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Managing the trade-off between conservation and exploitation of wetland services for economic well-being: The case of the Limpopo wetland in southern Africa

By

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Dedication

To my daughter, Celine, and wife, Phillipa

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Declaration

I declare that this thesis hereby submitted by me for the PhD degree in Environmental Economics at the University of Pretoria is entirely my own independent work and has not been submitted by me anywhere else for the award of a degree or otherwise.

Parts of the thesis have been published in journals.

Any errors in thinking or omissions are solely my responsibility.

Signed: ____________________ Date: ____________________

Name: Wellington Jogo.

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Managing the trade-off between conservation and exploitation of wetland services for economic well-being: The case of the Limpopo wetland in southern Africa

By

Wellington Jogo

Degree:	PhD Environmental Economics
Supervisor:	Professor Rashid M. Hassan
Department:	Agricultural Economics, Extension and Rural Development

Abstract

This study had two main objectives. The first objective was to determine the factors that influence rural households' labour allocation and supply decisions for competing livelihood activities, including wetland activities. The second objective was to: develop an ecological-economic model establishing the linkages between the economic and ecological components in a wetland system and apply the model to evaluate the impacts of alternative wetland management and policy regimes on wetland functioning; and supply ecosystem services and economic well-being.

To achieve the first objective an agricultural household framework was used. The reduced form labour use and supply equations for wetland products and agricultural grain, derived from optimising the agricultural household model, were estimated jointly using a seemingly unrelated regression model. The model was fitted to data collected from a survey of 143 households in a wetland system in the Limpopo basin of South Africa.

Results showed that poor households, most of whom are female-headed households, have less capacity to participate in off-farm employment and rely heavily on farm and wetland activities for their livelihood. This implies that environmental protection policies that limit access to the wetland resources will deepen poverty as the poor will suffer more from deprivation of resources, which play a key role as a livelihoods safety net for the poor. This suggests that in order to enhance the sustainable management of wetlands there is need to identify and promote local level wetland management practices that allow the poor to use wetlands to enhance their economic well-being with minimum adverse effects on wetland ecological conditions instead of adopting strict wetland protection measures. In addition, there is also a need to broaden the opportunities for the poor to diversify into off-farm livelihood activities. This minimises the risks of income fluctuations associated with farm and natural resource-base livelihood sources and therefore provides the necessary positive incentives for wetland conservation and sustainable use. Better access to education is an important instrument for enhancing the poor's ability to diversify into off-farm livelihood options. These results suggest that wetland conservation and sustainable use has to be integrated with the broader rural poverty reduction initiatives such as: improved access to education; investment in irrigation infrastructure; and improving access to markets.

Results also indicate that a household's exogenous income and wealth status (asset endowment) enhance farm production whilst reducing dependence on wetland products for livelihood. The government should pursue policy measures that reduce rural household liquidity constraints and enhance investment in productive assets (e.g. improving rural household access to credit and off-farm income opportunities) to boost farm production and enhance wetland conservation and sustainable use.

To achieve the second objective the study developed a dynamic ecological-economic model. The model is based on the system dynamics framework to capture the multiple interactions and feedback effects between ecological and economic systems. The application of the model in simulating policy scenarios suggests that wetland ecosystem

services (crop production and natural resource harvesting) are interlinked with trade-offs involved through their competition for labour, water and land resources. Policy scenario simulation results showed that diversifying livelihoods out of agriculture simultaneously improves economic well-being and enhances wetland conservation. Pure conservation strategies impose significant losses in the economic welfare of the local population unless supported by diversification of livelihood sources. The simulation results also show that the development of a competitive marketing system for harvested biomass products increases returns to wetland biomass products relative to that of wetland grain and it reduces conversion of wetlands to agriculture. Simulation of the predicted reduction in annual precipitation due to climate change in southern Africa showed that climate change is likely to accelerate the conversion of wetlands to agriculture, confirming the important role wetlands play in managing climate variability in smallholder agricultural systems. Government policies that support livelihood diversification into off-farm livelihood opportunities and improve the capacity of the rural poor to adapt to climate change, especially droughts, are critical for wetland conservation and sustainable use.

Keywords: wetlands; southern Africa; agricultural household model; labour allocation decisions; dynamic ecological-economic models; human well-being; ecological security.

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Acronyms and Abbreviations

CBA	Cost-Benefit Analysis
CPI	Consumer Price Index
EPA	Environmental Protection Agency
FAO	Food and Agriculture Organization
GDP	Gross Domestic Product
GLWD	Great Lakes and Wetlands Database
MCA	Multi-criteria Analysis
MEA	Millennium Ecosystem Assessment
NTFP	Non-Timber Forest Products
PCA	Principal Component Analysis
SAR	South Africa Rand
SUR	Seemingly Unrelated Regressions
UNDP	United Nations Development Programme
USD	United States Dollars
USFWS	United States Fish and Wildlife Service

CHAPTER 1

INTRODUCTION

1.1 Background and Statement of the Problem

It is now widely recognised that rural communities with livelihood strategies that combine subsistence agriculture with the utilisation of wetland[1] resources constitute a significant proportion of the population in developing countries (Silvius *et al*., 2000; Dixon and Wood, 2003; Adams, 1993). The report by the Millennium Ecosystem Assessment (MEA) (2005) to the Ramsar Convention entitled 'Ecosystems and Human Well-being: Wetlands and Water synthesis' extensively documents the importance of ecosystem services provided by wetlands for human well-being.

In southern Africa, wetlands play a significant role in the livelihoods of rural communities (Taylor *et al*., 1995; Breen *et al*., 1997; Frenken and Mharapara, 2002). The ability of wetlands to store water during the wet season and release it during the dry season provides farmers, who live in semi-arid areas, with opportunities to grow crops all-year round thereby improving their food security and incomes. Besides crop production, wetlands provide other services that support people's livelihoods such as: dry season livestock grazing and watering; domestic water supply; fishing; and natural products (Matiza and Chabwela, 1992; Mmopelwa, 2006).

However, wetlands are sensitive ecosystems that are threatened by human interventions. Altering the wetland environment through conversion to croplands and other uses has the potential to degrade the wetland and undermine its capacity to provide services in the future. As in many other parts of the world, wetlands in southern Africa are being increasingly degraded and lost through conversion to croplands (Taylor *et al*., 1995; Matiza and Chabwela, 1992; Breen *et al*., 1997; Biggs *et al*., 2004). This has been primarily driven by population growth and the increasing

[1] Wetland ecosystems are generally defined as 'areas of marsh, fen, peatland or water, whether natural or artificial, permanent or temporary, with water that is static or flowing, fresh, brackish or salt, including areas of marine water the depth of which at low tide does not exceed six metres'(Barbier *et al*. 1997; MEA 2005).

frequency of droughts. Given the importance of the direct and ecological services wetlands provide to human society, it is important that they are sustainably managed[2] so that they continue to provide services in the future.

Two major limitations to sustainable management of wetlands in Africa have been identified in the literature. The first limitation is that wetland users and decision-makers have insufficient understanding of the true values of wetlands and the consequences of alternative management and policy regimes on wetland functioning, ecosystem services and human well-being (Barbier, 1994; Schuyt, 2002; Schuyt, 2005).

The second limitation is the lack of understanding of the factors that influence people's decisions on the use of wetland resources. This aspect is critical, because while the use of wetlands is common in Africa, the extent to which households incorporate wetland activities into their livelihood strategies varies considerably due to significant socio-economic differentiation across households (McCartney and Van Koppen, 2004). Understanding how such differentiation influences the dependence on wetland resources is important when considering possible interventions for supporting rural livelihoods and promoting the sustainable use of wetlands.

In general, very little work has been done on the two constraints articulated above, particularly in southern Africa (Frenken and Mharapara, 2002). To the best of the author's knowledge: there is very little empirical knowledge of the impacts of alternative wetland management and policy regimes on wetland functioning, ecosystem services and economic well-being are currently available in southern Africa. This is particularly the case with modelling multiple benefits from an ecosystem to enable the evaluation of trade-offs between the provision of multiple

[2] Sustainable use or management of an ecosystem refers to human use of the ecosystem so that it yields continuous benefits to the present generation without compromising its potential to meet the needs of future generations (MEA 2003). The concept implies that people use and derive benefits from an ecosystem in a manner that does not exceed its carrying capacity and compromise the long-term productivity of the ecosystem. In contrast, ecosystem conservation implies non-use (strict protection) or maintenance of an ecosystem in its pristine state. It can be total (where the entire ecosystem is under protection) or partial conservation (where only parts of the ecosystem are under protection). Except in cases where a resource is non-renewable or its use has irreversible effects, strict conservation is seldom an optimal strategy especially in rural populations in Africa where the natural resource base is key to people's well-being.

services. Similarly, empirical knowledge on the factors that influence people's decisions on the use of wetland resources for wetland systems in the region is limited. Against this background, this study seeks to make two important contributions. The first is the analysis of the factors that influence household decisions on the use of wetland products using an agricultural household modelling framework. The framework takes into consideration the fact that rural households are both producers and consumers and that they allocate their scarce resources among competing livelihood activities.

The second contribution is the evaluation of trade-offs between provisions of various components of a bundle of multiple wetland services using a dynamic ecological-economic model to simulate the impacts of alternative policy and management regimes on wetland functioning, ecosystem services supply and human well-being. The results of this study should generate useful insights for improving policy and management interventions to promote the sustainable management of wetlands in southern Africa. The Ga-Mampa wetland, which is located in the Limpopo basin (on the South African part) of southern Africa, has been selected as the case study area.

1.2 Objectives of the Study

The primary objective of this study is to: analyse rural households' resource allocations and decisions among competing livelihood activities including wetland activities; and evaluate the impacts of alternative policy and management regimes on wetland ecosystem functions and human well-being. The specific objectives are to:

1. Identify the factors that influence rural household labour allocation and product supply decisions among competing livelihood activities, including wetland activities.
2. Develop an ecological-economic model establishing the linkages between ecological and economic systems in a wetland system and apply the model to evaluate the impacts of alternative policy and management regimes on wetland functioning, ecosystem services supply and economic well-being.
3. Draw relevant policy recommendations for the sustainable management of wetlands based on the findings of the study.

1.3 Hypotheses of the study

Based on findings in the literature on rural household labour allocation and supply decisions and also on the interactions between ecological and economic systems in developing countries, the following hypotheses are made:

1. Higher education, wealth and access to off-farm income contribute to the reduced participation in on-farm and wetland activities, which have positive impacts on wetland conservation.
2. Policy interventions that promote diversification out of agriculture, such as improving access for the poor to off-farm income and employment opportunities, can simultaneously enhance people's economic well-being and wetland conservation.

1.4 Approaches and methods of the study

Two main analytical approaches are employed to achieve the aforesaid study objectives. To pursue the first objective the agricultural household model is employed. The agricultural household model considers rural households to make joint production and consumption decisions to maximise utility. The model is used to derive a system of reduced form labour use as well as grain and wetland products supply equations, which are estimated jointly using a seemingly unrelated regression approach.

To achieve the second objective, an ecological-economic model, based on the system dynamics framework, is developed and applied. The system dynamics framework takes into consideration feedback effects between ecological and economic systems as well as involved trade-offs in the supply of individual constituents of multiple services provided by wetlands. This framework also captures the intertemporal effects of interventions on ecosystem dynamics. This model uses labour use with grain and wetland products supply functions' parameters estimated in the first part of the study.

1.5 Organisation of the thesis

The following chapter presents background information on the biophysical and socio-economic characteristics of the study area. It also briefly discusses: the characteristics of wetland ecosystems in southern Africa in terms of the main types of wetland ecosystems and their distribution; wetland services and their link to human well-being; and major threats to wetlands. Chapter 3 presents the analytical framework for analysing household labour allocation and supply decisions for alternative livelihood activities including wetland activities. The empirical model and results on the determinants of household labour allocation and supply decisions for wetland products and grain are presented and discussed in Chapter 4. Chapter 5 reviews analytical approaches used in analysing the linkages between ecological and economic systems and evaluating: the impacts of alternative management and policy scenarios on ecosystems and the supply of ecosystem services and economic well-being. Chapter 6 develops an empirical ecological-economic model establishing the linkages between the ecological and economic systems in the studied wetland and applies the model in simulating impacts of alternative management and policy regimes. Finally, Chapter 7 presents a general summary and conclusion and also derives policy implications based on the findings of the study.

CHAPTER 2

WETLAND ECOSYSTEMS IN SOUTHERN AFRICA AND THEIR IMPORTANCE FOR HUMAN WELL-BEING

2.1 Introduction

This chapter provides an overview of wetland ecosystems in southern Africa and demonstrates their significance for the well-being of people. The first section presents background information on the biophysical and socio-economic features of the study area. Section two characterises wetland ecosystems in the region in terms of the main types of wetland ecosystems and their distribution. The third section discusses the link between wetland ecosystem services and human well-being. The main threats to wetlands in southern Africa are discussed in section four and section five then concludes the chapter.

2.2 Biophysical and socio-economic characteristics of the study area

2.2.1 Climate and major ecosystems

The Limpopo Basin is situated in the eastern part of southern Africa and is one of the largest river basins in the region (Figure 2.1). The riparian countries are Botswana, Mozambique, South Africa and Zimbabwe. The drainage area of the river basin is estimated at 413 000 km^2 (FAO, 2004). Approximately 45% of the land area is located in South Africa (Table 2.1).

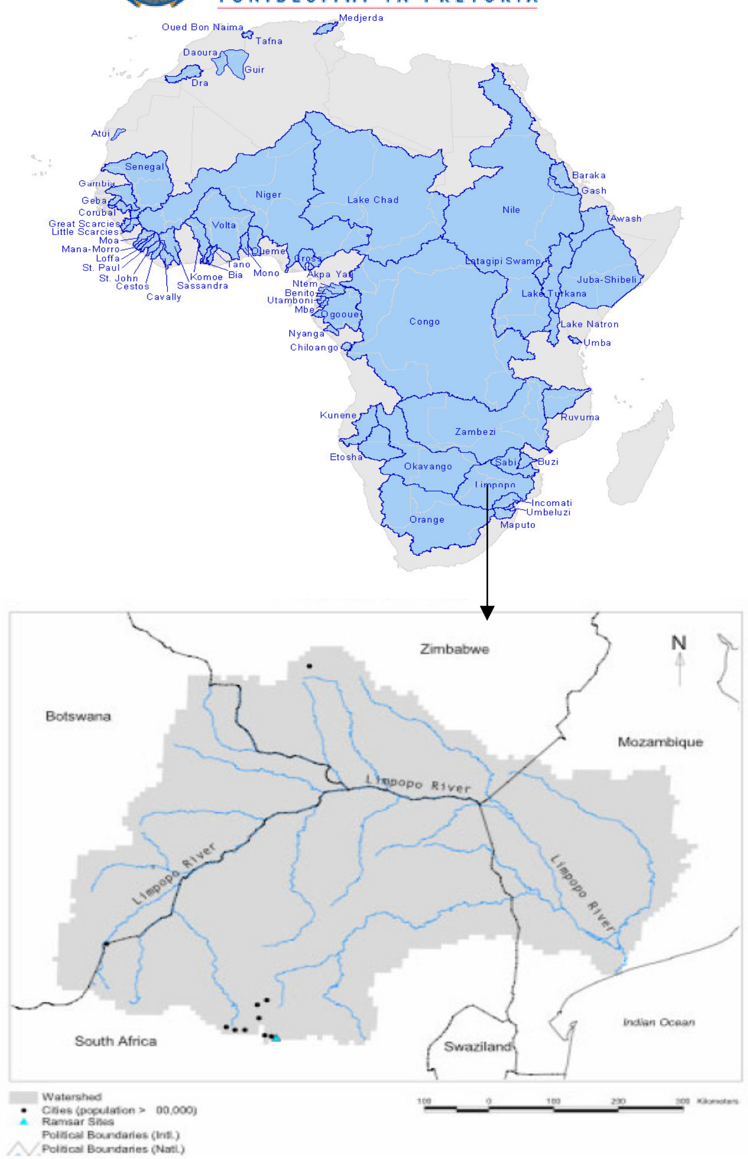


Figure 2.1: Map showing (a) African river basins and (b) the Limpopo river basin riparian countries (World Resources Institute, 2003)

Table 2.1: Area under the Limpopo river basin by riparian country

Riparian country	Area of country in basin (km^2)	Percentage of total area of basin
South Africa	183,500	45
Mozambique	87, 200	21
Botswana	81, 500	20
Zimbabwe	62,600	15

Source: FAO (2004)

The climate of the Limpopo basin is predominantly semi-arid. Rainfall is very low and varies from approximately 300mm in the hot dry western parts in Botswana to

1000 mm in the high rainfall areas in the South African part of the basin (Rosenberg, 1999).

Rainfall in the Limpopo basin is highly seasonal with 95% of it occurring between October and April, often with mid-season dry spells occurring during the critical stages of crop growth. With the exception of small areas on the outer limits of the basin, the rainfall season is very short (FAO, 2004). Despite the periodic occurrence of short and intense storms, rainfall is generally erratic and unreliable, and droughts are frequent. The seasonal nature of rainfall is reflected in the highly seasonal water flows with some surface water bodies completely drying up during the dry season.

Evaporation rates are higher than rainfall, ranging from 800mm to 2400mm per year, with an average of 1970mm per year (FAO, 2004). These high evaporation rates reduce effective rainfall and soil infiltration thereby increasing chances of crop failure in rainfed cropping systems.

Southern Africa has diverse ecosystems. Scholes and Biggs (2004) identified seven main ecosystems (biomes) in the region, the savanna being the dominant ecosystem (Table 2.2).

