods records were above average, save for the Mutubuki and Manjinji pan. The best and perennial hydrological flows were recorded at the Maturure rehabilitation site as the outflow from this fenced spring lasts throughout the year. However, there is the continued presence of the *Eucalyptus* species on the more than two ha plantation and the excessive abstraction by the community at the Mutubuki consolidated rehabilitation site. In addition, although hydrological deliverables were easier to determine, possible gains in wetland size could not be measured with certainty in one year.

Table 6.4: Performance scores out of 10

Name of wetland	Hydro score	Geomorphic score	Vegetation Score	Health category Score	Ecological Importance and Sensitivity	Economic contribution to community
Makanda	7	3	6	6	9	10
Mupunga	6	1	7	5	4	5
Mutubuki	8	5	3	5	7	9
Magwenzi	5	5	7	5	8	9
Maturure	10	9	9	9	10	8
Sedeya-Mangisai	5	8	8	7	9	6
Manjinji Pan	3	5	1	3	9	4

The recorded hydrological flow periods were above average, save for the Mutubuki and Manjinji pan. The community's excessive abstraction could not help restore wetland hydro period. The results of model testing were both positive and negative. The performance of the project achieved some measure of success in communities where traditional institutions and community cohesion are strong, as is the case with the Maturure wetland rehabilitation project. Therefore, strong institutions and environmental economics have ensured the success of the Maturure wetland rehabilitation project.

Table 6.5: Results of model testing

Name of wetland	Hydro score	Geomorphic score	Vegetation Score	Health category Score	Ecological Importance and Sensitivity	Economic contribution to communities
Makanda						
Mupunga						
Mutubuki						
Magwenzi						
Maturure						
Sedeya-Mangisai						
Manjinji Pan						

KEY

Score	Code	Interpretation	Implications
9-10		Excellent performance	Acceptable (Continue with plans)
7-8		Good performance	Partially Acceptable (Adjust Plans to suit wetland site and catchment)
5-6		Average performance	Average (Redesign plans)
3-4		Poor performance	Partial failure (Review planning)
1-2		Goals barely met	Fails (Planning overhaul)

Currently, some wetland rehabilitation projects do not balance ecological objectives such as water retention and biodiversity maintenance and economic objectives including poverty alleviation. There are various challenges in the implementation of interventions, such as the lack of alternative irrigation projects, which result in fence vandalisation. The removal of nutrition cropping plots and fencing alone is not enough, as shown in the Magwenzi project within the Chivi District. It is suggested that rain water harvesting strategies like weirs upslope of the wetland can facilitate both irrigation systems to nearby communities and the recharge and rewetting of the Magwenzi wetland.

Lack of research based solutions to wetland degradation also works against rehabilitation objectives. Instead of enhancing wetland recovery, the planting of *Eucalyptus* species has in actual fact accelerated wetland degradation. Alien species, such as gum trees, found at the Mutubuki rehabilitation project need to be removed immediately because research has shown that they contribute to climate change and further wetland loss rather than the re-establishment of its wetness.

The Makanda wetland rehabilitation project is unsustainable because it suffers from a lack of adequate funding, as evidenced by the installation of the untreated poles on which terminates feed on, spacing fence strands and heights. Financial resource mobilisation by both government departments and the communities is therefore required. The validity and reliability of the model was weakened by a lack of funds to fully test the model. However, the model offers a foundational baseline from which wetland degradation and loss can be arrested.

6.10 Summary

Chapter 6 presented a sustainable wetland rehabilitation model (WESUMO) for the South-Eastern Zimbabwe. It discussed the aim and assumptions of the model. The model parameters were described and explained in detail, just as the limitations of the model. The processes required in administering the model were applied in selected wetland rehabilitation projects in the Masvingo Province and the results obtained from the model testing presented. The next chapter concludes this study.

CHAPTER 7: SYNTHESIS AND CONTRIBUTION

7.1 Introduction

Chapter seven is a summary outline that synthesizes and wraps up the research, draws conclusions and presents recommendations drawn from the findings. This chapter also offers suggestions that could improve the state of current rehabilitation projects and their performance.

7.2 Synthesis

Wetland rehabilitation has been an on-going practice but with limited success. A number of rehabilitation projects fail to achieve their intended objectives because of poor planning and unfavourable socio-economic conditions. The aim of the study was to design a model for wetland rehabilitation that can simultaneously promote socioeconomic development and wetland sustainability. The study was carried out in South Eastern Zimbabwe which covers the six districts of Bikita, Chiredzi, Chivi, Gutu, Masvingo and Zaka, in the Masvingo Province. The quantitative research design was used for the research. Observations and interviews were used as data collection methods. Random sampling was used in the selection of the sample population for the interviews. A background literature survey was used to identify the knowledge gaps and locate a niche that requires immediate attention.

The study results revealed that the Masvingo Province experiences extreme rainfall variability such that a single season is unpredictable and uneven. Climate change is an on-going trend characterised by an increase in intensity and frequency of drought. In the same study area. Hamandawana et al., (2005) observed that crop failure occurs in 3 out of every 5 years mainly due to poor distribution of rainfall within a wet season. The use of the Standard Precipitation Index (SPI) helped to reveal this occurrence. Current rehabilitation efforts are commendable but fail to simultaneously address socioeconomic development and wetland integrity. Wetland loss is an on-going phenomenon and unless urgent rehabilitation efforts are taken to reverse the trends, their deterioration will worsen. However a weak relationship exists between wetland loss and the changing rainfall patterns in South-Eastern Zimbabwe.