Table 2.2: The main ecosystems of southern Africa

Ecosystem (biome)	Sub-biome	Soil/geology	Area ($1000km^2$)		
			Pre-colonial	Area remaining untransformed by cultivation by year 2000	Percentage (%) remaining untransformed by cultivation by year 2000
Forest	Lowland forest	Generally infertile	1815	1693	93
	Montane forest	Fertile, but steep	190	149	78
Savanna	Miombo	Infertile, sandy	3558	3217	90
	Mopane	Fertile and loamy	605	469	77
	Acacia	Fertile, loamy & clayey	1785	1504	84
Grassland	Montane grasslands	Fertile or infertile	434	298	69
Arid shrubland	Non-succulent	Fertile often calcareous	671	663	99
	Succulent	Often very stony	103	102	100
Desert	Namib	Sandy or gravelly	126	126	100
Fynbos	*Fynbos*	Generally infertile	78	68	87
Wetland	Permanent wetland	Organic (peaty)	172	153	89
	Seasonal (dambo, *vlei*)	Often cracking clays (turf)	990	885	89
	Estuaries & mangroves	Saline, mangroves	23	22	95
	Salt pans		40	38	95
	Inland water and coastal waterways		197	197	100

Source: Scholes and Biggs (2004)

2.2.2 Demographic and socio-economic characteristics

Approximately 14 million people reside in the Limpopo basin. The basin is predominantly rural, with almost 57% (8 million) of its population residing in rural areas. Although South Africa has the highest number of people living in the basin, in comparison Botswana has the highest proportion of its population residing in the basin. The population density, over much of the basin, is less than five people per km^2 (Mgonja *et al*., 2006). Population density is highest in high rainfall areas and in large urban and industrial areas.

Table 2.3: Selected population statistics for the Limpopo basin

Riparian country	Total population of country in 1998 (million)	Population residing in basin (million)	Percentage of country's population in basin
South Africa	42.1	10.7	25
Mozambique	16.5	1.3	8
Botswana	1.6	1.0	63
Zimbabwe	11.4	1.0	9
Total	71.6	14.0	

Source: FAO (2004)

Most of the people living in the basin rely mainly on agriculture (i.e. crop and livestock production) for their livelihood. Non-farm sectors such as mining are also important sources of livelihood, particularly in areas with significant industrial and urban developments. However, low levels of education and skills among the majority of the rural population limit their opportunities for employment in non-farm sectors.

Agricultural production in the Limpopo basin is predominantly rainfed. Maize, which is the staple crop in the basin countries, is produced largely under rainfed conditions. Consequently, production varies from year to year due to annual rainfall variability. Although there is surplus maize available at the basin level, household food insecurity is a major problem in most rural areas in the basin due to low agricultural productivity, which is a result of several factors: frequent droughts; land degradation; low use of fertilisers and improved crop varieties; limited access to markets; limited irrigation; and limited agricultural knowledge (FAO, 2004; Mgonja *et al*., 2006).

In terms of the standard of human well-being, the Human Development Index (a composite index of human welfare, which includes health, education and income dimensions of human welfare) for the basin countries ranges from 0.35-0.7, which indicates that the level of human well-being in the basin is quite low (UNDP, 2003). It is estimated that 57% of the basin's population is below the poverty line (Amaral and Sommerhalder, 2004). The increasing level of poverty is partly due to declining supply of ecosystem services (Scholes and Biggs, 2004).

2.3 Characterisation of wetland ecosystems

2.3.1 Definition of wetlands

The term 'wetland' has been defined in many ways. The difficulty in defining wetlands arises partly because of their highly dynamic character and the difficulties in defining their boundaries (Turner *et al*., 2000).

The Environmental Protection Agency (EPA) of USA defines wetlands as 'areas where water covers the soil and is present either at or near the surface of the soil all year or for varying periods of time during the year'. They define two broad categories of wetlands: coastal and inland wetlands (EPA, 2004).

The United States Fish and Wildlife Service (USFWS) defines wetlands as 'lands transitional between terrestrial and aquatic systems where the water table is usually at or near the surface or the land is covered by shallow water' (Cowardin *et al*., 1979). According to this definition wetlands must have one or more of the following three attributes:

- (i) at least periodically, the land must predominantly support hydrophytes;
- (ii) the substrate must consist of predominantly undrained soil; and
- (iii) the substrate must be non-soil and be saturated with water or covered by shallow water at some time of the growing season each year.

In southern Africa, wetlands are defined differently across the region, thus showing the different perceptions people have of wetlands in this region. For instance, in South Africa wetlands are loosely defined as places where marine, aquatic and terrestrial ecosystems meet and interact. Whereas in Zimbabwe wetlands are understood to be lands that are subjected to permanent or seasonal flooding or areas of subsurface water accumulation through seepage such as *vleis* or dambos (Hirji *et al*., 2000).

The most widely accepted definition is that proposed under the Ramsar Convention (1971) which defines wetlands as 'areas of marsh, fen, peatland or water, whether natural or artificial, permanent or temporary, with water that is static or flowing, fresh, brackish or salt including areas of marine water the depth of which at low tide does not exceed six meters' (Ramsar Convention, Article 1.1) (Ramsar Convention Secretariat, 1971).

What is evident from the above definitions is that the term 'wetland' covers a wide range of habitats that share a number of common features, the most important of which is continuous, seasonal or periodic standing of water or saturated soils with characteristic fauna and flora (Finlayson and Van der Valk, 1995).

2.3.2 Types of wetland ecosystems

Wetlands vary in type and size. Southern Africa's wetlands are among the most diverse, both physically and biologically, of any other in the world (Taylor *et al*., 1995). Wetlands differ in habitat or in their physical features, such as depth of water, perennial flow and types of vegetation. However, very little work has been done to systematically characterise and classify wetland ecosystems in the region. Yet, this kind of information is necessary for wetland conservation and management (Finlayson and Van der Valk, 1995).

A number of wetland classifications exist in literature. Just as some disagreements exist on the definition of wetlands so too is there no universally agreed classification system of wetlands. This is partly attributed to the fact that wetlands occupy an intermediate position between truly terrestrial and aquatic ecosystems and therefore encompass a diverse array of habitats (Finlayson and Van der Valk, 1995). One classification system categorises wetlands by their: geographical location; water quality; and mode of formation. This has given rise to classifications such as: inter-tidal and sub-tidal marine systems; lakes (artificial and natural); riverine systems;

floodplains; swamps; marshes; and dambos. Dugan (1990) classified wetland systems into three main categories, based on the quality of water and the mode of formation, namely: saltwater wetlands; freshwater wetlands; and artificial wetlands.

Roggeri (1995) classified wetlands according to geomorphological units (the main sources of water and nutrients) and ecological units (in particular vegetation). The geomorphological units distinguish four parts: alluvial lowlands; small valleys; lakeshores; and depressions. In addition to this, three ecological units were specified: periodically flooded ecosystems; swamps and marshes; and permanent shallow lakes and water bodies.

The most comprehensive and widely applauded wetland classification system is that developed by Cowardin *et al*. (1979). This classification is hierarchical and includes several layers of detail for wetlands including: a subsystem of water flow; classes of substrate types; subclasses of vegetation types; and dominant species. It classifies wetlands into five major categories based on hydrologic, geomorphic, chemical and biological features, which are: marine; estuarine; lacustrine; riverine and palustrine.

Breen *et al*. (1997) classified the main wetland systems in southern Africa based on the Cowardin *et al*. (1979) classification system and identified six main wetland classes: marine; estuarine; lacustrine; riverine; palustrine; and endorheic systems. The main features of these wetland classes are discussed below.

2.3.2.1 Marine systems

Marine systems consist of the open ocean overlying the continental shelf and its associated coastline. They are exposed to the waves and currents of the open ocean and their water regimes are determined primarily by the ebb and flow of oceanic currents. In southern Africa, the marine system also includes the coastline of the Indian and Atlantic oceans that is characterised by coral reefs, seagrass beds and intertidal areas. These systems are poorly understood and their potential has not been fully investigated (Breen *et al*., 1997).

2.3.2.2 Estuarine systems

These systems include tidal wetlands which are usually semi-enclosed by land but have open, partially obstructed or sporadic access to the open ocean and in which water is at least occasionally diluted by freshwater run-off from the land. Estuarine systems are subdivided into sub-tidal areas, which are continually submerged, and intertidal areas, which are exposed and flooded by tides. The intertidal zone may include a variety of habitats such as lagoons, mud flats, marshes and mangroves. These systems are regarded as some of the most productive ecosystems in the world and are major breeding and feeding sites for fish and invertebrates.

2.3.2.3 Lacustrine systems

These systems are areas of permanent water with little flow. Their main characteristic features are that: they are situated in topographic depressions or dammed river channels; they lack trees, shrubs, persistent emergent mosses or lichens with more than 30% area coverage; their total area exceeds eight hectares (Cowardin *et al*., 1979). These systems include natural or constructed dams and lakes. Pans, which are categorised under lakes by other scholars, are sometimes classified under lacustrine systems (Cowan and Van Riet 1998). However, pans are slightly different from lakes in that pans have a water depth of less than three metres and dry up during the dry season, whereas lakes are more permanent in nature, larger in size, have a greater water depth and support a wider variety of fauna and flora (Richards, 2001). In southern Africa, lacustrine systems are mostly used for hydroelectric power and irrigated agriculture. However, they are threatened by pollution due to the disposal of industrial pollutants and siltation.

2.3.2.4 Palustrine systems

Palustrine systems can be described as transition zones between terrestrial and aquatic systems. These systems include freshwater habitats with a wide range of physical, water regime and vegetation characteristics. These include: permanent or seasonal marshes and swamps; peatlands and fens; springs; and headwater wetlands. These systems are the most widespread wetland systems in southern Africa (see Table 2.2). Of the different types of palustrine systems seasonal wetlands or dambos (*vleis*) are the most widespread. These wetland systems are extensively used for crop production and livestock grazing. Palustrine systems also include marshes and swamps which are typically dominated by reeds (*Phragmites sp*.) and papyrus (*Cyperus papyrus*) which are of importance to the livelihoods of many rural communities in southern Africa. Floodplain wetlands, which are areas of periodic flooding, situated between the river channel and valley sides, fall under this category. They are extensively used for agriculture, fisheries and wildlife.

2.3.2.5 Riverine systems

Riverine wetlands are composed of small, localised floodplains and swamps, which occur along river channels. These wetland systems are valuable sources of fish and are also used for agriculture. Riverine systems also play a key role in hydrological regulation (Dini *et al*., 1998).

2.3.2.6 Endorheic systems

These are commonly referred to as pans in South Africa and as small closed basins or playas in geomorphological literature. The endorheic system has been added to Cowardin's original five categories of wetland systems in recognition of the significant ecological role played by pan ecosystems in southern Africa (Hirji *et al*., 2000). Being located largely in dry regions, pans display characteristic patterns of ephemeral and irregular inundation.

Table 2.4 presents examples of wetland systems in the southern Africa region under each wetland category.

Table 2.4: Examples of major wetland types in southern Africa and the main services they provide

Wetland type	Major examples of wetlands in the region	Country	Main services it provides
Palustine wetlands (Floodplains)	Barotse floodplain	Zambia	Wildlife, fisheries, livestock grazing, water supply and cultural heritage
	Okavango delta	Botswana	Wildlife, agriculture, grazing, water extraction, fisheries and tourism
Riverine wetlands	Zambezi river	Angola, Botswana, Namibia, Malawi, Tanzania, Zambia and Zimbabwe	Wildlife, fisheries, hydropower, water supply, navigation and tourism
	Limpopo river	Botswana, South Africa, Zimbabwe and Mozambique	Wildlife, water supply, agriculture and irrigation
Lacustrine wetlands	Lake Kariba	Zambia and Zimbabwe	Hydroelectric power, wildlife, agriculture, fisheries and tourism
	Lake Chilwa	Malawi and Mozambique	Fisheries
Estuarine delta	Zambezi delta	Mozambique	Fisheries, agriculture, wildlife and waterfowl habitat
	Limpopo/Inkomati	Mozambique	Wildlife, fisheries, agriculture, tourism and forestry
Endorheic wetlands(Pans)	Cahora Bassa lake	Mozambique	Hydroelectric power and fisheries
	Makgadikgadi Pan	Botswana	Mining, wildlife, tourism and grazing

Source: Breen *et al*. (1997); Hirji *et al*. (2000)

2.3.3 The distribution of wetlands

It is estimated that 6% of the world's land area consists of wetlands (Mitsch and Gosselink, 2000). The MEA (2005) estimated the global extent of wetlands to be in excess of 1,280 million hectares, although it is well-known that this is underestimated. However, the estimates of the extent of wetlands globally and in Africa differ significantly across studies due to the different definitions of wetlands and methods used for delineating wetlands (Finlayson *et al*., 1999). Table 2.5 presents estimates of wetland areas by Ramsar region.

Table 2.5: Estimates of global wetland areas by Ramsar region

Region	1999 Global Review of Wetland resources (million hectares)	2004 Global Lakes and Wetlands Database (million hectares) (Lehner and Doll, 2004)
Africa	121-125	131
Asia	204	286
Europe	258	26
Neotropics	415	159
North America	242	287
Oceania	36	28
Total area	1276-1280	917

Source: MEA (2005)

Despite the widespread distribution of wetlands across Africa, knowledge on the extent of African wetlands is far from complete and is inadequate to support management needs (Taylor *et al*., 1995; Finlayson *et al*.,1999). Due to lack of scientific investigation and a single classification system, as well as inconsistent mapping policies, an exact estimate of the total extent of wetlands in Africa is unknown (Schuyt, 2005). However, it is estimated that 1% of the land surface in Africa is covered by wetlands (Schuyt, 2002). In sub-Saharan Africa, wetlands constitute approximately 4.7% of the land surface and this figure increases to 6% with the inclusion of lakes, rivers and reservoirs (Rebelo *et al*., 2009). Most of the wetlands occur within the major river basins in the region (Figure 2.2). Swamps and floodplains are the most widespread type of wetlands in Africa occurring mostly in central, eastern and southern Africa.

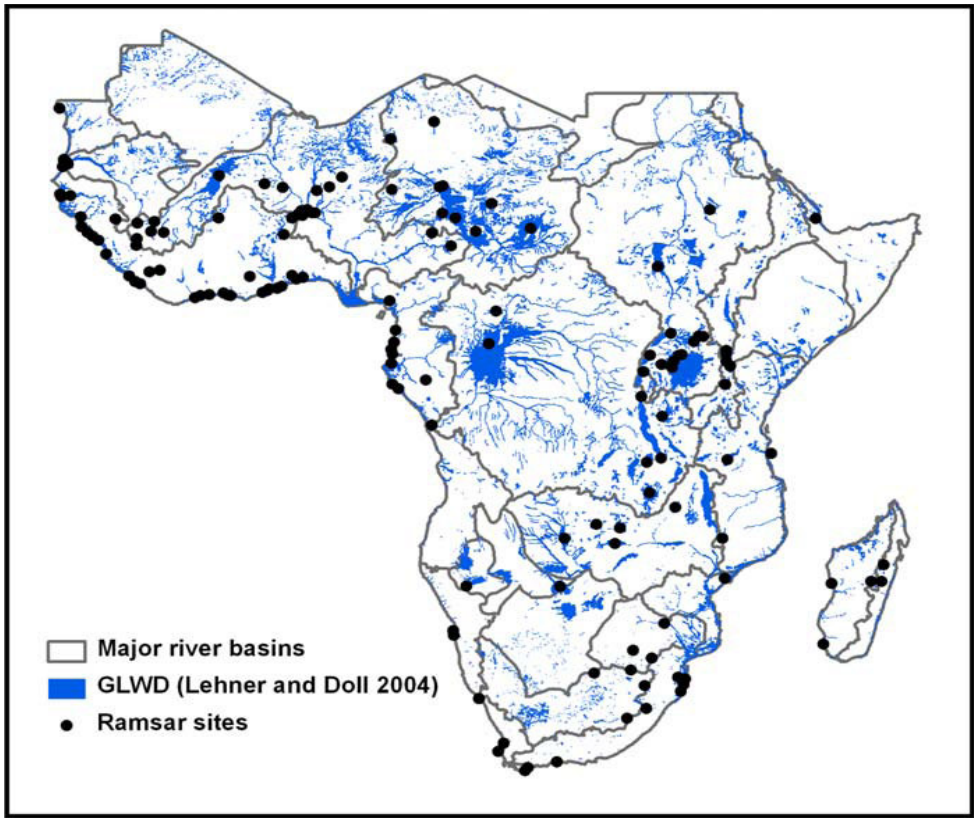


Figure 2.2: Wetland distribution and location of Ramsar sites across major river basins in Sub-Saharan Africa (Rebelo *et al*., 2009)

In southern Africa, wetland ecosystems were identified as one of the eight main ecosystems in the region (Scholes and Biggs, 2004). However, quantitative data on the extent of wetlands in the region is limited due to lack comprehensive national wetland inventories characterising and classifying wetlands in a systematic manner (Taylor *et al*., 1995; Frenken and Mharapara, 2002). In addition, as is the case at the global and continental levels, the figures on the total extent of wetlands in the region also differ significantly across studies due to different definitions of wetlands and delineation methods.

Within the Limpopo basin, it is estimated that 3% of the total land area is made up of wetlands (World Resources Institute, 2003). Table 2.6 presents estimates of area under wetlands in each of the riparian countries of the Limpopo basin from different sources.

Table 2.6: Estimates of wetland area (in km^2) in Limpopo basin countries

Country	Taylor *et al.* (1995)	Stevenson and Frazier (1999)	Country area	Percentage of wetland
Botswana	28,310	-	569,582	5
Mozambique	24,122	25, 632	799,380	3
South Africa	4,600	7,545	1,219,090	<1
Zimbabwe	12,800	16,832	390,310	3-4

Some of the wetland systems in the region are listed as being of international importance under the Ramsar Convention on Wetlands (Ramsar Convention, 1971). The Ramsar Convention is an intergovernmental treaty that provides a framework for national action and international cooperation for the wise use of wetlands. Six of the countries in southern Africa are parties to the Ramsar Convention: Botswana; Malawi; Namibia; South Africa; Tanzania; and Zambia. Some of the obligations of the parties to the Convention are to designate some wetland sites to the Ramsar list of wetlands of international importance and to promote the conservation and wise use of wetlands (Ramsar Convention Secretariat, 2004). The criteria for designating wetlands to the Ramsar list include: the uniqueness of the wetland system; its role in supporting populations of endangered species; and its role in supporting waterfowl populations.

Several wetland sites in southern Africa are designated Ramsar sites. Examples include the Okavango delta (Botswana), Lake Chilwa (Malawi), the St Lucia system (South Africa) and the Kafue Flats (Zambia). These wetland systems have socio-economic importance to the communities living around them and the countries in which they are found. Although some of the region's most significant wetland systems are not listed as Ramsar sites, this does not mean that they are not important. Indeed in many arid areas in the region, any wetland system of any size is of significant socio-economic importance to the local people (Hirji *et al*., 2000).

2.4 The importance of wetlands for human well-being

The fact that wetlands support human well-being through its provision of services is well-known. This was confirmed in the MEA (2005) to the Ramsar Convention, entitled: 'Ecosystems and Human Well-being: Wetlands and Water synthesis.' The linkages between wetland services and human well-being are shown in Figure 2.3. In southern Africa, the linkages between ecosystems and human well-being are stronger in poor rural communities, whose lives are directly affected by the availability of ecosystem products such as food, medicinal plants and firewood (Scholes and Biggs, 2004).

The services that wetlands provide can be classified into: provisioning; regulating; cultural; and supporting services (Turner *et al*., 2000; De Groot *et al*., 2002; Hein *et al*., 2006; MEA, 2005). Provisioning services are tangible products people obtain from wetlands such as: food; fibre; water; and genetic resources. Regulating services are benefits obtained through the role of wetlands in the regulation of ecosystem processes such as: water purification; climate regulation; and erosion control. Cultural services are non-material benefits people derive from wetlands through: spiritual enrichment; cognitive development; and recreational, educational and aesthetic values. Supporting services are those services that are necessary for the production of all other ecosystem services such as: soil formation; nutrient cycling; and biodiversity. Table 2.7 shows examples of services provided by wetlands under each of these categories.

It is worth noting that a wetland system may not provide the full range of services listed in the table. This is because the services that a particular wetland provides are determined by its characteristics and most fundamentally by specific factors such as size, climate, geology and topography. The services provided by wetlands contribute to human well-being in many ways (Barbier *et al*., 1997; MEA, 2005). It is well-known that the provisioning services from wetlands are strongly linked to the access of basic materials for the 'good life' dimension of human well-being (MEA, 2005). The regulating functions of wetlands also affect human well-being in multiple ways. For instance, water purification, flood attenuation and climate regulation functions affect the health, security and other components of human well-being. Supporting services are critical for sustaining vital ecosystem functions that deliver many benefits to people. In addition to these services, wetlands have significant aesthetic, educational, cultural and spiritual values and provide invaluable opportunities for recreation and tourism, thereby influencing the social relations aspect of human well-being.

Table 2.7: Ecosystem services provided by or derived from wetlands

Service	Examples
Provisioning	
Food	Production of fish, wild game, fruits and crops
Fibre and fuel	Production of fuelwood, fodder, building and craft materials
Fresh water	Storage and retention of water for domestic, industrial and agricultural use
Biochemical	Extraction of medicines and other materials from biota
Genetic materials	Genes for resistance to plant pathogens, ornamental species
Regulating	
Climate regulation	Source of and sink for greenhouse gases, influence local and regional temperatures and precipitation
Water regulation	Groundwater recharge and discharge
Water purification	Retention, recovery and removal of pollutants
Erosion control	Retention of soils and sediments
Natural hazard regulation	Flood control and storm protection
Pollination	Habitat for pollinators
Cultural	
Spiritual and inspirational	Source of inspiration, spiritual and religious value
Recreational	Opportunities for recreational activities
Aesthetic	Many people find beauty and aesthetic value in wetland ecosystems
Educational	Opportunities for formal education and training
Supporting	
Soil formation	Sediment retention and accumulation of organic matter
Nutrient cycling	Storage, recycling and processing of nutrients

Source: MEA (2005)

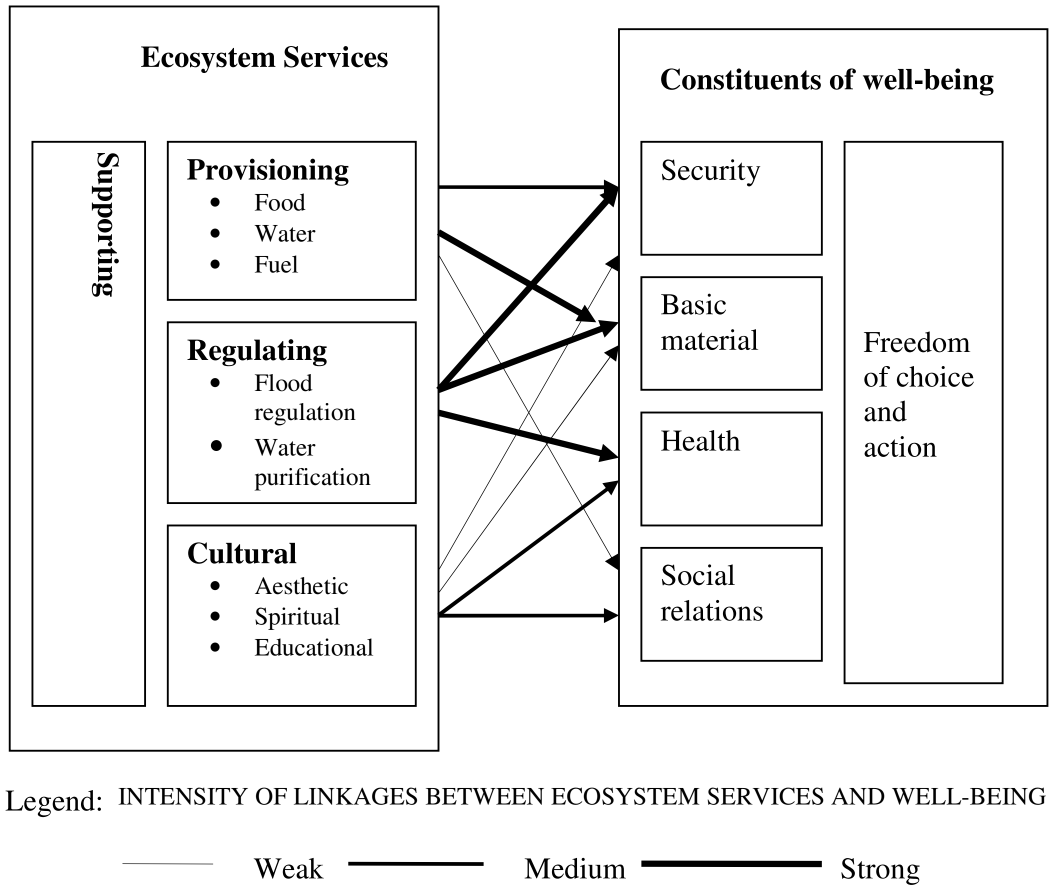


Figure 2.3: Linkages between wetland services and human well-being (MEA, 2005)

In southern Africa, many communities depend on wetlands for multiple values, including social, economic, ecological and aesthetic values (Breen *et al*., 1997; Hirji *et al*., 2000). As much of the region experiences semi-arid to arid climate conditions, many people rely on wetlands for agricultural production due to their ability to retain water throughout the year and for their fertile soils (Chabwela, 1991; Frenken and Mharapara, 2002; Breen *et al*., 1997). Wetland cultivation provides a coping mechanism by which communities mitigate crop yield losses that are associated with low rainfall and frequent droughts.

Besides agriculture, wetlands provide other provisioning services upon which a significant proportion of the rural population in the region depends. These include: dry season livestock grazing and watering; fisheries; wildlife; wetland plants (papyrus, reeds, sedges, edible plants, medicinal plants and thatching grass); clay for pottery; as well as water supply for domestic, irrigation and industrial uses (Breen *et al*., 1997).

Several studies quantified the economic contribution of wetland systems in southern Africa to human welfare. However, it is worth noting that most of these studies were carried out at local scales rather than at national and regional scales due to limited data on the actual extent of wetlands at national and regional levels. In addition, most of the valuation studies focused on quantifying a few key services due to the difficulty in quantifying some of the wetland services given the data and resource limitations. For example, Seyam *et al*. (2001) used a simple approach that takes into account the common problems with data limitations and estimated that the total use value of approximately 3 million hectares of wetlands in the Zambezi basin was about $145 million (USD) per year, which was equivalent to 4.7% of Zambia's GDP in 1990. Adekola (2007) estimated that the direct use value of the main provisioning services of the Ga-Mampa wetland, which covers an area of 120 hectares, is $90 000 (USD) per year (2005/2006 values).

Table 2.8 shows the net financial values per user household for selected wetland services in selected wetland systems in the region, including the study area. These net financial values deduct variable costs, but do not take into account labour costs. As most of the rural households rely on family labour for most wetland activities, deducting the opportunity costs of labour in environments of mostly low earning skills and limited labour opportunities is perhaps not a good idea.

The figures presented show that the net financial value per user household for wetland services varies from one wetland system to another, which confirms that the extent to which wetlands provide services and the contribution of wetland services to human well-being vary depending on the characteristics of the wetland. In some cases a service (or services) that is provided by one wetland system is absent in another wetland system.

Table 2.8: Net financial values per user household of selected services for selected wetland systems in southern Africa

Wetland service	Chobe and Caprivi wetlands, Namibia US$/user household/year	Barotse Floodplain, Zambia US$/user household/year	Lower Shire wetlands, Malawi US$/ user household/year	Ga-Mampa wetland, South Africa US$/user household/year
Crop production	205	85	310	1072
Livestock grazing	485	256	169	-
Fish production	299	325	56	12
Reeds collection	39	6	7	93
Sedge and papyrus collection	42	5	32	88

Source: Turpie *et al.* (1999); Adekola (2007)

Some wetland systems in the region have important recreational, aesthetic and spiritual values. Aesthetic value is reflected, for example, in the tradition of some tribes to have initiation rites in wetland areas. The abundant wildlife and scenic beauty offered by wetland ecosystems form the backbone of the tourism industry in the region (Hirji *et al*., 2000). Examples of wetlands in southern Africa that are important for tourism are the Okavango delta, Etosha pans and St Lucia to name a few. Apart from supporting nature-based tourism, some wetlands are used for a variety of recreational activities such as: sport hunting; fishing; bird watching; swimming; and sailing.

2.5 Major threats to wetland ecosystems in southern Africa

Globally, wetlands continue to be degraded and lost at an increasing rate (Moser *et al*., 1996; MEA, 2005; Ramsar Conservation Bureau, 1997). It is estimated that more than half of the wetlands in the world may have been lost since the start of the 20th century, with the greatest loss found in developed countries, while dramatic losses have occurred over a short space of time in developing countries (Barbier, 1993).

Southern Africa is no exception to this global trend (Taylor *et al*., 1995; Breen *et al*., 1997). However, data on wetland losses and conversion rates for the region are scanty and hard to compare as different sources provide very different estimates of wetland areas. In some cases the data is not available due to the lack of capacity in many countries to undertake wetland inventory studies (Taylor *et al*., 1995).

The few studies, which were conducted in the region, show that the rate of wetland degradation and loss is quite high. For example, in South Africa, Kotze *et al*. (1995) estimated that more than 50% of the wetland area had been lost countrywide. In a review of wetland inventories in southern Africa, Taylor *et al*. (1995) reported wetland losses in two areas in Natal, South Africa: the Tugela basin, where over 90% of the wetland area has been lost in parts of the basin; and the Mfolozi catchment, where 58% of the original wetland area had been lost.

The loss of wetlands disproportionately affects the well-being of poor people who depend on wetland services for their livelihoods. It is therefore important that wetlands are sustainably managed so that they continue to provide services in future. This is in line with the call by the Ramsar Convention (1971) on the 'wise use' and 'sustainable development' of wetlands. They define wise use as the sustainable utilisation of wetlands for the benefit of mankind in a way compatible with maintenance of the wetland ecological security.

The major threats to wetlands can be classified into direct and indirect drivers (MEA, 2005). Direct drivers are factors that directly affect wetland ecosystem processes. Indirect drivers are those factors that trigger one or more direct drivers. Moser *et al*. (1996) refer to direct drivers as proximate causes of wetland loss and degradation and the indirect drivers as underlying causes. Furthermore, the analysis of the threats to wetlands can be considered at two levels: the direct loss and degradation that occurs to the wetland itself; and the indirect loss and degradation which occur as a result of changes outside (upstream) of the wetland system.

The primary direct drivers of wetland degradation and loss are: infrastructure development (dams, dykes, irrigation, canals and mining); land use or cover due to conversion to agriculture or other uses; wetland drainage and filling; introduction of invasive alien species; overharvesting and overexploitation of wetland products (fish, wildlife and wild plants); water abstraction; water pollution (from sewage discharge, pesticides and sediments); and more recently, climate change (MEA, 2005). Conversion of wetlands to agriculture is the principal cause of wetland loss worldwide. It is estimated that by 1985, 2% of the wetlands in Africa had been converted to agriculture (MEA, 2005).

Socio-economic and political factors are the principal indirect drivers to the loss of wetlands (Kotze *et al*., 1995; Moser *et al*., 1996). These include: population growth; rising poverty and economic inequality; food insecurity; and other socio-economic factors including policy intervention failures, due to inconsistencies among government policies in different departments and institutional failures, related to institutions that govern wetland resources management (MEA, 2005). For example, in the studied wetland system, access and use of wetland resources for both agriculture and natural products is influenced by the interplay between:

- local level institutions (traditional leaders, the wetland committee and the Community Development Forum);
- civil society organisations (non-governmental organisations working on wetlands such as the Mondi Wetlands Project); and
- national level institutions (Department of Agriculture, Department of Water Affairs and Forestry, Department of Land Affairs and the Department of Environmental Affairs and Tourism) (Tinguery, 2006).

In southern Africa, the main underlying factors causing the loss of wetlands are: population growth; rising poverty; severe economic stress; and frequent droughts (Matiza and Chabwela, 1992). Barbier *et al*. (1997), Turner *et al*. (2000) and Schuyt (2005) noted that the underlying causes of wetland degradation and loss are:

(i) lack of understanding of wetland values and the impact of human activities on wetland functioning;
(ii) market failures associated with the character of externalities of many wetland services and the uneven distribution of their benefits across stakeholder groups; and
(iii) policy intervention failures.

Table 2.9 shows the main threats to wetlands in southern Africa.

Table 2.9: Major threats to wetlands in southern Africa ranked according to extent of occurrence

Threat	Rank	Areas at risk
Dams	1	All dam areas especially the Lower Zambezi
Irrigation	1	Most river basins and floodplains in the region
Vegetation clearing (conversion to agriculture)	1	Most parts of southern Africa
Overgrazing	1	Most parts of southern Africa
Over-hunting (Poaching)	1	Largely in Zambia, Angola, Tanzania and Mozambique
Overfishing	1	Most rivers, small lakes and floodplains
Over- extraction of water resource	1	Potentially Zambezi river and Okavango Delta
Population growth and human settlements	2	Coastal zone of Mozambique and dambos of Zimbabwe
Siltation (infilling)	2	Luangwa and Save rivers
Pollution (pesticides)	2	Common in all parts of the region
Pollution (agro-chemicals)	2	Common in all parts
Pollution (industrial)	3	Urban areas and mining sites
Eutrophication	3	Lake Chivero (Zimbabwe) and Kafubu (Zambia)

Legend: 1=A widespread problem seriously disrupting ecological and hydrological processes; 2=Causing serious damage, but is not yet widespread; 3=Present, but not yet widespread

Source: Breen *et al*. (1997)

2.6 Concluding Summary

This chapter briefly presented the biophysical and socio-economic characteristics of the region under study. The chapter also reviewed the major ecosystems in southern Africa and showed that wetlands are one of the eight major ecosystem types occurring in the region. Wetlands provide multiple services, which are important to the livelihoods of many rural communities in the region. The services range from agricultural production, natural products, dry season livestock grazing, water supply, fisheries and other aesthetic and cultural values. The services wetlands provide vary from one wetland to another depending on the biophysical characteristics of each wetland.

Despite their role in supporting people's livelihoods wetlands continue to be degraded and lost at an increasing rate. The major threats to wetlands in the region are conversion to agriculture and overexploitation of wetland products driven primarily by the increasing demand for wetland services due to population growth, increasing poverty levels and other socio-economic factors. Given the key role wetlands play in supporting the welfare of the rural poor in the region it is critical that they are sustainably managed so that they continue to provide services in future.

CHAPTER 3

ANALYTICAL FRAMEWORK FOR RURAL HOUSEHOLDS RESOURCE ALLOCATION DECISIONS AMONG COMPETING LIVELIHOOD ACTIVITIES

3.1 Introduction

Agricultural households in developing countries depend on farm, off-farm and natural resource activities for their livelihoods. These activities compete for household resources and households have to make decisions on how to allocate their resources among these activities. In this chapter, an analytical framework is developed for analysing the factors that influence household resource allocation and supply decisions for competing livelihood activities, including wetland activities in the context of a household labour resource allocation problem. The chapter is divided into three main sections. The first section reviews the empirical literature on the factors that influence rural household labour allocation decisions for competing livelihood activities, including natural resource use activities. The second section presents the analytical household model, derives optimality conditions and discusses the analytical results. The final section gives a concluding summary of the chapter.

3.2 Review of selected literature on the determinants of rural household labour allocation decisions for competing livelihood activities

There is widespread acknowledgement that the extent to which rural households incorporate natural resources into their livelihood activities varies considerably across different households. Similarly, the manner in which households allocate their resources among livelihood activities is different.

Many empirical studies have examined the socio-economic factors, which influence rural household decisions on the use of natural resources, in the context of a labour resource allocation problem. Most of these studies used agricultural household models as the analytical framework for analysing labour allocation decisions made by rural households. The reduced form approach is then used as the basis for empirical estimation of the factors influencing labour allocation and production decisions. However, three different approaches are used for empirical estimation of the reduced form functions. These approaches are: single equation estimation approaches (e.g. Tobit models and ordinary least-squares regression models); two-stage estimation techniques; and system estimation approaches. The first approach applies single equation econometric approaches to estimate the individual reduced form or structural equations, mainly using ordinary least-squares methods. Two-stage (or three-stage) least-squares methods are appropriate where there is need to take into account endogeneity, because single equation ordinary least-squares methods yield biased estimates. Lastly, system estimation approaches jointly estimate equations as a system taking into account across-equation error correlations, yielding unbiased and efficient estimates where such error correlations exist. Selected studies, which applied these approaches in analysing household resource allocation decisions and supply decisions, are reviewed below.