Socio-economic factors including education level, family size, crop output and income levels, pose a hindrance to effective wetland rehabilitation. Income that is accrued from wetland utilization is low. Currently, rehabilitation projects do not adequately incorporate the productive needs of the communities. The level of preparedness or willingness to pay for ecological services is high. Most of the institutions and communities responsible for wetland rehabilitation are weak and fragmented. The extent of wetland rehabilitation is not adequately measured and documented. Engineering project structures are poor, piece-meal, vandalised, basic and simple. Wetland rehabilitation only covers 23% of the total wetland area. The environmental engineering approach to the reinstatement of wetland ecological structure and functions can best be classified as technocratic, topdown, prescriptive and centrist. It is proposed in this study that participatory and more democratic, bottom-up strategies in wetland rehabilitation should be adopted.

Rehabilitation programmes are not adequately financed. The hypothesis testing results show a statistically significant relationship between the level of financial funding and the size of the total wetland under rehabilitation. Funding is limited and in cases where funding is availed by multilateral institutions and the performance of rehabilitation projects do not reflect the massive amounts injected into the project. A sustainable wetland rehabilitation model is viable for Zimbabwe. However, the sustainability of wetland rehabilitation projects demands an immediate address of the socio-economic challenges for communities that depend on wetlands for sustainable agriculture and water security. These are issues that assist in the improvement of the performance of wetland rehabilitation. In a study area in Zvishavane where rehabilitation was initiated, it was found that the conserved wetland increased its size and biodiversity.
(Marambanyika, et al., 2012). In short, the current state of wetland rehabilitation projects in South-Eastern Zimbabwe leaves a lot to be desired. The model proposed in this study could be deployed to address these inadequacies by ultimately improving performance and enhancing sustainability.

7.3 Contribution of the study

The research reported in this thesis makes a contribution to knowledge in several respects.

7.3.1 Modeling

The study aimed to design a new model of wetland rehabilitation that promotes socioeconomic development and wetland integrity in the study area. A new predictive model has been added to existing literature on modelling wetland rehabilitation. The model helps to achieve ecological sustainability and project viability.

The study proposed a new predictive model that can be used to predict whether rehabilitation projects can succeed or fail. It sets out the prerequisite parameters for the achievement of desired goals. WESUMO has been developed as a tool to fix and repair degraded wetland patches. The ultimate aim of the model is to provide the means for achieving ecologically sustainable and financially viable rehabilitation projects. The new model presented in chapter 6 promotes thinking by identifying the key pillars that strengthen wetland rehabilitation efforts. Current rehabilitation practices are simple, basic and piece-meal. The study also provides the key pillars on which the rehabilitation practitioners can rely upon.

7.3.2 Discipline

This research is housed within the discipline of environmental science but, it extends into the frontiers of sustainability science which goes beyond conventional wetland ecology and climate change adaptation. The spin-offs from this study do talk to several disciplines; among them, communities based natural resource management, integrated water resource management, agriculture, public participation, and water resources projects. It adds and extends new knowledge frontiers.

7.3.3 Planning

The study assists in designing a practical wetland rehabilitation plan for implementation in both Zimbabwe and other Third World countries in similar circumstances. The plan should clearly specify the objectives of rehabilitation, action to be taken, the responsible individuals, the timeframes, and deliverables expected from the project. The new tool or instrument for wetland rehabilitation has flexible applicability. The study, therefore, equips environmental practitioners with the necessary tools to repair and fix both degraded wetlands and other ecosystem components.

The study makes a significant contribution to the sustainability paradigm. The paradigm shift towards sustainability has recently gained ground. Sustainability is a way of thinking which makes it easier for both wetland production and wetland preservation to operate side by side. Fencing, among other remedial initiatives, promotes a green economy when done together with income generating projects that include cultivation and grazing.

7.3.4 Ecosystem sustainability and climate change

This research raises awareness on wetland conservation and advocates for the use of the ecological systems approach in wetland rehabilitation. The study widens the horizon of knowledge on the better practical options for achieving ecological sustainability in an era of climate unpredictability. The key underpinnings of the model seek to achieve both the hydro-ecological objectives of rehabilitation and the socio-economic hopes of the community. The catering for the socio-economic demands of local communities is also vital.

7.3.5 Wetland rehabilitation

Quantifiable and measurable parameters of the model provide values that can be used to set and test the index that can be used to achieve a sustainable rehabilitation programme. The performance of sampled rehabilitation projects was measured. The mathematical values are critical in the implementation, monitoring and evaluation of rehabilitation techniques.

7.4 Limitations of the Study

One limitation of the study related to the gathering of data on change in wetland size for a number of wetlands. Satellite images were not used, not only on change in wetland size but land use cover changes that threaten wetland degradation and rehabilitation. Data on change in wetland size in this study depended on availability of aerial photographs and orthophoto from the Surveyor-Generals Office. However as explained in Chapter 3, no aerial photographs have been taken in Zimbabwe since the turn of the century. Nonetheless, literature helped to fill-in the data gaps.

Another limitation is that there were no measurements of the water table level of wetlands following rehabilitation initiatives, an issue that needs to be ascertained as part of the project evaluation and monitoring process. The following measurement parameters should be taken into consideration during an evaluation of rehabilitation projects; water level changes, water quality measures, channelization patterns, species number and abundance.

The study was limited in time. Testing was done over a period of two years which was not enough to measure the probability of performance success. A period of at least three years is needed to get a clear picture on the effectiveness of WESUMO to repair wetland ecosystems. However, this limitation was partially addressed by the use of a tailor-made rapid assessment scoring method to evaluate pilot rehabilitation projects that applied to the model.

7.5 Conclusion

It can be noted that the current wetland rehabilitation projects lack a systems thinking approach in addressing the underlying causes of wetland loss. The purpose of this investigation was to design a wetland rehabilitation model that achieves socio-economic development and ecological sustainability. The research was conducted in SouthEastern Zimbabwe, which covers the entire seven districts of the Masvingo province, namely Zaka, Chivi, Gutu, Bikita, Masvingo, Mwenezi and Chiredzi. A literature review helped to design observation schedules and interview guides which were used to gather information during fieldwork surveys. Literature also assisted in the identification of knowledge gaps. Research instruments, such as an observation schedule and interview guide, were designed using a literature review of wetland rehabilitation.

From the interviews it emerged that age, sex, level of education, marital status, family size and income levels have a large influence on wetland degradation and rehabilitation. In addition the width of buffer zones, proximity of homesteads to wetlands, sources of water for domestic and agricultural purposes pose serious challenges to wetland management and rehabilitation. Results obtained from the observations conducted in the field and interviews held with riparian and non-riparian community members point to a strong need for the use of an integrated water resource management strategy. This has to be augmented by communities based water resource management that enhances participation in wetland rehabilitation. In addition research results show that diversification of alternative livelihood options and income generation need to be underscored in implementation of wetland rehabilitation projects. This helps to promote socio-economic progress and enhance wetland vitality.

The findings from the study demonstrate that wetland loss can be averted by implementing remedial measures. The results reveal that a paradigm shift in wetland management can reinstate the ecological health of degraded wetlands. Current wetland rehabilitation structures such as fences, gabion blocks and weirs are in a poor state. Funding is scarce and where available, the rehabilitation structures do not reflect the huge amounts invested into the project. Corrective measures should be taken to ensure that sustainability in its strictest sense is achieved by addressing the root causes of the degradation. Addressing key findings relating to funding, food security and water security will help towards achieving sustainability. The study has contributed towards the designing of a new model called WESUMO (Wetland Sustainability Model).

7.6 Recommendations

A number of recommendations are put forward on the basis of these findings. The recommendations are directed to different stakeholders involved in wetland rehabilitation in Zimbabwe and other countries in similar circumstances. The critical masses of stakeholders for whom these recommendations are intended are government departments, the EMA, NGOs, communities and farmers.

The recommendations are as follows:

7.6.1 Formulation of Zimbabwe Wetland Rehabilitation Policy (ZWRP)

The national wetland rehabilitation policy should contribute towards giving the direction the government must take in wetland management and rehabilitation. This has to start with making it mandatory to carry out a national wetland inventory to determine the size of wetlands in Zimbabwe. The determination of a wetland inventory will help to ascertain their status and classification into natural, degraded and severely degraded classes.

The intention would be to arrest wetland loss and mitigate the impact of rainfall variability among other factors on wetland loss. This will help to fill the knowledge gap that currently exists in the country whereby little is known on wetland coverage in Zimbabwe. This could then be followed by designing rehabilitation strategies for degraded wetlands and preventative measures to preserve pristine wetlands.

7.6.2. Adoption of integrated wetland management approach

There is need to promote wetland productivity and functionality which is based on wetland hydrology. Such an approach has to incorporate catchment management and integrated watershed management encompassing resources such as dams, rivers, water well and boreholes are in the catchment. Their presence helps in wetland rehabilitation. Therefore in wetland rehabilitation modelling, adoption of an integrated watershed approach that considers integrated water resource management principles should restore wetland vitality. These ideas are incorporated in the WESUMO model designed in this study.

7.6.3. Development of a Community Based Wetland Degradation Response Strategy (CBWDRS)

There is a need to develop a Community Based Wetland Degradation Response Strategy. A community based wetland response strategy helps to acknowledge that there are degraded wetlands in the different parts of the country and prescribe the nature of rehabilitation that has to be implemented on each site. A community based wetland degradation response strategy should include but not be limited to wetland rehabilitation. The degradation response strategy should be site specific and comprehensive enough. Key to this strategy is that it should be a community based approach to wetland management strategy as a guide. The model is represented as a wetland rehabilitation plan in the thesis which is informed by the model. The basic principles underlying wetland rehabilitation can encompasses the model designed in this research.

7.6.4. Establishment of the National Wetland Rehabilitation Fund (NWRF) to harness financial resources from both external and community actors.

The results have shown that there is a lack of funding for rehabilitation projects. It is for this reason that a purse and budget have to be established to cater for that. The fund should be administered by an autonomous or semi-autonomous body or agency responsible for financial allocation on a site by site basis. Financial mobilisation for wetland rehabilitation from global organisations, such as the Green Climate Fund (GCF), Global Environment Fund (GEF) and United Nations Environment Programme (UNEP), is a vital cog that can keep rehabilitation projects going and running. However, it should be pointed out that donor driven projects are not sustainable and therefore need community financial support. Some of the proceeds from wetland production by the community should be reinvested for wetland rehabilitation through buying of fences and introducing agroforestry activities instead of over-reliance on donor fund.