Chen *et al*. (2006) developed a household labour allocation model to analyse the factors that determine the choice of energy and labour allocation for fuelwood collection in rural China. The household model captures a situation in which a household allocates labour across crop production, off-farm work, fuelwood collection and leisure. The empirical model consisted of three reduced form equations for the quantity of fuelwood collected, the time spent collecting fuelwood and the quantity of coal consumed. The explanatory variables used in the three equations are: stove ownership; household characteristics (household size, share of adults, education of household members and household wealth); distance from the forest; total cultivated area; household exogenous income; and village dummies to capture price differences of agricultural goods, marketed goods, coal and off-farm wage rates. A Tobit model is used for empirical estimation of the reduced form equations. The results of the study showed that education and wealth play a role in explaining fuelwood collection and the time input into it. Both education and wealth were found to be negatively related to fuelwood collection. The negative relationship between wealth and fuelwood collection is consistent with the findings of Shackleton and Shackleton (2006), who found for a rural area in South Africa that fuelwood consumption significantly decreases with a household’s wealth status although this was not always true for other non-timber forest products (NTFP). Based on their findings Chen *et al*. (2006) concluded that the promotion of alternative energy sources, the investment in rural infrastructure and policies to stimulate basic education in rural areas can reduce pressure on forest resources.

Dayal (2006) developed a household model that captures the interrelationships between grazing, crop production and fuelwood collection to examine the factors that influence decisions on the levels of extraction of forest biomass by rural households in India. The household model, developed in this study, added the complementary aspects between activities by assuming that rural households can collect fuelwood by: spending labour time for fuelwood collection only; collecting fuelwood while grazing; and/or collecting fuelwood while spending time on crop production. In addition, the model captures the fact that agricultural residues can be used as an energy source and as livestock feed. Also dung is used as a source of energy and as fertilizer in crop production. The empirical model is based on the reduced form equations related to the levels of biomass extracted as functions of exogenous variables. The regressors include household characteristics, such as: household size: quantity of males; social order; wealth (type of house); number of cattle; number of goats; land area; and village dummies. A Tobit model was used for empirical estimation. The study found that location, ownership of biogas and social order are significant factors influencing the levels of extraction of forest biomass. Based on the results, it was concluded that installing biogas plants can potentially reduce pressure on forest biomass.

Heltberg *et al*. (2000) used a non-separable household model to study the links between forest scarcity and household energy consumption. The model focuses on the substitution of fuelwood and other domestic energy sources including crop residues, animal dung and biogas for rural households in Rajasthan, India. They developed a household model to capture household labour allocation to agriculture (crop and livestock production), off-farm work and fuelwood collection. Three reduced form equations showing the amount of fuelwood that was collected, the amount of labour and time spent on colleting and the private energy consumption (animal dung, crop residues and wood from own farm) as functions of all exogenous variables, were estimated empirically using the maximum entropy approach. The study observed that fuelwood collection time, household endowments of land, labour, livestock and trees and village-level indicators of forest stock and access are significant in explaining fuel mix at household level. It concluded that rural households respond to forest scarcity and increased fuelwood collection time by substituting fuels from private sources for forest fuelwood.

A number of studies have used two-stage estimation techniques for empirical estimation. For example, Matshe and Young (2004) developed a household model to analyse off-farm labour allocation decisions of rural households in Zimbabwe. They used a double hurdle model to empirically model the joint decisions to participate in the off-farm labour market and the decision regarding the amount of labour time allocated to off-farm work. Their results showed that education, gender, asset holding, remittances and land holding influence household off-farm labour supply decisions among rural households. They found that education, access to productive assets and remittances are positively related to labour supply for off-farm work. The study concluded that females are less likely to engage in off-farm activities than males due to the various commitments to activities that women have within the household.

Adhikari (2002) constructed a household production model to explore the socio-economic factors influencing household labour allocation decisions for the collection and gathering of non-timber forest products (NTFP) in Nepal. The household model captures a household engaged in crop and livestock production as well as NTFP collection activities. The production functions for firewood, fodder, cut grass and leaf litter were specified as Cobb-Douglas functions and estimated as log-linear functions using two-stage least-squares method to capture the potential endogeneity of labour used in the production of the different forest products. The explanatory variables included in the production functions consist of: labour time allocated to the collection of forest products; household demographic variables (ethnicity, sex, education and household size); ownership of tools; labour time spent on activities; membership to organisations; and household endowments (landholding size and livestock assets). The study concluded that poor households were facing limited access to community forestry and therefore were less dependent on forest resources than households who were relatively better off.

Jolliffe (2004) developed an agricultural household model to examine how education affects household allocation of labour between farm and off-farm activities and farm and off-farm profits in rural Ghana. To capture these effects, household utility was modelled as a function of leisure and the sum of farm and off-farm profits. The reduced form farm and off-farm labour supply and farm and off-farm profits equations were empirically estimated using a two-stage least-squares approach to capture the direct and indirect effect of education on labour allocation and farm and off-farm profitability. The two-stage estimation approach was adopted to capture the potential endogeneity of labour. The study concluded that off-farm work has a much higher return to education than farm work and increased education results in reallocation of labour from farm work to off-farm work and therefore increases off-farm profit. Fafchamps and Quisumbing (1998) found a similar result in a study in rural Pakistan.

Very few studies used the systems approach for empirical estimation. For example, Fisher *et al*. (2005) developed a household labour allocation model to examine the determinants of livelihood activity choices affecting forest use among rural households in Malawi. In their household model they assumed that households allocate family labour across three livelihood activities, namely: maize production; forest activities; and non-forest activities. The empirical model comprised of a system of three reduced form labour share equations. A system estimation approach similar to that used in commodity or factor demand systems used to estimate the labour share equations jointly using constrained maximum likelihood method assuming that the labour allocation decisions across activities are related. Explanatory variables included in the empirical model are: household characteristics (age and education of the head of the household); farm size; dependency ratio; shadow prices or wages of forest and non-forest activities; and the price of maize. Their study found that labour share that is allocated to forest activities is negatively related to the return to non-forest employment, secondary education of the household head and wealth.

Though there is a large body of empirical literature on the determinants of rural household labour allocation for competing livelihoods activities (including natural products), no study yet has analysed the factors determining household decisions on the use of wetland products in the context of an overall household labour allocation problem. To date, existing studies which attempted to look at the factors influencing decisions on use of wetland resources mainly focused on relating household socio-economic characteristics and the different type of uses of wetland resources using statistical and single equation econometric approaches, which are not based on a structural behavioural model of the rural household decision-making process. For example, Mulugeta *et al*. (2000) used a discriminant analysis to study the socio-economic factors influencing the decision to cultivate wetlands in the Metu and Yayu-Hurumu Weredas of Illubabor zone in southwest Ethiopia. Using household survey data, their results showed that wetland cultivators: are less wealthy; are young; have large family sizes; own small landholdings; have less livestock; own few farm implements; and are food insecure.

Mulugeta (2004) applied a binomial logit model to assess the factors that influence the decision to cultivate wetlands in Kemise, Illubabor zone of south-western Ethiopia. The study found that wetland cultivators had large family sizes, with more male members and suffered less out-migration of family members in the preceding years in comparison to non-cultivators. Contrary to the findings of Mulugeta *et al*. (2000), this study found that wetland cultivators are wealthier households who have access to productive assets, earn more cash income, use more agricultural inputs and generally enjoy higher yields than non-wetland cultivators.

Chiputwa *et al*. (2006) used a series of binomial logit models to examine the factors influencing the decision to cultivate wetlands and collect wetland natural products in a wetland system situated in the southwestern part of Zimbabwe. Their results showed that wetland cultivation is positively and significantly related to irrigation plot ownership, income from non-agricultural activities and to the total land area, but is negatively related to the number of livestock. They also found that male-headed households are more likely to engage in wild fruit and reeds collection as well as cultural practices than their female counterparts. The education level of the head of a household significantly reduced the likelihood of a household engaging in sedge collections and the use of wetlands for cultural purposes.

Using household survey data from selected wetland sites in Tanzania, McCartney and Van Koppen (2004) used cross tabulations to analyse the relationship between wetland uses and a household's wealth status. They found that poor households are more likely to use wetlands for the collection of reeds, sedges and domestic water than the medium ranked and rich households. Medium ranked households were more likely to use wetlands for cropping than the poor and rich households. However, their results showed that the proportion of a household's income derived from wetland cultivation is highest among the rich households compared to the poor and medium ranked households. This suggests that the rich households were more dependent on wetland cropping than the other two wealth classes. In addition, they found that wealthier households were more likely to use wetlands for livestock grazing than poor households.

Based on case studies of selected wetlands in Zambia, Masiyandima *et al*. (2004) found that poor households are more likely to engage in the collection of natural products and wetland cultivation than the wealthier households. However, in contrast to the findings by McCartney and Van Koppen (2004), their results showed that poor households obtain a significantly higher proportion of their household's income from wetland cultivation than the medium and wealthier households, suggesting that poor households were more dependent on wetland cultivation for their livelihood than the medium and wealthier households. The differences in findings could be attributed to the differences in biophysical and socio-economic conditions across sites.

As mentioned earlier, most of the empirical studies on wetlands to date have focused on assessing the factors that influence the type of uses of wetland products. While such analyses are important, it is essential for policy purposes to go a step further and analyse the factors which influence the level of dependence on wetland products (measured in terms of quantities of wetland products collected or the proportion of income derived from wetland products). This is because, as demonstrated by Narain *et al*. (2008), it is possible that those households that are less likely to participate in a natural resource use activity are actually more dependent (i.e. collect more quantities) if they engage in that use.

Few studies have attempted to look at the factors that influence households' decisions on the use of wetland products. For example, Turpie *et al*. (1999) used a simple bivariate analysis to compare the quantities of wetland natural products collected by rural households of different wealth classes in selected wetlands in the Zambezi basin in southern Africa. They found evidence of decreasing levels of collection of wetland natural products (reeds, sedges, palm leaves and thatching grass) with an increase in wealth status in the Barotse floodplain wetlands (western Zambia) as well as the Lower Shire floodplain wetlands (in Malawi and Mozambique). However, in the Caprivi wetlands in Namibia and Zambia they found that wealthier households harvested more natural products than the poor, presumably because wealthier households are larger and therefore have a higher demand for resources and also have more labour resources to collect products. These findings show that the effect of wealth on the demands for wetland natural products is mixed and can vary across sites.

Kipkemboi *et al*. (2007) analysed the socio-economic factors that influence the dependence on wetland products by households in the Lake Victoria wetlands in Kenya using a multiple linear regression model. A household's dependence on wetland products was measured in terms of the quantity of wetland products collected. Independent variables included in the model are: household size; the age and education level of the respondents; gender; and access to wetlands. Their results showed that females are more dependent on wetland products than males; a finding they attributed to the fact that in rural areas women are more directly involved in household food provision and interact with the environment on a daily basis. They also found that poor and middle-income households are more dependent on wetlands for both cultivation and natural products, while wealthy households are less dependent on wetlands as they obtain significant non-farm income to meet household demands.

The empirical studies reviewed in this section generally confirm that household socio-economic characteristics influence household labour allocation and production decisions among rural households. However, the factors influencing household resource allocation decisions and production decisions vary with local context and type of resources. To date, empirical studies, which attempted to examine factors influencing rural household decisions on use of wetland products, have used econometric approaches. These econometric approaches are not based on any structural behavioural model of rural household decision-making behaviours. The major contribution of this work is that the factors that influence rural household decisions on the use of wetland products by formally modelling household resource use decision-making process based on a structural household model, which takes into account the fact that rural households engage in multiple livelihood activities, which compete for resources (e.g. labour, capital and land).

The above literature highlights the relevance of the agricultural household modelling approach in analysing rural household labour allocation, production and supply decisions in developing countries. As households in the study area both produce and consume wetland products and agricultural output (Adekola, 2007), the agricultural household modelling approach is most appropriate for analysing household labour allocation and supply decisions for wetland and agricultural products (Singh *et al*., 1986; Chen *et al*., 2006).

3.3 The Analytical Framework

The neoclassical model of a farm household (agricultural household model) described by Singh *et al*. (1986) has been the main analytical approach used for analysing resource allocation, production and consumption decisions made by rural households in developing countries. This approach is based on the observation that rural households in subsistence economies are joint producers and consumers. The households can separate production and consumption decisions by first maximising profit from food production and use the profits from production to maximise utility from consumption. The major difference between the farm household model and the pure consumption model is that in the latter the household budget is exogenously fixed whereas in the former it is influenced by production decisions that contribute to income through farm profits.

The author drew upon the neoclassical model of the farm household presented in Singh *et al*. (1986) to develop a model for analysing factors influencing household labour allocation and supply decisions. The model presented below captures the situation of a farm household engaged in crop production, livestock production, off-farm work and wetland product collection.

The model assumes that a representative household maximises its utility, which is dependent on: the consumption of a composite wetland product (X_H); agricultural grain (X_G); livestock product (X_N); market good (X_M); and leisure time (L_Z). Household utility is assumed to vary with different household characteristics (Ω), including family size and the age of household members, which may influence household consumption preferences. For the sake of simplicity, it is assumed that the market good, X_M, is purchased from the market. Thus, the household utility maximisation problem is defined as:

$$\text{Max } U = U(X_H, X_G, X_M, X_N, L_Z; \Omega) \tag{3.1}$$

The quantity of the wetland product consumed by the household (X_H) is equal to the wetland product harvested from the wetland by the household (X_H^H), plus the quantity purchased from the market (X_H^P), minus the quantity sold in the market (X_H^S):

$$X_H = X_H^H + X_H^P - X_H^S \tag{3.2}$$

The production constraint of the wetland product describes harvesting of the wetland product as a function of household labour allocated to wetland products collection (L_H), household characteristics (Ω), which influence the harvesting of wetland products (such as household size and education level of the household) and a vector of production technology parameters (β):

$$X_H^H = X_H^H(L_H, \beta; \Omega) \tag{3.3}$$

The household also depends on grain production for its livelihood. The production technology for the agricultural grain (G_q) is: a function of household labour allocated to agricultural production (L_G); a vector of household asset endowments influencing grain production, such as land and farm implements (ploughs and hoes) (ω); a composite input capturing all the inputs used in grain production, which are purchased from the market, such as fertiliser and seeds (Y_G); and the production technology parameter (α).

$$G_q = G_q(\alpha, L_G\ Y_G; \omega) \tag{3.4}$$

The household can purchase additional agricultural grain (G_q^p) from the market to meet any consumption requirements, which are not supplied by its own production. In addition, the household can sell surplus grain (G_q^s) in the market and hence faces a grain balance of:

$$X_G = G_q + G_q^p - G_q^s \tag{3.5}$$

The household is also engaged in livestock activities that supply meat and milk products. The production of a composite livestock product (V_N) is: a function of labour time spent grazing animals (L_V); and other livestock inputs such as water (N) and production technology parameters (θ).

$$V_N = V_N(L_V, N, \theta) \tag{3.6}$$

As is the case with agricultural grain, livestock products can be bought and sold in the market. Thus, the amount of livestock products consumed (X_N) is equal to the amount produced by the household (V_N) plus the amount purchased from the market (V_N^P) minus the amount sold in the market (V_N^S):

$$X_N = V_N + V_N^P - V_N^S \tag{3.7}$$

Household cash expenditures are constrained by the income from selling the agricultural grain, livestock product, wetland product, off-farm labour income and exogenous income (E). Exogenous income includes income in the form of pension, social grants and remittances. The household can spend income on purchasing wetland products, livestock products, agricultural grain, market goods and agricultural inputs used in grain production. Farm inputs, Y_G, are bought but not sold. It is assumed that all market prices are exogenous. Cash expenditures cannot exceed the total cash income. Thus the household budget constraint is given by:

$$P_H X_H^S + P_G G_q^S + P_V V_N^S + L_o W_o + E \geq P_M X_M + P_H X_H^P + P_G G_q^P + P_V V_N^P + P_Y Y_G + P_N N \tag{3.8}$$

Where P_H; P_G; P_V; P_M; P_Y; P_N; W_o; E refer to market prices of the wetland product, agricultural grain, livestock product, market good, inputs used in grain production, livestock inputs, exogenous off-farm wage rates and exogenous household income (non-wage income), respectively. L_o refers to the labour time spent on off-farm wage work.

Households have limited total labour time available (L_T) and divide this time between wetland product collection, off-farm activities, grain production, livestock activities and leisure. Thus, household labour time constraint is given by:

$$L_T = L_H + L_o + L_G + L_V + L_Z \tag{3.9}$$

The decision problem for the subsistence farm household is to maximise the utility function (3.1) subject to production, budget and time constraints specified in 3.2 to 3.9 above. The Lagrangian for an internal solution to this problem is:

$$\begin{aligned}\ell = {} & U\{X_M, X_H, X_G, X_N, L_Z; \Omega\} - \lambda_1 (X_H^H - X_H^H(L_H, \beta; \Omega)) - \lambda_2 (G_q - G_q(\alpha, L_G\ Y_G; \omega)) \\ & - \lambda_3 (V_N - V_N(L_V, N, \theta)) - \lambda_4 (P_M X_M + P_H X_H^P + P_G G_q^p + P_V V_N^P + P_Y Y_G + P_N N - P_H X_H^S \\ & - P_G G_q^S - P_V V_N^S - L_o W_o - E) - \lambda_5 (L_H + L_o + L_G + L_V + L_Z - L_T)\end{aligned} \tag{3.10}$$

There are 21 decision variables to solve in the model, which are: $L_H; L_G; L_V; L_o; Y_G; N; X_M; X_H^H; X_H^S; X_H^P; G_q; V_N; G_q^P; G_q^S; V_N^P; V_N^S;$
$\lambda_1; \lambda_2; \lambda_3; \lambda_4; \lambda_5$

Therefore, one needs 21 equations to solve these 21 endogenous variables. From the first order conditions with respect to these decision variables, a system of 21 reduced form equations are derived. The system of equations, A1.1 to A1.21 in Appendix A1, gives the complete set of 21 equations needed to solve the 21 endogenous variables. All endogenous variables will be reduced form functions of the set of exogenous variables in the model, which are: P_H; P_G; L_T; P_V; P_M; P_Y; P_N; W_o; E; Ω; β; α; θ; and ω.