7.6.5. Establishment of Wetland District Rehabilitation Team (WDRT)

Strong institutions responsible for rehabilitation should be established. The starting point would be to form wetland district rehabilitation teams that should comprise of 10-15 project implementers. The composition of the teams should comprise civil engineers, ecologists, local leadership and AREX officials. Their responsibility will be to erect and maintain rehabilitation structures. These teams can be employed on a fulltime basis.

7.6.6. Strengthening of the Environmental Management Agency (EMA) Current efforts by the EMA in fencing wetlands are commendable but it is also recommended that this vital institution should be strengthened. The organisation needs more personnel, specialists, equipment and financial support.

7.6.7. Initiating Payment for Ecosystems Service (PES)

A vibrant system for the payment ecosystem services that is tailor-made to suit local circumstances and conditions should be put in place. The need for PES stems from the user pays principle and polluter pays principle. These principles underpin the wetland sustainability model, which is WESUMO. It is of little doubt that wetland users directly benefit from the ecosystem and inadvertently degrade it. Thus, from an environmental justice and ethics point of view, users of wetlands have an obligation to maintain and repair wetlands.

7.6.8. Future research

Another prospect for future study would be an investigation into the state of biodiversity in individual wetlands. This should include a measurement of wildlife, plant and bird species at project sites to determine effectiveness of rehabilitation structures. Wetlands research has been mostly interdisciplinary in nature and involving contributions from ecology, economics, biology, and hydrology. Thus, it is also suggested that a collaborative multi-disciplinary approach be adopted in future studies.

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APPENDICES

Appendix 1. Annual rainfall totals for districts in the Masvingo Province Zimbabwe (mm)

YEAR	RAINFALL							
	BIKITA	CHIREDZI	CHIVI	GUTU	MAKOHOLI	MASVINGO	MWENEZI	ZAKA
1980	1033.5	706.1	924.6	667.2	615.1	632.8	681.6	596.3
1981	1607.9	718.5	867	1086.6	916.3	773.6	762.3	1030.4
1982	628.3	449.5	435	439.9	384.4	341.1	339.2	329.2
1983	924.8	309.7	456	476.2	239.6	241.7	258.4	362.2
1984	1148.9	653.3	534	576.1	604.4	588.8	463.7	872.9
1985	1273.9	672.0	1067.4	976.5	746.0	838.3	652.6	936.5
1986	1009.9	657.0	687	713.6	632.6	515.6	582.0	690.7
1987	807.0	427.4	460	555.2	490.9	591.2	309.9	629.9
1988	982.6	403.0		784.5	609.5	586.7	433.8	489.1
1989	878.2	425.2	433.4	674.0	457.7	600.3	307.2	573.5
1990	857.5	431.0	828	723.6	748.1	680.8	471.8	531.7
1991	672.8	354.4	231.4	373.0	315.0	219.7	304.1	412.3
1992	460.6	371.6	374.2	583.8	507.0	513.7	291.9	436.4
1993	1200.0	922.4	493.8	988.2	579.7	630.9	429.0	559.1
1994	886.1	287.8	398.5	559.9	499.4	348.0	239.5	433.6
1995	919.8	478.9	433.7	343.4	479.7	592.8	393.1	519.9
1996	872.3	705.0	730.9	422.2	839.7	797.0	754.0	883.8
1997	921.3	531.0	604.8	662.2	1092.9	667.8	443.2	914.8
1998	1228.7	561.6	664.0	753.4	662.0	635.6	680.0	665.1
1999	1129.3	661.7	609.5	547.7	591.8	698.3	342.5	1022.9
2000	1820.2	1176.6	1077.8	986.6	1041.6	1134.8	1024.6	1474.4
2001	1490.0	673.4	800.4	983.3	736.9	1022.2	725.8	1342.4
2002	594.1	314.4	217.6	641.9	368.5	421.2	410.0	331.2
2003	1424.7	714.7	516.0	804.2	958.3	1013.4	427.5	1036.1
2004	1342.7	578.7	491.8	258.5	790.0	836.3	585.0	520.9
2005	848.5	285.9	508.0	772.5	674.7	515.3	272.2	420.9
2006	951.0	471.7	348.5	564.3	841.4	719.8	569.2	580.2
2007	1538.2	749.2	435.7	615.0	1005.9	729.3	617.2	1025.6
2008	806.6	315.1	528.9	376.0	366.4	474.2	396.0	515.0
2009	932.2	633.7	472.8	649.0	759.0	644.4	383.7	425.2
2010	857.7	498.3	828.0	619.5	741.2	673.3	424.0	647.4

2011	1005.4	591.8	417.3	751.9	675.1	768.8	539.9	787.2
2012	575.8	306.6	241.9	338.1	381.5	308.2	248.2	344.8
2013	1233.8	574.0	369.1	230.8	756.5	488.5	436.5	752.5
2014	1306.8	713.3	554.6	648.2	889.8	839.4	506.6	1096.0
2015	726.6	330.6	367.7	377.6	349.9	347.3	356.9	360.0

Source: (Meteorological Services Department of Zimbabwe, 2014)

Appendix 2. Monthly rainfall for Masvingo District in Masvingo Province Zimbabwe (mm)

Year/Month	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	TOTAL
1980	2.2	9.9	0.2	72.4	104.5	127.7	49.7	207.4	47.8	8.5	2.5	0	632.8
1981	2	4.8	56.4	52.2	95.6	111.2	328.5	94.9	62.8	27.5	35.7	0.5	872.1
1982	0.1	8.7	7.7	47	126.1	34.1	102.2	75	0.7	34.4	5.3	0	441.3
1983	0.4	1.8	4.1	45.9	17.9	53.4	1.5	38.7	17.2	0.2	26	0.9	208
1984	31.1	7.4	0	18.3	35.7	64.7	72.6	58	159.9	5.7	4.2	1.5	459.1
1985	4.8	0	24.6	26.8	133.1	97.6	365.3	121	43.1	4.2	14.3	3.5	838.3
1986	4.8	2.2	24.9	50.3	25.9	121.4	184.6	41.3	32.9	126.6	0.2	1.4	616.5
1987	1.1	0	0.2	56.3	34.3	36.7	62.2	76.6	4.5	0.4	0	0.3	272.6
1988	0	0.1	14.3	22.6	67	343.2	51.5	146.7	119.9	20.4	17	54.1	856.8
1989	2.4	11.6	0	27.2	86	49.9	7.6	247.2	8.8	73.9	0.3	12	526.9
1990	0	78.3	2.1	49.6	61.5	59	303.7	30.2	38.9	55.6	0.9	1	680.8
1991	0	2.3	2.7	5.7	43.6	75.9	23.2	54.7	77.8	0	7.2	0	293.1
1992	1	0.4	6	0.8	25.2	23.4	19.3	3.6	23.2	0.7	2.5	3.6	109.7
1993	0	0.2	0	2.3	81.9	376.4	78.1	198.2	7.9	2.8	0	8	755.8
1994	27	2.3	0	1.2	196.9	108.5	77.6	5.8	9.5	0.4	0.7	0	429.9
1995	3	1.5	2.5	74.5	23.9	148.6	100.7	101	108.5	17	9.5	2.1	592.8
1996	2.5	0.2	0.2	4.7	57.1	146.1	437.3	107.6	18.1	5	10.4	4.8	794
1997	9.4	0	1.7	1.2	85.5	116	202.3	121.5	86.5	104.1	1.2	0	729.4
1998	13.5	0.3	35.9	13.8	86.1	2.6	192.4	7.6	31.1	4.6	1.5	0.2	389.6
1999	0.5	1.2	0	7	152.6	236.9	78.8	236.1	90.5	13.5	0	0	817.1
2000	7.3	1.1	9.2	11.8	161.8	88.2	261.2	412.3	76.8	44.3	18.4	42.4	1134.8

Source: (Meteorological Services Department of Zimbabwe. 2016)

Appendix 3: Observation Schedule: Current state of wetland rehabilitation projects

Date of Observation-------------------------------------Wetland Patch GPS (Latitude and Longitude) -------------------------- Wetland

Name---Type of wetland (Tick Appropriately) Dambo, Swampy, Floodplain, Pan)

Location of the wetland (Tick Appropriately) Communal land /Commercial land /State land

CODE Scale of rehabilitation

1. Extent of wetland buffer zone ------------------------------

2. Area under rehabilitation as % of wetland-------------------

3. Evident rehabilitation to biodiversity indicator species— -

4. Area of re-vegetated wetland planted in Ha----------------

5. Bare wetland soil as a %------------------------------------

6. % of organic matter per unit of soil--------------------------

7. Total length of gullies in the wetland-------------------------

Agro-ecology related State

8. Distance of nearest housing unit from wetland rehabilitation project--------------------------------

9. Wetland rehabilitation friendly agronomic practices-------

10. Number of stock watering facilities near fenced wetlands-

11. Ridge height in wetland vegetable garden----------------

Rehabilitation engineering related state

12. Wetland rehabilitation interventions------------------------

13. % of use of loose rock packs------------------------------

14. Size in of wetland under rehabilitation-(in Ha)-------------

15. % of paddocked area of total wetland-------------------

0	1	2	3	4
<100m	100-200m	201-300m	301-400m	>500m
1-20%	21-40%	41-60%	61-80%	81-100%
Sedges *Cyperus species* *Nhokwe*	Reeds *Phragmites Australis* *Shanga*	Cut grass *Leersia hexandra* *Majekacheka*	Bulrushes *Typha capensis* *Mhungadondo*	Waterberr *Cordatum syzgyium* *Mukute*
None	1ha	2ha	3ha	4ha
1-20%	21-40%	41-60%	61-80%	81-100%
1-20%	21-40%	41-60%	61-80%	81-100%
<50m	50m-99m	100m-149m	150m-199m	>200m
<100m	100-200m	201-300m	301-400m	>500m
None	Multicropping/ intercropping	Organic farming	Doublecropping	Agro-forestry
None	1	2	2	3 OR mor
None	<20 cm	21-30 cm	31-39 cm	>40 cm
Fencing	Geotextile	Sisal	Eucalyptus	IKS/cultu
None	1-25%	26-50%	51-75%	76-100%
<1ha	2ha	3ha	4ha	>5ha
None	1-25%	26-49%	50-75%	75-100%

Appendix 4. Observation Schedule: Performance limitation of current wetland rehabilitation projects

Date of Observation------------------------------------Wetland Patch GPS (Latitude and Longitude) ----------------------------

Wetland Name---Type of wetland (Tick Appropriately) Dambo, Swampy, Floodplain, Pan)

Location of the wetland (Tick Appropriately) Communal land /Commercial land /State land