First order conditions A1.1, A1.2, A1.3 and A1.4 show how the household allocates its labour among the productive activities and leisure. The four conditions show that the optimum labour allocation is such that the marginal value of labour across the productive activities is equalised. By rearranging the first order conditions A1.8, A1.11 and A1.12 to $\partial U / \partial X_H^H = \lambda_1$; $\partial U / \partial G_q = \lambda_2$ and $\partial U / \partial V_N = \lambda_3$, respectively and then substitute the λ's in the first order conditions A1.1, A1.2 and A1.3. The three conditions will also show that, at the optimum, the household allocates its labour across the productive activities that the marginal utility of labour in each of the activities is equal and is also equal to the marginal utility of leisure (λ_5) (which represents the shadow wage or opportunity cost of household labour time). This shadow wage is internal to each household and depends on the full set of exogenous variables.

First order condition A1.4 can be rearranged to $\lambda_4 W_o = \lambda_5$. This condition shows that the decision on the participation in off-farm work is influenced by: off-farm wage rates (W_o); marginal utility of income (λ_4); and the marginal utility of leisure (λ_5). The marginal utility of leisure can be equal to or higher than the off-farm wage rate. If it is equal, the household participates in off-farm work. If it is higher than the wage rate, the household will not supply labour to off-farm work.

First order condition A1.8 shows that in making decisions on the collection of a wetland product, a household equates the marginal utility of consuming the wetland product collected to the shadow costs of collecting the product (λ_1) (which represents the opportunity cost of supplying labour for collecting the wetland product).

Similarly, the first order condition A1.11 shows that the household makes grain production decisions by equating the marginal utility of consuming grains produced with the marginal costs of grain production (λ_2) (which represents the opportunity cost of labour used in grain production).

First order conditions A1.10, A1.13 and A1.15 relate to purchasable wetland, grain and livestock products and give us the familiar consumer theory results that the marginal rate of substitution between two goods purchased in positive quantities is equal to the ratio of their relative prices. In addition, these first order conditions also show that the household can improve its welfare by purchasing additional products from the market. However, in making the decision to purchase products from the market the household compares the costs of purchasing (the price) and the marginal utility gained from consuming purchased products (the welfare benefit). This result is the fundamental micro-economic theory of consumer behaviour, which states that a consumer equates the marginal utility to the price (or the marginal cost of collecting or producing its own) in purchasing goods from the market.

The selling of products (wetland, livestock and grain) reduces household welfare. The first order conditions for the decision to sell products A1.9, A1.14 and A1.16 show that the marginal rate of substitution between two goods is equal to the ratio of their relative prices. These first order conditions also show that in making the decision to sell a product in the market the household equates the marginal utility of income (λ_4) derived from selling the product to the marginal utility forgone by choosing not to consume the product (welfare loss to the household). At the optimum, the marginal utility of income across the products is equalised at (λ_4). In summary, the first order conditions for selling and purchasing decisions show that those households that sell and purchase products face a market price.

Conditions A1.17, A1.18 and A1.19 recover the production functions for: wetland products; grain and livestock products, which are functions of labour; production parameters; inputs (for the case of grain and livestock); and household endowment characteristics. First order conditions A1.20 and A1.21 recover the full budget and time constraints, respectively.

3.4 Concluding Summary

Rural households allocate their labour, capital and other resources between competing livelihood activities that include crop and livestock production, off-farm activities, harvesting of wetland resources and leisure. Households decide on the allocation of resources between these activities which maximises their utility given their resource endowment; prices; the efforts required (production technology); and household characteristics.

This chapter developed an analytical framework for analysing household labour allocation and production decisions for different livelihood activities including wetland activities. Drawing on previous works, an agricultural household model was developed as the analytical framework for analysing determinants of household labour allocation and supply decisions. The reduced form equations derived from the household model will be the basis for empirical analysis of the determinants of labour allocation and supply decisions for wetland products and agricultural output presented in the next chapter.

CHAPTER 4

EMPIRICAL MODEL AND RESULTS OF THE DETERMINANTS OF HOUSEHOLD RESOURCE ALLOCATION AND SUPPLY DECISIONS

4.1 Introduction

This chapter presents the empirical model for examining the determinants of household labour allocation and product supply decisions based on the analytical framework developed in Chapter 3. It also discusses results of the empirical analysis. The first section of the chapter gives a brief description of the study area. Section two presents data and data collection methods while a survey of the main uses of the studied wetland system is presented in the third section. Section four presents the empirical model and discusses the econometric estimation procedures used in the empirical analysis. Empirical results are presented and discussed in section five and a concluding summary of the chapter is given in section six.

4.2 Description of the study area

4.2.1 Location of the area

This study was carried out in the Ga-Mampa wetland, which lies in the catchment of the Mohlapitsi River; a tributary of the Olifants River in the middle part of the Limpopo basin in South Africa. The wetland is a riverine system covering an area of approximately 120 ha (Kotze, 2005). The catchment is characterised by seasonal rainfall that largely occurs during the summer months (October to April). The area is located in the former homeland[3] area of Lebowa in Mafefe Ward 24 of the Lepelle-Nkumpi municipality in the Capricorn district of the Limpopo province in the northern part of South Africa. Typical of the former homelands of South Africa: the area is predominantly rural; employment levels are low; basic infrastructure is lacking; and poverty levels are high. In 2006, it was estimated that 2 800 people (394

[3] These are also termed native reserves or tribal lands which were delineated under the Natives Land Act of 1913 (Wickins, 1981) for black people. They are typically located in marginal areas with low rainfall, less fertile soils and lack of access to basic services such as water and education facilities.

households) reside in the two main villages around the wetland, which represents 18% of the total population of the ward (Adekola, 2007).

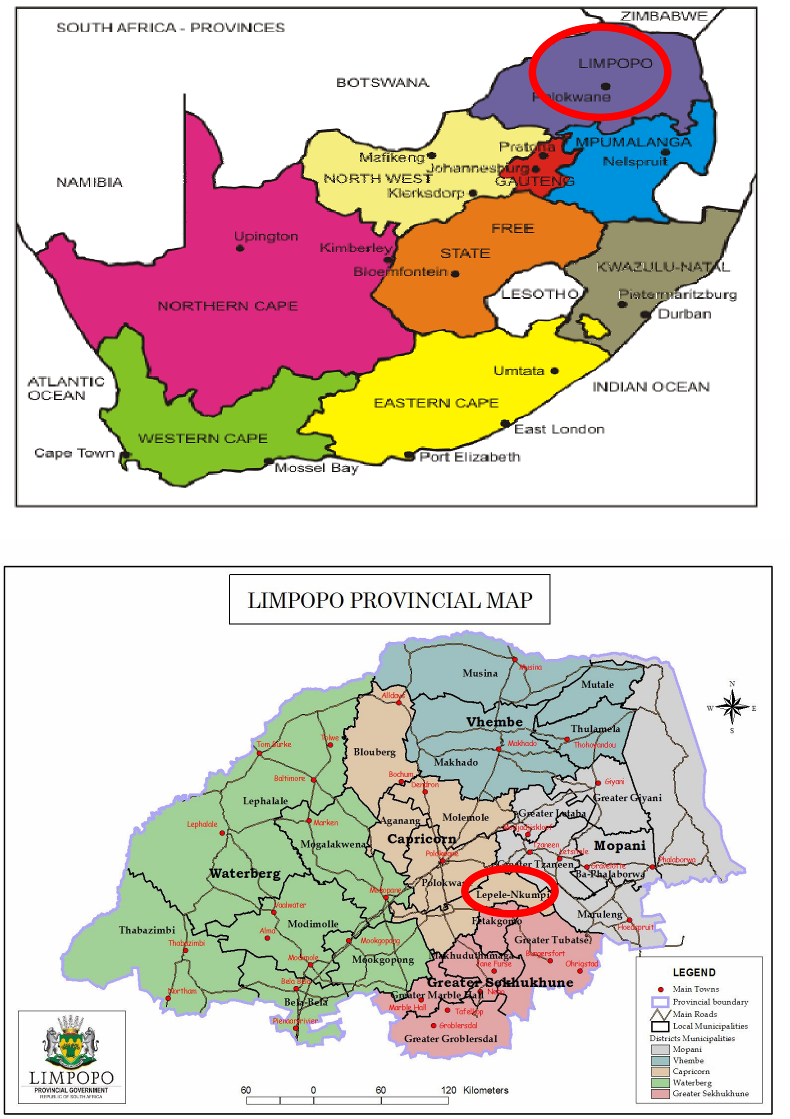


Figure 4.1: Maps showing the location of the Limpopo province and the Ga-Mampa area (Adekola, 2007)

4.2.2 Characterisation of the hydrology and ecology as well as trade-offs between ecosystem services in the studied wetland system

The Ga-Mampa wetland lies along the Mohlapitsi River. The geology underlying the wetland is a complex assemblage of sedimentary rocks, such as banded ironstone, chert and limestone. The soil formations in the wetland reflect the strong influence of the underlying parent rock material, climatic features and biological activity. Much of the wetland consists of fine-textured, poorly drained soils deposited on the valley floor by the river as well as well-drained sandy soils to sandy loam soils (Ferrand, 2004). The poorly drained areas support extensive organic (peat) soils maintained by permanent saturation and are surrounded by seasonally to temporarily saturated areas with predominantly mineral soils. The wetland soils support subsistence crop production although the productivity of the wetland soils has been undermined by progressive depletion of soil organic matter due to active tillage, artificial drainage and erosion (Kotze, 2005). In contrast, the adjacent hill slopes and dryland areas tend to have fragile, shallow, sandy soils with less agricultural potential.

The geology of the studied area supports groundwater storage. Dolomitic rocks, shales and banded ironstone, which are the main geological feature of the wetland, have an intermediate to high groundwater storage capacity (Kotze, 2005). In the wetland, shallow weathered aquifers are recharged by groundwater outflows from the adjacent hillslopes (Tinguery, 2006).

Most of the utilisable water in the Mohlapitsi catchment area is in the form of surface water. The wetland is an integral part of the hydrograph of the catchment. The Mohlapitsi River shows marked seasonal and inter-annual variation in flow due to seasonal and inter-annual variation in rainfall and unpredictable climate events such as floods and droughts. The seasonal and inter-annual variation in the river flow affects the welfare of communities in the Ga-Mampa area, as it is the main source of potable and irrigation water (Chiron, 2005).

Previous studies on the hydrology of the wetland system highlighted that there are some hydrological interactions between the wetland, Mohlapitsi River and the Olifants River. Darradi *et al*. (2006) reported that there is a common perception by stakeholders living outside the Ga-Mampa valley that the wetland performs important hydrological functions, most notably the maintenance of dry season flow in the Olifants River downstream. McCartney (2005) investigated this phenomenon using historical flow data of the Mohlapitsi and Olifants Rivers and showed that the Mohlapitsi catchment contributes 3.9% of the mean annual runoff and approximately 16% of average flows at the end of the dry season (Figure 4.2).

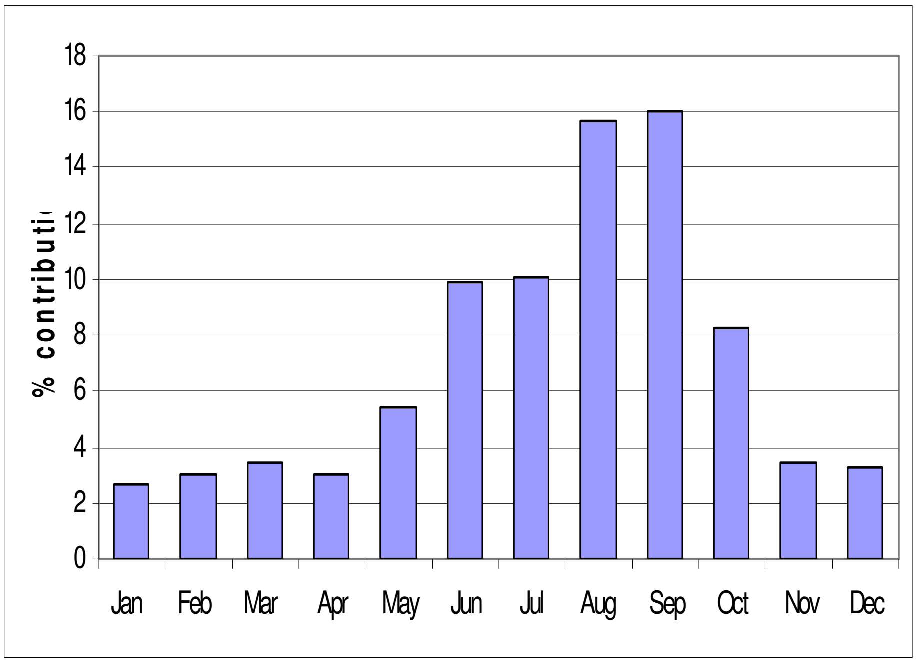


Figure 4.2: Contribution percentage of flow (i.e. monthly average) from the Mohlapitsi catchment to the Olifants River (McCartney 2005)

An ecological assessment study of the Ga-Mampa wetland by Kotze (2005) concluded that the hydrological input by the river to the wetland is very low and the wetland hydrology appears to be maintained predominantly by upstream flow and seepage of groundwater from the adjacent hillslopes. McCartney (2005) confirmed that the hydrology of the wetland is dominated by groundwater inflow from the surrounding catchment as shown by the presence of a large number of springs located at the edges of the wetland and close to the break of the slope at the valley sides. The main hydrological fluxes in the studied wetland are shown in the schematic diagram (Figure 4.3).

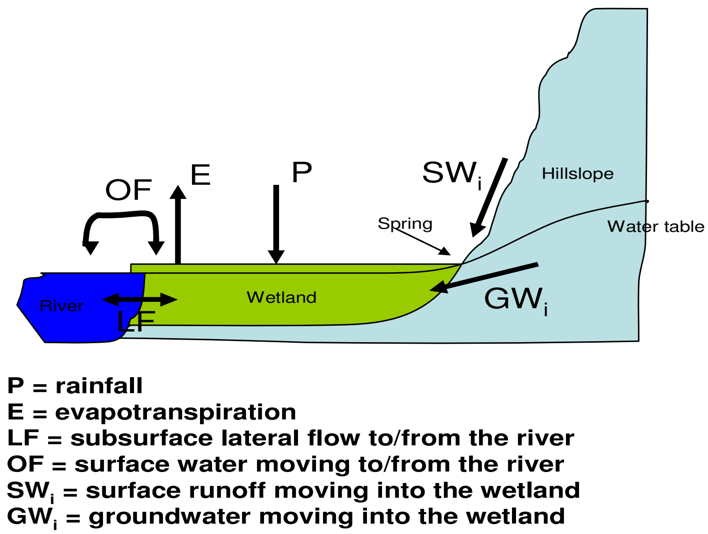


Figure 4.3: Conceptual picture of the main hydrological fluxes in the Ga-Mampa wetland (McCartney, 2005)

The vegetation in the Ga-Mampa area comprises of relatively natural grassland vegetation and a distinct upper layer of woody plants (Sarron, 2005). Bushy vegetation dominates the surrounding mountains while riparian forests grow adjacent to the river channel or at the transition from the steep hillslope to the valley floor (Kotze, 2005). The valley bottom vegetation is predominantly herbaceous and the wetland supports different vegetation types, which vary according to their particular site preferences. The most extensive plant species in the wetland are reeds (*Phragmites australis* and *Phragmites mauritanus*) and sedges, which are used for construction and craft material, respectively. A wide range of edible plants occur across the wetland. Table 4.1 shows the vegetation characteristics of the Ga-Mampa wetland.

Table 4.1: Vegetation characteristics of the Ga-Mampa wetland

Vegetation type	Predominant species	Structure	Site characteristics	Natural extent
Phragmites marsh	Predominantly *Phragmites mauritianus* but also with *Phragmites australis*	Very tall (>3m) uniform stands	Permanently wet areas on the valley floor and in the river channel and its margin	Very extensive
Cladium mariscus marsh	*Cladium mariscus*	Very dense uniform stands (2m)	Permanently wet areas on the valley floor	Limited
Mixed marsh	*Pycreus mundii, Thelypterus interrupta* cf., *Leersia hexandra* and *Phragmites mauritianus*	Variable (0.5-2 m)	Permanently wet areas on the valley floor	Moderately extensive
Typha capensis marsh	*Typha capensis*	Uniform stands (2-3 m)	Primarily within the river channel in permanently inundated sites	Limited primarily to within the main stream channel
Miscanthus junceus meadow	*Miscanthus junceus*	Dense clumps (2 m) interspersed with short	On the valley floor in areas with seasonal wetness	Extensive
Mesic grassland	*Cynodon dactylon* and *Phragmites mauritianus*	Short (mainly <0.5 m)	On the valley floor in areas with sandy, moderately well drained soils	Limited
Hygrophilous grassland	*Paspalum dilatatum*, *Pycreus mundtii, Phragmites mauritianus,* and *Imperata cylindrica*	Short (mainly <0.5 m)	On the valley floor in areas with somewhat poorly drained soils (temporarily saturated)	Extensive, particularly along the margins
Riparian forest	*Syzygium cordatum*, *Rauvolfia caffra* and *Ficus sycomorus*	Generally closed canopy, >5 m	Adjacent to the river channel or at the transition from steep hillslope to valley floor where shallow, surface water is readily available to the trees	Moderately extensive

Source: Kotze (2005)

As will be discussed in detail later, the studied wetland provides several services with trade-offs between them. Trade-offs between wetland services occur locally and in the short term between crop production and livestock grazing while natural vegetation compete for land, water and labour resources. At a larger spatial scale, there is a potential trade-off between crop production and the river flow regulation and water supply downstream. In the long term, continuous use of wetland for agriculture may undermine the ecological integrity of the wetland through depletion of organic matter, soil erosion and lowering of shallow water thus impacting on the wetland's ability to provide ecosystem services, including crop production

4.2.3 Main livelihood activities in the study area

The main source of livelihood for communities in the study area is small-scale subsistence agriculture. Households self-consume most of their production and sell the surplus in the market to raise cash income to purchase agricultural inputs and meet other expenses such as clothing, school fees etc. Agricultural production is mixed crop and livestock systems with cropping taking place under small-scale irrigation and in the wetland. There are three small-scale irrigation schemes in the area with an estimated area of 170 ha (Chiron, 2005). Approximately 160 households have access to irrigation plots, with an average irrigated area of 0.60 ha per household. Maize is the main crop grown under irrigation and in the wetland. A large proportion of the maize produced is used for home consumption while vegetables constitute the bulk of the marketed output.