0	1	2	3	4
Hydrological	Ecological	Food security	Job creation	Cultural

CODE

Technical Limitations

1. Rehabilitation objectives at patch ----------------------------

2. Number of rehabilitation objectives--------------------------

3. Gully density (m/km^2)--

4. % ar of area of wetland fenced--------------------------------

5. Evident rangeland rehabilitation--------------------------------

6. Re-vegetation plants on slopes of more than 25°---------

7. % of indigenous trees on steeper slopes--------------------

8. Number of strands for barbed wire fencing-----------------

9. % of herbaceous plants on shallow banks/gentle slopes---

Infrastructural

10. Number of motorized pumps with possibilities of drying up due to over abstraction of water----------------------------

11. Water harvesting rehabilitation structures to counter rainfall variability---

Financial

12. Amount of funding per rehabilitation projects---------------

13. Source of funding of rehabilitation project------------------

Managerial

14. Source of technical rehabilitation skills applied -----------

15. Performance rating of project officers wetland rehabilitation out of 10---

Communities

16. Distance from wetland to housing unit------------------------

1	2	3	4	5
None	1-50 m/km^2	51-100 m/km^2	101-150 m/km^2	>150/km^2
0-20%	21-40%	41-60%	61-80%	81-100%
None	Planting grass/trees	Gabion weirs	Planting vertivar	Paddocks
None	Sisal/Vertiver	Indigenous	Eucalyptus	Other
0-20%	21-40%	41-60%	61-80%	81-100%
None	3	4	5	6
None	0-25%	26-50%	51-75%	76-100%
None	1	2	3	4 or more
Weirs	Ponds	Canals	Raised beds	Mulching
<US$1000	US$2000-US$5000	US$5000 US$10000	US$10000 US$15000	>US$15000
NGO	Government	EMA	Communities	No funding
Agritex	Envt Engineer	Civil Engineer	IKS	Rudimentar
1-2	3-4	5-6	7-8	9-10
<100m	100-200m	201-300m	301-400m	>500m
0-20%	21-40%	41-60%	61-80%	81-100%

17. % of water abstraction for domestic use--------------------

Apppendix 5: Interview guide for Riparian households

Name of interviewer---District--

Ward-----------------------Name of Village---------------------Interview Reference Number-------------------------

Objective 2. Socio-economic interactions that influence wetland rehabilitation

SOCIAL INFORMATION

1. Respondent

Household head	Spouse	Child	Other-specify
1	2	3	4

2. Age group of respondent

16-25	26-35	36-45	46-55	56 and above
1	2	3	4	5

3.

Marital status of respondent

Single	Married	Divorced/Separated	Widow
1	2	3	4

4.

What is the size of your household?

<2	3-4	5-6	7-8	>10
1	2	3	4	5

5. State the level of formal education achieved

Primary	Secondary	Diploma	Graduate	Post-graduate
1	2	3	4	5

6. What is the distance from the nearest wetland?

<100m	100-200m	201-300m	301-400m	>500m
1	2	3	4	5

7. What is the distance to the fields?

<50m	50m-99m	100m-149m	150m-199m	>200m
1	2	3	4	5

8. What is the distance to the nearest river?

<1km	2km	3km	4km	>5km
1	2	3	4	5

9.

What is the distance to the source of water?

200m	201m-400m	401-600m	601m-800m	>800m
1	2	3	4	5

10. What are the sources of water for your animals?

Borehole	Dam	River	Water well	Spring
1	2	3	4	5

11. State the % of people following cultural norms on wetlands

0-20%	21-40%	41-60%	61-80%	81-100%
1	2	3	4	5

12.

State the number of wetland law enforcers visible in the communities

<2	2-4	5-6	7-8	>8
1	2	3	4	5

13. State examples local taboos or beliefs relating to the wetland patch

----

ECONOMIC INFORMATION

14. State the total quantity of harvest of the previous farming season in tonnes
15. State the amount of income from crop production in US dollars
16. State examples of high-water demand crops in the wetland
17. State examples of low-water demand crops in the wetland
18. State the size of the farm in hectares

<4	5-6ha	7-8ha	9-10ha	>10ha
1	2	3	4	5

19.

What is the % of cultivated land in the wetland patc ı?

0-20%	21-40%	41-60%	61-80%	81-100%
1	2	3	4	5

20. What is the % of income generated from use of wetlands?

0-20%	21-40%	41-60%	61-80%	81-100%
1	2	3	4	5

21.

State the m ·an per capita inco ne

≤50US	50-99US	100-149US	150-199US	≤200US
1	2	3	4	5

22. What is the size of garden portion per household (ha)?

≤0.5ha	0,5-1ha	1-1,5ha	1,6-2,0ha	≤2ha
1	2	3	4	5

23. Number of livestock owned per household-(cattle; goats; sheep; chickens)-Tropical Livestock Unit)

≤10	11-20	20-39	40-49	≥50
1	2	3	4	5

24. Use-non-mechanized cultivation

Ox-drawn plough	Hoe	Ox-drawn harrow	Manual methods	Other-specify

1	2	3	4	5

25. Number of cattle water troughs close to fenced wetlands

<2	3	4	5	>6
1	2	3	4	5

26. Possible economic trade-offs to wetland cultivation

Craftwork	Informal trading	Informal work	Remittances	Other-specify
1	2	3	4	5

27. Resting of rehabilitated wetland

1yr	2yrs	3yrs	4yrs	5 yrs
1	2	3	4	5

28.