More than 80% of the households in the study area are considered to be poor, earning a monthly income of less than 1000 South African Rands[4] (R). The main sources of income are agriculture, government social grants, pensions and remittances. Households receive social grants of R200 per month for children under the age of 14 years and adults aged over 64 years receive R800 per month. Approximately 35% of households depend on pensions while 30% of the households depend on off-farm activities for income (Ferrand, 2004). Those engaged in off-farm activities are mostly middle-aged males working in mines, large-scale commercial farms and other industries located in nearby towns. Part of their income is remitted to family members

[4] One United States dollar ($) was approximately equal to 7.5 SAR in 2009.

in rural areas. Some households hire labourers to ease labour shortages during peak farming periods (Ferrand, 2004). The average wage rate in the local labour market is R8 per hour (Adekola, 2007).

4.3 Data and data collection methods

A combination of participatory rural appraisals (focus group discussions and key informant interviews) and formal methods (household surveys) were used. The former was used to gain a baseline understanding on the main livelihood strategies, the uses of the wetland and the types of users who make use of these resources as well as guide the design of the subsequent household survey. Two complimentary face-to-face household surveys, using structured household questionnaires, were carried out in the study area in October, 2006. In both surveys a stratified random sampling strategy was used to select households for interviews. The stratification of the population was based on access to a wetland plot or not. The first survey was done in two rounds: the first was conducted in May, 2006; and the second in October, 2006. A total of 102 households were interviewed in the two phases using a structured questionnaire administered by local trained enumerators in the local language. The household questionnaire collected data on: household demographics; access to different types of assets (physical, financial or natural); use of wetland resources; description of crop production activities (area under cultivation, production levels, input use including labour, prices of inputs and output); sources of food and food security; and sources of income (Appendix A3).

The second complimentary survey was conducted in October 2006 and was aimed at generating information to assess the economic value of the provisioning services of the Ga-Mampa wetland (Adekola, 2007). In this survey a total of 66 households (thirty-three wetland cultivators and the same number of non-wetland cultivators) were interviewed and some of these households were part of the first survey. The household questionnaire used in this survey was aimed at collecting detailed quantitative information on: the harvesting of wetland products; wetland cropping; input use in wetland activities (including labour use); and prices. The questionnaire had three main sections: the demographic and socio-economic characteristics of respondents; general information on access and use of the wetland; and detailed quantitative information on wetland products (i.e. quantity of product harvested, labour use and prices) (Appendix A4). Input-output information was also asked on crop production. Where market prices of wetland products could not be ascertained through the household survey and group discussions, information acquired during a visit to the local market in Ga-Mampa and Mafefe was used. Also prices of substitutes were also used as surrogates for market prices for wetland products where market prices could not be easily ascertained.

The data from the two surveys were pooled resulting in a sample size of one hundred and forty-three households. These households account for thirty-six percent of the total number of households residing in five villages around the wetland. Table 4.2 shows the distribution of the sampled households in the five villages. The sample fraction selected from each village (column 5) is proportional to the percentage of the village population in the area's total population (column 3).

Table 4.2: Sample distribution of interviewed households

Village	Estimated total number of households in village*	Number of households in village as percentage of total population in study area	Number of sampled households	Sampled households as percentage of total sampled households (%)
Mapagane	215	55	71	49.7
Ga-Moila	60	15	24	16.8
Manthlane	43	11	20	14.0
Mashushu	41	10	19	13.3
Marulatshiping	35	9	9	6.2
Total	394	100	143	100

*Figures are based on estimates by Adekola (2007) compiled through field data.

As detailed, quantitative data on wetland products collected and labour time used while collecting were missing for households interviewed in the first survey, which were not part of the sample in the second survey[5] (although information on whether a

[5] As households in the study area do not keep records of the quantities collected and the time used it was difficult to collect reliable data on these for all 143 households. However, the second survey collected more reliable data, because the survey was followed up with focus group discussions to validate information collected from the survey.

household harvests wetland products or not was available for these households). Mean values calculated from the second survey were used for the missing values.

Also it was not possible to collect reliable quantitative information on labour time used in off-farm activities, although the survey collected information on whether a household had members engaged in off-farm work. We therefore resorted to using a coefficient (or ratio) calculated using off-farm to on-farm mean labour shares presented in the work of Fisher *et al*. (2005) to calculate off-farm labour time by weighting farm labour time with the off-farm to farm labour share ratio for the households engaged in off-farm work.

4.4 The survey of wetland uses

In the survey, households were asked about their use of wetland products. Table 4.3 shows the number of households using the wetland for different uses and the estimated economic values per household for each service. Of the 143 households interviewed, 92% of them use the wetland in one way or another. The main provisioning services for households in the study area that are derived from the wetland are: edible plant collection; livestock grazing; crop production; domestic water extraction; reeds collection (*Phragmites mauritianus* and *Phragmites australis*); and sedge collection (*Cyperus latifolius* and *Cyperus sexangularis*). Using a direct market pricing approach, Adekola (2007) showed that the annual net financial value of these services is $211 (USD) per household (excluding livestock grazing value) with crop production contributing the highest to the total financial value of the wetland with an estimated value per household of $1072 (USD) per annum. The same study showed that the wetland contributes a cash income of $35 (USD) per household per annum, with sedge harvesting contributing the most to the household cash income compared to all the other services.

The intensity of use varies throughout the year. The uses are discussed in detail below.

Table 4.3: Number of households using wetlands for different uses and estimated values per household

Wetland use	Number of households in sample (n=143)	Net financial value of service per user household (US$/household/annum)	Cash income per user household (US$/household/annum)
Edible plants collection	80 (56%)	84	2
Livestock grazing*	66 (46%)	192	0
Crop production	60 (42%)	1072	10
Domestic water abstraction	37 (26%)	9	0
Reed collection	34 (24%)	93	4
Sedge collection	33 (23%)	88	20
Firewood collection	2 (1.4%)	667	0
Fishing	5 (3.5%)	12	0
No use	11 (8%)	-	-

* Values for livestock grazing are unreliable as data used was unreliable

Source: Household survey data& Adekola (2007)

4.4.1 Edible plants collection

The studied wetland system provides a wide range of edible plants which play an important role in the diversification of people's diet. The plants grow across the wetland in both the cultivated and wetland areas. Of the 143 households interviewed, 56% collect edible plants from the wetland. Collection of edible plants takes place all year round with most of the collection taking place between November and March. Some households collect excess plants in the wet season and sundry them for use in the dry season when they are no longer obtainable.

4.4.2 Crop production

Wetland agriculture contributes significantly to food security and incomes of households residing in the vicinity of the wetland. Adekola (2007) found that crop production contributes the highest to the total financial value of the wetland with an estimated value per household of $1072 (USD) per annum. The wetland is a key agricultural resource because of its fertile peat soils and ability to store water during the dry season, which enables dry season crop production. However, the conversion of the wetland to agriculture is quite recent and partly due to the collapse of irrigation schemes, which used to account for the bulk of agricultural production in the last 10 to 15 years. Recurring droughts, which were experienced in the area since 2000, also contributed to the increasing trend in the conversion of the wetland to croplands. Sarron (2005) estimated that between 1996 and 2004 half the wetland had been converted to agriculture with a corresponding decrease in the wetland area (Figure 4.4). By 2006, 66 ha of the wetland had been converted to agriculture (Adekola, 2007).

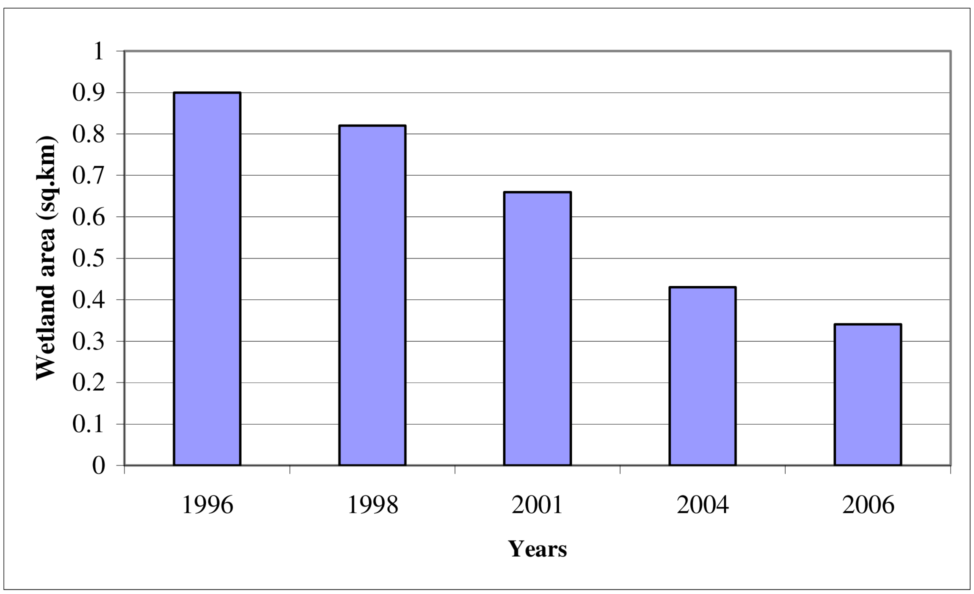


Figure 4.4: Trend in wetland area in the Ga-Mampa wetland (Sarron, 2005)

Of the households who were interviewed, 42% reported that they use the wetland for crop production although 25% of all households in the study area cultivate in the wetland. An average wetland plot size per wetland-cultivating household is 5.3 *bambas*[6] (0.66 ha). Most of them (82%) reported that the reasons why they cultivate

[6] *Bamba* is the local unit for measuring a land area. 12 *bambas* = 1 hectare.

in the wetland are because of recurrence of droughts, its fertile soils and its all year round soil moisture.

Maize is the main crop that is produced during the rainy season (October to April) and is often intercropped with vegetables and groundnuts. Coriander and beans are the main dry season crops. Few farmers grow vegetables (tomatoes, onions, spinach, cabbages, etc.).

4.4.3 Livestock grazing

Livestock grazing is another important service provided by the wetland. Livestock generally graze in the adjacent uplands during the wet season. However, during the dry season the wetland is the main source of dry season grazing and watering, because the wetland is more accessible to animals during this period as levels of soil moisture are lower and crop production is limited. During this period livestock also feed on crop residues from the preceding wet season's wetland crops. The crop-livestock interaction is important, but the two systems do compete for space. Grazing in the wetland is mostly uncontrolled and, in some instances, livestock trespass into the crop fields as the cropped area is not fenced.

4.4.4 Reeds and sedge harvesting

Reeds and sedges are harvested by some households in the study area, but in relatively small quantities compared to other wetland areas, mainly due to the availability of preferred substitutes for their uses as well as the scarcity of these resources in the wetland system. Approximately 24% of the interviewed households harvest reeds and sedges from the wetland. Reeds are used in fencing courtyards and for construction purposes (as roofing material). Sedges are used in making art and craft materials. Approximately 19% of the harvested reeds are sold on the local market (Adekola, 2007). Unlike reeds, sedges are rarely used in raw form, they are processed into different art and craft items such as baskets and floor mats, the bulk of which is sold in the local market. Sedge harvesting contributes the most to the households' cash income compared to all the other provisioning services and is estimated to contribute a cash income of $20 (USD) per household per year.

Based on information collected through focus group discussions, the quantities of reeds and sedge harvested from the wetland have declined over the past five years due to the decrease in their availability. A decrease in the accessibility of these resources is as a result of the expansion of wetland agriculture, which demonstrates the existence of trade-offs between crop production and collection of natural products (Kotze, 2005; Sarron, 2005). Also, the harvesting of reeds has declined due to "modernisation" as people now prefer modern roofing materials such as zinc.

The reeds and sedge are harvested at a certain time; this is regulated by the local leaders (the headman). Harvesting of these wetland products is restricted to the winter period (June and July) to allow for the regeneration of the products. Those who violate this restriction are summoned by the village head for a disciplinary hearing. However, most of these hearings just end up with the violators being cautioned and in very rare cases fined. This is done so as to maintain harmony in the community.

4.4.5 Domestic water abstraction

Water is abstracted from the wetland for a variety of purposes, including: drinking, washing, bathing; and building among others (Darradi *et al*., 2006). Of the interviewd households, 26% abstract water for domestic purposes. Most of the households that abstract water from the wetland are from one of the villages which have a limited water supply. In addition, some households from the other villages use wetland water for drinking and bathing while engaging in crop production or edible plant collection. Domestic water abstraction is highest during the wet season due to its complementarity to wetland cropping.

Based on the household survey and previous studies carried out in the study area (Adekola, 2007) it was shown that some households engage in a combination of uses and there are complementarities between wetland uses for some households. For instance, it was noted that there are some complementarities between wetland cropping, edible plants collection, domestic water abstraction and reeds and sedge collection.

4.5 The empirical model

From the solution of the first order optimality conditions presented in the previous chapter, a set of reduced form equations can be derived showing the endogenous variables as functions of all the exogenous variables. As done in other similar studies, these equations form the basis for empirical estimation (Heltberg *et al*., 2000; Fisher *et al*., 2005; Chen *et al*., 2006). As shown earlier, the household model comprises of 21endogenous variables and therefore we have 21 reduced form equations. However, it is not necessary to estimate the full system of equations (Sadoulet and De Janvry, 1995).

Given that our primary interest is to examine the factors that influence household labour use in each of the livelihood activities (grain production, livestock production, off-farm work and collection of wetland products) and the supply of grain and wetland products, we focus our empirical analysis on the following endogenous variables: household labour time used in each of the productive activities (L_o, L_H, L_V, L_G); the quantity of grain supplied (G_q); and the wetland product harvested by households (X_H^H). The reduced form functions for G_q and X_H^H will give rise to household supply functions for grain and wetland products, respectively. These are specified as:

$$G_q = G_q(L_T, E, \Omega, P_j, W_o, \beta, \alpha, \theta, \omega, \mu_G) \qquad (4.1)$$
$$X_H^H = X_H(L_T, E, \Omega, P_j, W_o, \beta, \alpha, \theta, \omega, \mu_H)$$

Where μ_G and μ_H are error terms and P_j denotes market prices for wetland products, grain, livestock, agricultural inputs, livestock inputs and other market goods.

The main crop grown in the study area is maize and hence represents grain in this case. Livestock labour use and products supply functions are not included in the empirical analysis as livestock data (labour time spent and products) were not reliable in part because livestock grazing is mainly uncontrolled with minimum labour use and livestock is mainly used for draft power and less for meat and milk. The reduced form equation for household labour time used in each of the livelihood activities is given by:

$$L_i = L(L_T, E, \Omega, P_j, W_o, \beta, \alpha, \theta, \omega, \mu_i) \qquad (4.2)$$

Where subscript i represents wetland product collection, grain production and off-farm work while μ_i is the error term.

4.5.1 Model variables and expected direction of relationships

The dependent variables in this study's empirical model are the amount of labour time used in each of the productive activities; and quantities of grain and wetland products supplied. The selection of explanatory variables for the empirical model was based on the analytical framework developed earlier. The explanatory variables in the labour use equations and the grain and wetland products supply functions include: exogenous variables, such as household demographic and endowment characteristics; products and inputs prices; household exogenous income and off-farm wage rates based on this study's analytical framework.

The selection of explanatory variables pertaining household demographic and endowment characteristics is informed by theoretical and empirical literature and data availability. Table 4.4 presents definitions of variables used in the empirical analysis.

Various studies have shown that household demographic characteristics such as gender, the size of the household, the age of the head of the household and a household's education level influences rural household labour supply decisions for different livelihood activities, including natural resource activities (Reardon and Vosti, 1995; Fafchamps and Quisumbing, 1998; Jolliffe, 2004; Matshe and Young, 2004). A household's size is used as a proxy for household labour time endowment (L_T). It is expected that a household's size is positively related to the labour that is allocated to grain production, collection of wetland products and off-farm work, because of the availability of surplus labour. Accordingly, it is expected that a household's size should be positively related to grain and wetland product supply due to the availability of labour to use in the production of these products.

Matshe and Young (2004) showed that gender influences labour allocation decisions of rural households and found, like Fafchamps and Quisumbing (1998) that because of their time commitment to activities within the household, females are less likely to participate in off-farm activities than males. In most subsistence farming communities in Africa women tend to do much of the agricultural work and interact with the environment more often than their male counterparts. Therefore, one can expect female-headed households to allocate more time to grain production and collection of wetland products and less time to off-farm work. One can also therefore expect female-headed households to supply more grain and wetland products than their male-headed counterparts.

It can expected that the head of the household's age is positively related to labour used in grain production and collection of wetland products, but negatively related to labour time allocated to off-farm work. This is based on the expectation that older heads have more experience in farming and collection of wetland products. Their experience creates inertia and results in them being interested in their traditional sources of livelihood (farming and natural product collection). The position of older heads in the social network might also give them better access to natural resources including wetland products (land for cropping in the wetland and natural products). Accordingly, it is expected that the age of a household head has a positive effect on grain and wetland product supply.

Many empirical studies have shown that education increases potential employment opportunities in off-farm work, but negatively affects the labour time allocated to the collection of natural products and farm work (Fafchamps and Quisumbing, 1998; Abdulai and Regmi, 2000; Jolliffe, 2004; Matshe and Young, 2004; Fisher *et al*., 2005; Chen *et al*., 2006). Therefore, it is hypothesised that the education level of the head of the household is negatively related to labour allocated to grain production and the collection of wetland products, but positively related to time worked off-farm. It is also expected that the education level of a household's head to be negatively related to supply of wetland products and grain.

Table 4.4 Definition of variables used in the econometric analysis

Variable	Definition of variable	Value/measure
Dependent variables		
L_i	Labour time used in grain production, wetland products collection or off-farm activities	Hours per year
X_H^H	Quantity of wetland products supplied (sum of harvested reeds and sedges)	Quantity (in kilograms) per year
G_q	Quantity of maize supplied	Kilograms per year
Explanatory variables		
L_T	Household labour time endowment. Household size is used as a proxy	Number of household members
E	Household exogenous income (includes income from social transfers and pensions)	Rands per month
P_G	Price of agricultural grain[1]	Rands per kilogram
P_H	Price of wetland products (average price of reeds, sedge and edible plants was used)	Rands per kilogram
P_M	Price of market goods. Expenditure on basic food items per capita is used as proxy	Rands per capita per year
P_Y	Price of agricultural inputs. Price of maize seed is used as a proxy.	Rands per kilogram
W_o	Off-farm wage rate	Rands per hour
Houseduc	Education level of household head	Number of years of schooling
Head gender	Gender of household head	1=male 0=female
Head age	Age of household head	Number of years
Wealthind	Household wealth status. An index capturing household assets (land, livestock, farm assets) is constructed	Index

[1]For P_G, P_H, P_M and P_Y a village's average prices are used as there was less variation in these prices for households in the same village. Similarly, a village's average wage rate was used.

A household's exogenous income is another explanatory variable in the labour and wetland product and grain supply equations with social grants, pensions and remittances representing its main forms in the study area. According to Fafchamps and Quisumbing (1998) and Chen *et al*. (2006) a household's exogenous income decreases labour time allocated to crop production and off-farm work and induces higher consumption of leisure. Following this, it is expected that a household's exogenous income to be negatively related to labour time used in off-farm work, grain production and the collection of wetland products.

With regards to the impact of exogenous income on grain supply, Collier and Lal (1986) found that non-farm income is positively related to crop output and hence, supply of crop output due to a better ability to hire labour and purchase agricultural inputs. In contrast, Holden *et al*. (2004) found that better access to non-farm income (exogenous or off-farm work income) reduces incentives to do farming, which leads to lower agricultural production (i.e. households become net buyers of food). Therefore, the impact of exogenous income on supply of grain could be positive or negative. We expect a household's exogenous income to be negatively related to labour time used in wetland products harvesting since it relaxes the household cash constraint inducing higher consumption of leisure thereby reducing labour time used in wetland products harvesting. Similarly, wetland products supply is expected to be negatively related to a household's exogenous income as it reduces the incentive to seek additional income from wetland activities.

One expects that the price of wetland products to be positively related to labour used in collecting wetland products and the supply of the product. Similarly, one can expect the price of grain to be positively related to labour used in grain production and grain supply. Both the price of wetland products and grain are expected to negatively impact on labour used in off-farm work.

An increase in the price of agricultural inputs reduces returns to agriculture and is therefore expected to result in the shifting of household labour resources away from grain production towards off-farm work and wetland product collection. As a result, the supply of wetland products is expected to increase and that of grain reduced. The price of market goods is expected to be positively related to labour time used in the grain production, off-farm work and collection of wetland products since an increase in the price of market goods reduces household real income, inducing the household to forego leisure. Accordingly, the supply of wetland products is expected to be positively related to the price of market goods, but a negative relationship with grain supply is expected since a high price of market goods reduces the affordability of agricultural inputs.

The off-farm wage rate is expected to be positively related to labour used in off-farm work but negatively related to labour used in grain production and in the collection of wetland products. Therefore, a negative relationship between off-farm wage rates and supply of grain and wetland products is expected.

Many studies have shown that wealth status influences labour allocation decisions of rural households. Although wealthier households are more likely to participate in off-farm work than the poor, they spend less time in the activity (Matshe and Young, 2004). Several studies have found that the poor spend more time on the collection of natural products and collect more quantities than the non-poor (Turpie *et al*., 1999; Campbell *et al*., 2002; Chen *et al*., 2006; Kipkemboi *et al*., 2007). But the effects of wealth on the collection of wetland products and the supply of these could also be positive in situations where wealthier households have better access to the wetland products, as was demonstrated by Turpie *et al*. (1999) for some wetland sites in the Zambezi basin.

Thus, the relationship between wealth status and labour use and the supply of wetland products could be positive or negative. The relationship between a household's wealth status and the supply of grain is expected to be positive as wealthier households are expected to have more farm assets to enhance farm productivity. However, one may expect wealthier households to allocate less of their time to grain production given that they can hire labour and also can use machinery for some of the activities which are done manually by poor households.

In developing the wealth index, the author followed the approach of Campbell *et al*. (2002) and Démurger and Fournier (2006) in developing a composite wealth index computed as a linear combination of household assets using a principal component analysis (PCA)[7]. The key household asset variables used for constructing the wealth index are based on household assets identified by Tinguery (2006) through participatory wealth ranking conducted in the study area[8]. In constructing the household wealth index, physical assets were first categorised into three main variables: farm assets (hoe, shovel, plough etc.); domestic assets (radio, television, telephone etc.); and transport equipment (bicycle, motorcycle etc.). A PCA was then done using 6 variables namely: housing type; farm assets; domestic assets; transport equipment; number of livestock (expressed in Tropical Livestock Units); and land area. The index was computed by multiplying the standardised value of each of the 6 variables by the first factorial coordinate of the variable in the PCA and then summed across all 6 variables. A wealth index computed in this way is much more encompassing and better reflects the wealth status of a household than the use of a single proxy variable, as done in most studies.

4.5.2 Econometric estimation procedures

Reduced form models 4.1 and 4.2 constitute the system of equations, which we estimate econometrically. As the error terms across the equations in the system are potentially correlated due to the fact that the same explanatory variables and unobserved characteristics may influence the different equations, estimating the individual equations using ordinary least-squares yields biased and inconsistent estimates as it ignores error correlations across equations (Woodridge, 2002). Seemingly unrelated regression (SUR) models proposed by Zellner (1962), are the most appropriate econometric techniques to account for the cross equation correlations. The merit of the SUR model is that it allows the estimation of the system of equations simultaneously, thereby controlling correlation across the error terms (residuals) in the different equations. This yields unbiased and efficient estimates (Bartels and Fiebig, 1991).

This study accordingly used the SUR procedure to jointly estimate models 4.1 and 4.2 as a system. It should be noted that if the regressors in each equation are the same as

[7] This technique involves combining several original variables into few derived variables or principal components (factors). In this case the single derived variable is a wealth index.
[8] A detailed discussion on the construction of the wealth index is given in Jogo *et al*. (2008)

is in this study's case, then the parameters of each independent variable obtained by a SUR model are identical to those obtained through equation-by-equation ordinary least-squares estimation (Greene, 2003). However, it is important to know that even when this is the case, there is still a good reason to estimate the equations jointly using a SUR model (Woodridge, 2002). One reason for this is that one may be interested in testing joint hypotheses involving parameters in different equations.

The Breusch-Pagan test was employed to test the null hypothesis that the error terms of the equations in the system are independent. The results of the test showed that $\chi^2(6) = 47.17$; $p<0.001$ and therefore the null hypothesis of independence of errors across the equations is rejected and hence the use of the SUR model to jointly estimate the equations is justified.

4.6 Empirical results and discussion

4.6.1 Summary statistics of variables used in the econometric analysis

Table 4.5 presents descriptive statistics of the variables used in the econometric analysis. The statistics show that of the 143 households interviewed, 53% were female-headed. The average age of household heads is 55.5 years. Household size ranges from 2 to 18, with an average of 7.3 persons per household. Education levels in the study area are quite low; the average number of years of education of a household head is 5.5 years, which corresponds to primary level education. This mirrors the picture at the district level where a large proportion of the population attained up to primary level education (Statistics South Africa, 2004). Only 28% of the interviewed households had a member with secondary level education. The low education attainment in the area could be attributed to poor access to basic educational facilities, which characterises most rural areas in South Africa due to the segregationist policies implemented during the apartheid era.

More than 60% of the households in the study area depend on exogenous income sources in the form of social grants, remittances and pensions. Household monthly exogenous income varies widely across households due to differences in demographic structure of households, especially in terms of age composition[9]. Of the households in the sample, 23% had a household member engaged in off-farm work. Segmentation in the labour market prohibits some people from engaging in off-farm wage employment possibly due to lack of required education level, skills and capacity. Opportunities for off-farm work are limited to jobs in mines, temporary road works, working in nearby large-scale farms and government jobs in health and education departments.

Prices of agricultural output, agricultural inputs, wetland products and market goods and off-farm wage rates are almost the same for all households living in the same village and therefore village average prices and wage rates were used.

Table 4.5: Descriptive statistics of variables used in the econometric analysis

Variable	Mean (n=143)
Dependent variables	
Labour used in grain production(hours/household/year)	285 (126)
Labour used in off-farm work (hours/household/year)	40 (14)
Labour used in collection of wetland products (hours/household/year)	66 (112)
Grain supply (kgs/household/year)	843 (581)
Wetland products supply (kgs/household/year)	246 (357)
Explanatory variables[1]	
Household size	7.3 (3.2)
Head of household's age (years)	55.5 (12.9)
Household head's education (years)	5.5 (3.7)
Head of household's gender (% male-headed)	46.9
Household exogenous income (Rands/month)	1000 (757)
Price of grain (Rands/kg)	1.58 (5.46)
Price of agricultural inputs (Rands/ kg)	5.29 (3.60)
Price of wetland product (Rands/kg)	2 (4.44)
Price of market goods (Rands)	342 (548)
Wage rate (Rands/hour)	8 (10.2)

Figures in parenthesis are standard deviations

[1]Wealth index is not reported as it is an index ranging from -4.3 to 4.3 with a mean of 0.

[9] The amount of exogenous income depends on the age structure of the household. Households receive social grants for children under the age of 14 years at the rate of R200 per month and old people aged over 64 years receive R800 per month.

Table 4.5 also shows the average household labour time used in different livelihood activities[10]. The figure for labour time allocated to off-farm work compares reasonably well with that from a study on smallholder agricultural households in Zimbabwe by Matshe and Young (2004) although it's higher presumably due to the fact that there are more off-farm opportunities in the study area than those in Zimbabwe.

Households spend most of their time on farm activities presumably due to the high priority given to food security through own production. Low levels of education and skills reduce the productivity and returns from off-farm work, which reflect the opportunity cost of farm labour time. Therefore households rationally allocate more time to farm work and collection of wetland products than off-farm work. This finding is consistent with that of Laszlo (2008) and Jolliffe (2004) that on average rural households particularly those with lower levels of education allocate more labour time to farm activities than to off-farm activities despite the fact that the returns to labour time are lower in farm activities than in off-farm work. This can also be attributed to the overriding importance of farm activities in enhancing food security among rural households in developing countries.

4.6.2 Econometric results

Table 4.6 presents results of the SUR model for labour allocation and supply decisions for grain and wetland products. The results indicate that household size is positively related to the amount of labour time used in grain production, collection of wetland products and off-farm work. This result can be attributed to the fact that larger families have surplus labour to allocate to these livelihood activities. The positive relationship between household size and labour allocated to off-farm work is consistent with income diversification strategies for risk smoothing. As the household size increases the household diversifies its income base and diverts part of its labour force into off-farm activities to generate more income in order to meet the increased consumption demands (Fafchamps and Quisumbing, 1998). This hypothesis is

[10] Labour hours worked per year were calculated from respondent estimates of how many hours are worked per week and the number of weeks worked per year for each activity.

supported by the findings from our survey data which shows that 55% of the households engaged in off-farm activities are large (above average) families.

The positive relationship between household size and the supply of grain and wetland products can also be explained by availability of labour resources to use in grain production and the collection of wetland products.

As expected, results indicate that female-headed households spend more time in grain production and collection of wetland products and accordingly supply more grain and wetland products than their male-headed counterparts. This could be explained by the fact that in most rural smallholder farming communities in South Africa women do most of the agricultural work and have more farming experience than men. In addition, this result could be attributed to the fact that female-headed households have limited access to off-farm income opportunities (this study's household survey data shows that the proportion of households with access to income from off-farm activities is 27% and 20% for male and female-headed households, respectively) and have surplus labour to engage in harvesting of wetland products (average household size for female headed households is 7.8 and that for male-headed households is 6.7). This result corroborates with that of Kipkemboi *et al*. (2007) who found that female-headed households collect more quantities of wetland products than their male-headed counter-parts.

As expected, the education level of the head of the household has a positive effect on labour time allocated to off-farm work and a negative effect on labour used in grain production and the collection of wetland products. The significant positive effect of education on labour time spend in off-farm work can be explained by the fact that education increases one's potential productivity in off- farm work (because, for example, educated household heads are more knowledgeable of employment opportunities and more adaptable in a range of tasks that they are able to perform) and therefore increases the opportunity for lucrative off-farm work. Households with better-educated heads spend less time collecting wetland products, because the opportunity cost of spending their time collecting wetland products (in terms of off-farm income foregone) is very high. Accordingly, household education is negatively related to the supply of wetland products. Other studies by Fisher *et al*. (2005); Chen *et al*. (2006) and Narain *et al*. (2008) also found a negative relationship between education and the quantity of natural products collected.

While education has a negative effect on labour input in grain production, it has a positive effect on grain supply. Hence, households with more educated heads are more efficient in grain production. This could be because education enhances opportunities for off-farm work and therefore leads to less labour allocated to on farm work but the resultant increased income from off-farm activities provides the necessary financial resources required to purchase agricultural inputs, which has a positive effect on grain supply.

Household exogenous income has a significant negative impact on labour used in grain production, collection of wetland products and off-farm work. By relaxing the household income constraint, exogenous income reduces the need to undertake on-farm, off-farm and natural products collection activities and induces higher consumption of leisure. Findings consistent with ours are reported by Matshe and Young (2004), who found exogenous income to be negatively related to hours worked off-farm and Chen *et al*. (2006) who found a negative relationship between exogenous income and labour input in fuelwood collection.

In line with the negative relationship between labour input in the collection of wetland products and exogenous income, the supply of wetland products is negatively related to household exogenous income. Although a household's exogenous income reduces labour input in grain production as highlighted above, it increases the supply of grain. A possible explanation for this result is that exogenous income relaxes household liquidity constraints thereby enhancing the ability to purchase productivity-enhancing inputs. Although this result contradicts that of Holden *et al*. (2004), who found a negative relationship between non-farm income and production and supply of agricultural output, it is in line with that of Collier and Lal (1986) that non-farm income is positively related to crop output and supply.

Though statistically insignificant the signs of the coefficients for price of wetland products and that of grain show the expected negative cross-price effects on labour allocation, which shows that the livelihood activities compete for labour resources.

This is also confirmed by the negative cross-price effects of supply of grain and wetland products. With regards to own price effects on supply, the results show a positive supply response of grain and wetland products to price, which is consistent with the microeconomics foundations of an upward sloping supply curve. The insignificance of prices could imply that markets for wetland products are too thin such that labour allocation and supply decisions are influenced more by subsistence considerations in which case a possible extension of this work would be to use endogenously determined household-specific shadow prices.

The results show that the price of agricultural inputs is positively related to labour allocated to off-farm work and wetland products harvesting, but negatively related to labour input in grain production and the supply of grain. A possible explanation for this result is that increased agricultural input prices increase input costs and reduce returns to production to which households respond by using less labour and shift some of their labour resources towards off-farm work and wetland product harvesting thereby reducing grain supply. The other possible explanation is that as price of maize seed increases farmers switch to using traditional seed varieties with a low productivity potential with a negative impact on supply and use less labour because of the expected low returns to labour investment.

Off-farm wage rates were found to be negatively related to labour input in grain production and the collection of wetland products, but positively related to labour supply to off-farm work. As labour returns to grain production and wetland biomass harvesting are quite low (Adekola [2007] estimated that the returns to labour in reeds and sedge harvesting to be approximately R15 and R9 per hour, respectively), a higher off-farm wage rate increases the opportunity cost of labour used in grain production and the collection of wetland biomass products and therefore results in labour resources being shifted away from these activities towards off-farm work. Accordingly, the supply of wetland products significantly decreases. The positive relationship between off-farm wage rates and labour used in off-farm work conforms with the upward sloping labour supply curve, which shows that as the wage rate increases leisure becomes relatively more expensive (the opportunity cost of leisure increases) causing households to substitute away from leisure to more work.

Table 4.6: Seemingly unrelated regression results for labour use in productive activities and supply of grain and wetland products.

	Dependent variables				
Independent variables	Labour used in grain production	Labour used in off-farm work	Labour used in collection of wetland products	Grain supply	Wetland products supply
Household size	0.71* (1.93)	0.37* (2.34)	2.09 (0.73)	0.47* (3.21)	12.13* (2.15)
Age of household head	0.24 (0.50)	-0.66 (1.03)	0.43 (0.14)	0.27 (0.98)	3.83 (0.18)
Gender of household head	-0.19** (1.37)	0.45 (0.78)	-0.73 (0.01)	-0.18 (1.12)	-0.62 (0.95)
Education level of household head	-0.26(1.56)	0.07 **(4.17)	-0.72** (3.15)	0.95(0.15)	-0.75 (1.23)
Household exogenous income	-0.016** (2.06)	-0.74* (2.57)	-0.02* (1.53)	0.01* (1.08)	-0.09** (4.57)
Price of market goods	-0.001 (0.96)	0.93 (1.07)	-0.12 (1.37)	-0.08 (0.13)	-0.37 (0.89)
Price of agricultural input	-0.01 (0.12)	0.64 (1.12)	0.34 (1.24)	-0.08** (3.16)	0.11 (1.67)
Price of grain	0.054 (0.12)	-0.12 (1.67)	-0.45 (0.15)	0.058** (0.37)	-0.13 (0.78)
Price of wetland products	-0.01(1.20)	-0.01 (0.01)	0.02 (0.45)	-0.01 (0.13)	0.01 (0.220
Wage rate	-0.039** (6.32)	0.014* (3.24)	-0.086* (1.47)	-0.013 (0.03)	-0.036** (3.07)
Wealth index	-0.07 (0.20)	-0.12* (3.27)	-0.17* (1.84)	0.24** (3.91)	-2.17* (2.89)
Constant	4.63 (2.97)	-9.69 (0.11)	2.13 (0.23)	-2.19 (1.19)	-1.62 (0.50)
Breusch-Pagan test for independence of residuals (χ^2)	47.17				

Absolute values of z-statistics in parenthesis; **denotes significance at 5% and * at 10% level of significance.