cropping intensity in wetland (number crops grown)

<1crop	1-2crops	2-3 crops	4-5 crops	>6 crops
1	2	3	4	5

29. Number of months of wetland burning before 1 October (Onset of rainfall season in Zimbabwe

1 months	2 months	3 months	4 months	5 months
1	2	3	4	5

ECOLOGICAL INFORMATION

30. Describe the wetland hydrological status/Hydro-period

Temporary	Episodic	Seasonal	Permanent

1	2	3	4

31. State the duration of water flow from the wetland

<2months	3-4 months	5-6 months	7-8 months	>8 months
1	2	3	4	5

32. State the number of months wetland soil is at field capacity

<2months	3-4 months	5-6 months	7-8 months	>8 months
1	2	3	4	5

33. State the source of funding of wetland rehabilitation projects in your communities

Communities	Rural District Council-RDC	NGO	Government Agency	EMA
1	2	3	4	5

34. Rehabilitation project governing institution or authority

Communities	Rural District Council -RDC	NGO	Government Agency	EMA
1	2	3	4	5

35. Rehabilitation objectives at patch

Hydrological	Ecological/Biodiversity /Scenery	Food security/ livelihood	Job creation	Cultural
1	2	3	4	5

36. Is there use of motorized pumps in the wetland

Yes	No
1	2

37. If yes in 37, what are the possible impacts of the use of motorised pumps?

----

38. During your lifespan, have you witnessed a loss in wetland size

Yes	No
1	2

39. If yes in 39, what possible reasons explain the loss of wetlands

----

----

40. If no in 39, explain why wetland size has remained the same

----

----

41. State the substitute or alternatives to wetland cultivation for livelihood

Wood craftwork	Upland irrigation	Remittances	Public work programmes	Other-specify
1	2	3	4	5

42. Suggest your preferred wetland rehabilitation methods

----

43. Are you prepared to payment for ecological services mechanism policy (PES)?

Yes	No
1	2

44. If yes in 44, what mechanism would you prefer for PES, if no proceed to 47

Royalties from dams	Upland irrigation projects	Public work contract jobs	Food parcels	Other-specify
1	2	3	4	5

45. If no in 44, explain why you are not in support of PES

Appendix 6: Interview guide for Non-Riparian Communities (Catchment and Upland Management)

Name of Interviewer---District ------------------------------------

Ward----------------- Name of Village--------------------------------------Interview Reference Number----------

Objective 2. Socio-economic interaction that influence wetland rehabilitation

SOCIAL INFORMATION

1. Respondent-

Household head	Spouse	Child	Other-specify
1	2	3	4

2. Age group of respondent

16-25	26-35	36-45	46-55	56 and above
1	2	3	4	5

3. State the level of formal education achieved

Primary	Secondary	Diploma	Graduate	Post-graduate
1	2	3	4	5

4. State your marital status

Single	Married	Divorced	Widow
1	2	3	4

5. What is the distance to the nearest wetland in km

<1km	2km	3km	4km	>5km
1	2	3	4	5

6. Do your grazing areas have fencing?

Yes	No
1	2

7. If yes in 6, what other mechanisms would you prefer for managing rangeland

----

----

8. If no in 6, explain what can be done to facilitate rotational grazing

----

----

9. What are the sources of water for your animals?

Borehole	Dam	River	Water well	Spring
1	2	3	4	5

10. What is the distance to the farthest water point from the grazing area?

<1km	2km	3km	4km	>5km
1	2	3	4	5

ECONOMIC INFORMATION

11. List your source of income

----

12. What is the per capita income in the family?

≤50US	50-99US	100-149US	150-199US	≤200US
1	2	3	4	5

<1	2ha	3ha	4ha	>5ha
1	2	3	4	5

13. What is the size of your arable land (ha)?

14. What is per capita arable land area (ha)

≤0.5ha	0,5-1ha	1-1,5ha	1,6-2,0ha	≤2ha
1	2	3	4	5

15. What is the source of water for cultivation activities?

Borehole	Dam	River	Water well	Other-specify
1	2	3	4	5

16. What is the number of livestock that you own (livestock: cattle; goats; sheep; chickens)

≤10	11-20	20-39	40-49	≥50
1	2	3	4	5

OFF-SITE (CATCHMENT) WETLAND REHABILITATION

17. % households complying with woodland management by-laws

0-20%	21-40%	41-60%	61-80%	81-100%
1	2	3	4	5

18. % households attending village meetings

0-20%	21-40%	41-60%	61-80%	81-100%
1	2	3	4	5

19. State the material that you used for fencing your field/s

Sisal	Hedge	Dichrostachys cinerea (mupangara)	wire	Other-specify
1	2	3	4	5

20. Does contouring and ridge spacing comply with slope orientation and gradient?

21. Are there rules for rangeland management?

Yes	No
1	2

22. If YES to 21, what strategies are used to manage rangelands

----

----

23. % of households obeying environmental by-laws e.g. 100m from stream bank or not cutting fruit trees

0-20%	21-40%	41-60%	61-80%	81-100%
1	2	3	4	5

24. % of households complying with specified cultural norms (respecting sacred springs)

0-20%	21-40%	41-60%	61-80%	81-100%
1	2	3	4	5

25. What is your opinion on women participation in communities events?

----

26. Give suggestions on what you think should be done to improve wetland health

----

Appendix 7: Interview Schedule for EMA Project Officer

Objective 1. Current state of wetland rehabilitation

1. State the provincial size of wetland under rehabilitation hectares
2. State the provincial % of the size of wetland under rehabilitation

0-20%	21-40%	41-60%	61-80%	81-100%

1	2	3	4	5

3. What is the amount of government financial funding on wetland rehabilitation in (US) dollars 4. What are the current technical rehabilitation strategies being implemented?
5. What are the trade-off strategies in areas where rehabilitation strategies are implemented?
6. Which measures do you think can be implemented as a way forward to improve current wetland rehabilitation?
   i--
   ii---
   iii--
   iv---
   v--

Objective 5. Performance limitation of current rehabilitation projects

7. Identify key partners that you work with for successful rehabilitation
   i--
   ii---
   iii--
   iv---
   v--
8. Identify key government ministries and their role that you work with for successful rehabilitation
   i--
   ii---
   iii--
   iv---
   v--
9. Identify policy and legislative instruments for wetland management
   i--
   ii---
   iii--
   iv---
   v--
10. Which measures do you implement to enhance capacity building in the communities for successful rehabilitation?
   i--
   ii---
   iii--
   iv---
   v--
11. Challenges that you encounter in facilitating a Communities Based Natural Resources Management (CBNRM) strategy of wetland rehabilitation projects.
   i--
   ii---
   iii--
   iv---
   v--
12. Which measures do you think can be implemented to improve the performance of rehabilitation projects

i--
ii--
iii---
iv---
v---

Appendix 8-Statistical analysis tables

Descriptive Statistics

	Mean	Std. Deviation	N
wetland loss	194331.8929	354735.65671	28
mean annual rainfall	831.4357	298.80080	28

Correlations

		wetland loss	mean annual rainfall
Pearson Correlation	wetland loss	1.000	-.100
	mean annual rainfall	-.100	1.000
Sig. (1-tailed)	wetland loss	.	.305
	mean annual rainfall	.305	.
N	wetland loss	28	28
	mean annual rainfall	28	28

Variables Entered/Removed[a]

Model	Variables Entered	Variables Removed	Method
1	mean annual rainfall[b]	.	Enter

a. Dependent Variable: wetland loss

b. All requested variables entered.

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.100[a]	.010	-.028	359662.93473

a. Predictors: (Constant), mean annual rainfall

ANOVA[a]

Model		Sum of Squares	Df	Mean Square	F	Sig.
1	Regression	34316333752.606	1	34316333752.606	.265	.611[b]
	Residual	3363293092110.071	26	129357426619.618		
	Total	3397609425862.678	27			

a. Dependent Variable: wetland loss

b. Predictors: (Constant), mean annual rainfall

Model		Unstandardized Coefficients		Standardized Coefficients	T	Sig.	
		B	Std. Error	Beta			Partial
1	(Constant)	293532.761	204243.544		1.437	.163	
	mean annual rainfall	-119.313	231.650	-.100	-.515	.611	-.100

Regression

Descriptive Statistics

	Mean	Std. Deviation	N
	$20,875.00	$22,912.489	8
capital expenditure in US$ on project size under rehabilitation expressed in square kilometres	23.2250	57.31033	8

Correlations

		capital expenditure in US$ on project	size under rehabilitation expressed in square kilometres
Pearson Correlation	capital expenditure in US$ on project	1.000	.907
	size under rehabilitation expressed in square kilometres	.907	1.000
Sig. (1-tailed)	capital expenditure in US$ on project	.	.001
	size under rehabilitation expressed in square kilometres	.001	.
N	capital expenditure in US$ on project	8	8
	size under rehabilitation expressed in square kilometres	8	8

Variables Entered/Removed[a]

Model	Variables Entered	Variables Removed	Method
1	size under rehabilitation expressed in square kilometres[b]	.	Enter

a. Dependent Variable: capital expenditure in US$ on project

b. All requested variables entered.

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.907[a]	.824	.794	$10,396.070

a. Predictors: (Constant), size under rehabilitation expressed in square kilometre

ANOVA[a]

Model		Sum of Squares	Df	Mean Square	F	Sig.
	Regression	3026405376.362	1	3026405376.362	28.002	.002[b]
	Residual	648469623.638	6	108078270.606		
1	Total	3674875000.000	7			

a. Dependent Variable: capital expenditure in US$ on project

b. Predictors: (Constant), size under rehabilitation expressed in square kilometres

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	95.0% Confidence Interval for B	
		B	Std. Error	Beta			Lower Bound	Upper Bound
1	(Constant)	12448.691	4005.673		3.108	.021	2647.163	22250.220
	size under rehabilitation expressed in square kilometres	362.812	68.563	.907	5.292	.002	195.045	530.579

a. Dependent Variable: capital expenditure in US$ on project

Appendix 9. Ethics Approval Letter

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2013/07/30

ETHICS APPROVAL OF PROJECT

This is to certify that the next project was approved by the NWU Ethics Committee:

Project title.
Towards a model of Wetland Rehabilitation in South Eastern Zimbabwe
Project leader: Prof Ruhiiga and Makarati
NWU Ethics approval no: NWU-00094-13-A9

The Ethics Committee would like to remain at your service as scientist and researcher, and wishes you well with your project. Please do not hesitate to contact the Ethics Committee for any further enquiries or requests for assistance.

Yours sincerely

Me.Marietjie Halgryn
NWU Ethics Secretariate