Household wealth status has a significant negative effect on labour input in wetland products collection and the supply of these products. This implies that poor households spend more time collecting wetland products and accordingly supply more of these products than the wealthier households. This could be attributed to the fact that unlike the wealthier households, poor households have limited access to assets and other sources of income (non-resource based off-farm income sources) that can buffer them against negative income and food shortfalls and they also cannot afford alternatives to wetland products. The results of the author's survey show that of the 23% of the surveyed households who have access to off-farm income only 27% belong to the poor category. This result is in line with the evidence found in other studies in rural South Africa that more well-off households often substitute collected goods with purchased alternatives (e.g. Dovie, 2001). This result also supports findings by studies that show that poorer households are more reliant on environmental resources than wealthier households (Barrett *et al*., 2001; Fisher, 2004; Shackleton and Shackleton, 2006). With regards to wetland products, a study by Turpie *et al*. (1999) also found that poor households collect greater quantities of wetland products than the wealthier households in the Barotse floodplain wetlands (western Zambia) and in the Lower Shire floodplain wetlands (Malawi and Mozambique) although other wetlands in the same study showed an opposite result demonstrating the mixed nature of the findings on the relationship between wealth and natural resource use. .

This study's results also indicate that a household's wealth status has a negative effect on labour time allocated to grain production and off-farm work. Asset-poor households put more labour input into food production and spend more time with off-farm work due to their low marginal productivity of farm labour and the need to meet household food requirements. Wealthier households do less on-farm and off-farm work compared to the poor. This result is similar to that of Matshe and Young (2004) and Fafchamps and Quisumbing (1998) who also found that wealthier households spend less time working off-farm.

Although households who are better-off allocate less time to grain production than their poorer counterparts, they supply more grain presumably due to their better access to productive assets (livestock, farm implements, land), which enhance agricultural productivity.

4.7 Concluding Summary

This chapter analysed the factors that influence household labour allocation and supply decisions by rural households for grain production, off-farm work and wetland products. Reduced form labour use and grain and wetland product supply equations derived from an agricultural household model were estimated jointly using a SUR approach to analyse the determinants of household labour allocation and product supply decisions.

The results presented in this chapter indicated that large families have more workers available to diversify their income base by allocating more labour time to on-farm and off-farm activities than smaller families. The positive and significant effect of household size on grain supply shows that it is critical to alleviate labour bottlenecks (perhaps through adoption of labour saving technologies) in order to improve the supply of the staple crop and enhance food security among rural households.

Our results showed that education is positively related to labour time allocated to off-farm activities, which implies that investment in education and skills development of the rural population is important for the rural population to benefit from growth in the non-farm sector. Since women have relatively limited access to off-farm employment opportunities, gender mainstreaming in rural education programmes is important to improve education opportunities for women to enhance their potential for employment in the off-farm sector.

The positive effect of exogenous income on grain supply and its negative effect on the supply of wetland products shows that policy measures, which reduce household liquidity constraints (e.g. improved access to credit and off-farm income opportunities), can improve food security among rural households and at the same time provide incentives for rural households to conserve wetland resources.

The responsiveness of grain supply to prices (of input and grain) shows that government intervention in agricultural markets can have significant impacts on farm supply. Government regulations, which artificially suppress producer prices and increase input prices, can create a disincentive for farmers to produce. Therefore, the government, in close partnership with the private sector, should strongly support and strengthen reforms in the input and output markets to ensure that input and output prices provide incentives for farmers to invest in agriculture.

The finding that poor households spend more time on the collection of wetland products and supply more of these products has two implications: first, there is need to integrate wetland management and poverty reduction to provide incentives for the poor to conserve wetland resources; and second, environmental protection policies limiting access to the wetland resources increase inequality among rural populations and deepen poverty, because poorer households suffer more intensively from deprivation of the resource.

CHAPTER 5

REVIEW OF APPROACHES TO ASSESS THE IMPACTS OF MANAGEMENT AND POLICY SCENARIOS ON ECOSYSTEM FUNCTIONING AND HUMAN WELL-BEING

5.1 Introduction

As highlighted in Chapter 1, one of the limitations to the sustainable management of wetlands in Africa is: the poor understanding of the consequences of alternative policy and management regimes on wetland functioning; and the supply of ecosystem services and human well-being. This chapter reviews different analytical approaches used in the literature for establishing the linkages between ecological and economic systems and evaluating the impacts of alternative management and policy regimes on ecosystem functioning and economic well-being. The review will be used as the basis for choosing an analytical framework to adapt to this study.

5.2 Review of analytical approaches

Three main analytical approaches are used for evaluating the impacts of alternative management and policy regimes on ecosystem functioning and economic well-being in the literature. These are: economic valuation; multi-criteria analysis; and integrated ecological-economic models. These approaches are discussed in detail below.

5.2.1 Economic valuation

Ecosystems provide services that are of value to human welfare. The value of these services depends on the type of functions that are perceived as valuable to society. Only functions that provide services that satisfy a society’s demands directly or indirectly have an economic value (Costanza *et al.*, 1989; Turner *et al.*, 2000).

The total economic value framework disaggregates the total economic value into use and non-use values (Figure 5.1). A use value refers to the value of ecosystem services that are used for human and production services. It includes the tangible ecosystems services that can be consumed directly (direct use values) as well as ecosystem services that are intermediate inputs for production of final goods and services for human consumption (indirect use values), such as soil nutrients, water and biological support. A non-use value (also referred to as 'existence value' or 'option value') is the value that humans ascribe to ecosystems for preserving the option to use in future, despite the fact that they may not presently be deriving utility from them.

Economic valuation is an attempt to quantify the direct and indirect benefits from ecosystem services in monetary terms. It is aimed at providing a common metric in which to express the benefits of the diverse services provided by ecosystems (Barbier *et al*., 1997). Valuation can be used in three main ways, according to Pagiola *et al*. (2004). The first is total valuation, which aims at estimating the total value of ecosystem services at a given time (e.g. for national income accounting or to determine its worth as a protected area). This type of valuation can provide useful information on the contribution of ecosystems to human welfare. Most of the wetland valuation studies conducted in southern Africa fall in this category (Seyam *et al*., 2001; Schuyt, 1999).

It is believed that an improved awareness of the contribution of ecosystems to human welfare ensures that the values of ecosystems are better taken into account in decision making and can also be applied at the macroeconomic level for making adjustments to national income accounts. One limitation of this approach is that in most instances it is practically difficult to determine non-market ecosystem services. As a result, most of the valuation studies quantify few selected services.

Secondly, economic valuation can be used as a tool to examine the distribution of costs and benefits of ecosystem services among stakeholders. In this way, economic valuation allows for understanding of how different management interventions affect the poor and other stakeholders (i.e. equity considerations).

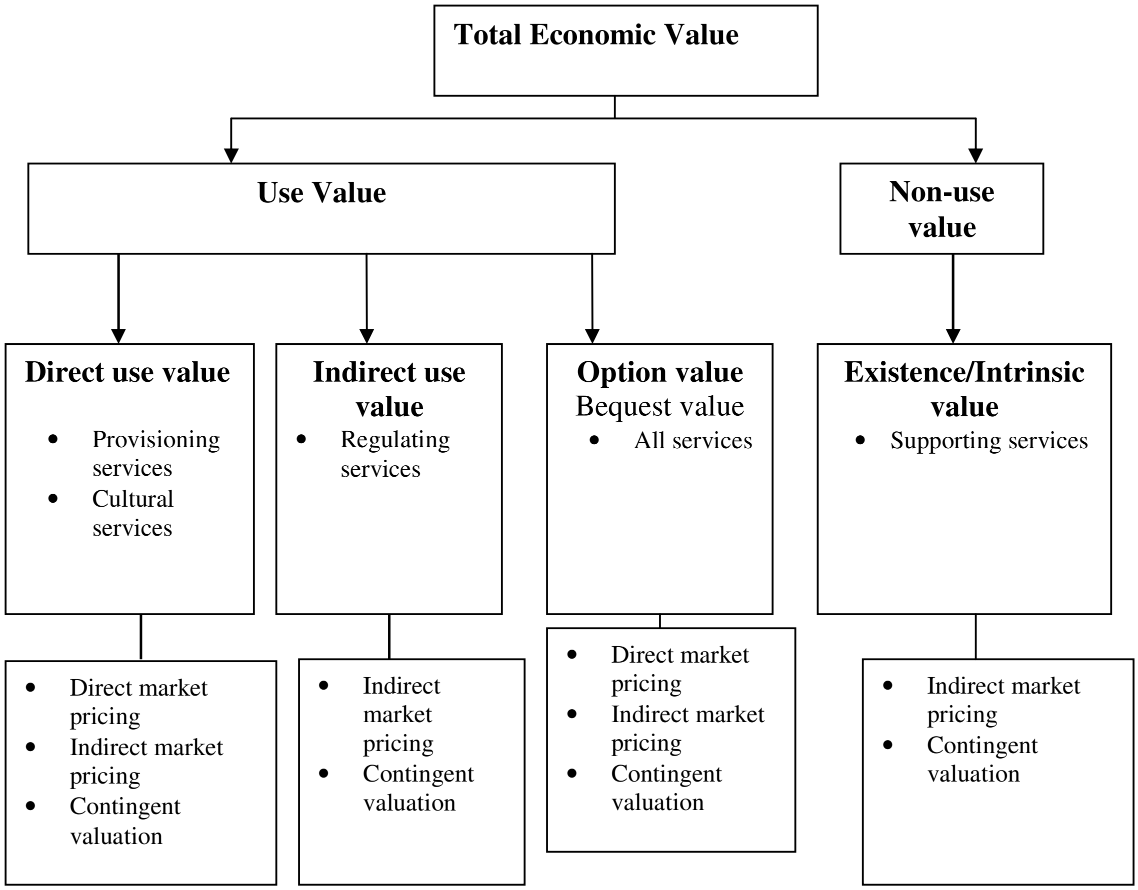


Figure 5.1: The Total Economic Value framework (Adapted from: MEA, 2003)

Thirdly, valuation can be used to evaluate the trade-offs between alternative ecosystem management regimes that alter ecosystems condition and the multiple services they provide. This approach focuses on assessing the impacts of alternative management and policy regimes on ecosystem services. This valuation approach is referred to as partial valuation (Barbier *et al*., 1997). In this approach, the first step is to quantify the biophysical relationships of the impact of management alternatives on ecosystem functioning and how this affects the provision of ecosystem services. The second step is to apply valuation in the narrow sense, which monetarises ecosystem services using prices. This type of valuation is more relevant to policy since it quantifies the trade-offs among alternative uses of an ecosystem.

Economic valuation approaches can also be categorised into those that are static in nature and those that are dynamic. The former quantifies the value of ecosystem services at a single time period. It does not trace the effects of changes in ecosystem condition and ecosystem services over time and thus assumes that ecological processes and ecosystem services are constant over time. Most of the wetland valuation work in Africa falls in this category mainly due to data limitations (e.g. Barbier *et al*., 1991; Schuyt, 1999; Emerton *et al*., 1999). In contrast, the dynamic approach takes into account the fact that changes in ecological functioning play out over time and result in changes in the supply of ecosystem services in the short, medium and long-term. Examples of the application of the dynamic approach to wetland ecosystems are studies by: Chopra and Adhikari (2004); Eppink *et al*. (2004); and Güneralp and Barlas (2003).

The Cost-Benefit Analysis (CBA) is the most widely used framework for valuing ecosystem services. The framework quantifies the costs and benefits of environmental services and enables quantification of trade-offs among ecosystem services. Under the CBA framework, there are several techniques that can be used to value ecosystem services. These can be classified into three broad categories: those that use directly observed market prices for valuation; those that use surrogate market prices for valuation; and those that use survey techniques for valuation[11].

In the first category, valuation is based on direct (observed) market prices of goods and services (revealed preference methods). It includes techniques such as: change in value of direct output; the production function approach; the replacement cost approach; the damage cost avoided approach; and the defensive expenditure method. The second category of methods is based on surrogate markets, that is to say the market value of complementary and substitute goods in cases where the ecosystem service to be valued does not have an observed market price. Examples of valuation techniques which fall in this category include travel cost methods and hedonic pricing. Finally, survey techniques (stated preference methods) can be used to directly ask consumers to state their preferences regarding a non-marketed ecosystem service by presenting to them hypothetical scenarios. Valuation techniques under this category include: contingent valuation methods; conjoint analyses; and choice experiments. The different valuation techniques discussed here have been applied for

[11] See Freeman (1993) for a detailed discussion of the different economic valuation techniques and Barbier *et al.* (1997) for a discussion on the application of valuation techniques to wetland ecosystems.

valuing wetland services in Africa (see Barbier *et al*., 1991; Schuyt, 1999; Turpie *et al*. 1999; Emerton *et al*. 1999).

Although the CBA approach has been applied extensively in valuing ecosystem services, the framework has a number of shortcomings. Apart from its significant data requirements, which affect the accuracy and reliability of results, the framework is primarily based on economic efficiency without considering the distribution of costs and benefits among stakeholders (Acreman, 2001; Gregory and Slovic, 1997). For this reason, other scholars recommend that the CBA needs to be complemented with measures other than economic efficiency to be able to guide decision making (Barbier *et al*. 1997).

5.2.2 Multi-criteria analysis

Considering the limitations of the CBA, some scholars have opted to use multi-criteria analysis (MCA) to evaluate the alternative ecosystem management options based on multiple criteria such as: economic efficiency; environmental security; and equity (Barbier *et al*. 1997; Acreman, 2001; Brouwer and Van Ek, 2004). The MCA approach allows for comparing and ranking different management outcomes using multiple economic, environmental and social indicators. The actual measurement of indicators need not be in monetary terms, but are often based on scoring, ranking and weighting of a wide range of qualitative criteria.

The MCA approach, however, has its own shortcomings. The main shortcoming is related to the subjectivity of the choice of weights that are assigned to each objective. A common technique used to deal with this problem is to undertake a sensitivity analysis of outcomes with varying weights. For this reason, some scholars recommend introducing stakeholders' perceptions, derived from a stakeholder analysis to help in the weighting of different criteria.

The MCA and CBA should not be considered as parallel approaches. In some cases the two approaches complement each other (Brouwer and Van Ek, 2004; Tiwari *et al*. 1999). The MCA can also take the form of integrated disciplinary models, which take into account environmental security, economic value and distributional aspects.

5.2.3 Integrated ecological-economic models

Integrated ecological-economic models are used for evaluating ecological and economic impacts of alternative ecosystem management and policy regimes (Costanza and Ruth, 1998; Cox, 2005; Farber *et al*., 2006). These models integrate various aspects of ecosystem functioning (e.g. hydrology), ecosystem services and their economic value. The models can be analytical or numerical and describe either steady-state or dynamic change. The models are most easily carried out at a local scale, where the interactions between elements in the system can be easily identified.

Turner *et al*. (2000) and Chopra and Adhikari (2004) highlighted that the impacts of management interventions on wetland functioning and human well-being can be better understood through the integrated modelling of ecological and economic processes of wetland systems and scenario analysis. In such models, economic valuation plays an intermediate role of expressing ecosystem services associated with the different management scenarios in monetary terms so that scenarios are comparable.

Two forms of integrated models are used in the literature for evaluating the impacts of alternative management and policy regimes on ecosystem functioning, the supply of ecosystem services and human well-being: modular or heuristic models; and system dynamics models (Turner *et al*. 2000; Ringler and Cai, 2003; Costanza and Ruth, 1998). These forms of models and examples of their applications are discussed in detail below.

5.2.3.1 Heuristic models

In these models, ecological and economic systems are constructed separately with output from one disciplinary model used as an input in another. In other words, the submodels operate independently with loose connections and no feedbacks between models.

A good example of the empirical application of this approach is provided by Van den Bergh *et al*. (2001) who developed spatially integrated economic, hydrological and ecological models to analyse the impacts of alternative land use scenarios (housing, infrastructure, recreation, agriculture and nature conservation) on a wetland system in the Netherlands. Hydrological models were developed to simulate the impacts of these land use scenarios on the ground and surface water quantity and quality in the wetland. The outputs of the hydrological models were fed into an ecological model, which was used to estimate the effect of changes in water quality and quantity on the vegetation species' diversity. The net present value and environmental quality were the two aggregate performance indicators computed for each land use scenario and were later combined to form one welfare index on the basis of which land use options were compared.

The major advantage of heuristic models is that they allow for a detailed analysis of each of the components included in the model. However, by modelling ecological and economic systems separately the approach does not take into account the interactions and feedbacks between elements in the system.

5.2.3.2 System dynamics models

System dynamics models are based on systems theory, which was developed during the mid-1950s as an approach to understand the dynamic behaviour of complex systems (Forrester, 1968). This approach recognises that elements of complex systems are tightly interwoven into one system with direct interactions and feedbacks between them. It is on this premise that the system dynamics approach has also been referred to as the holistic approach (Brouwer and Hofkes, 2008).

What makes system dynamics models different from other modelling approaches used in studying complex systems is the use of stocks and flows. To take into account the links between the natural system and socio-economic system, the two systems are usually integrated as modules of models (Costanza *et al*. 1993). Difference equations are used to describe the dynamics of stocks in the system together with equations specifying relationships between flows (e.g. human consumption of ecosystem services) and other elements in the system. The totality of the model equations constitutes the structure of the model (or the system). It is essential in the system dynamics methodology that the model structure provides a reasonable representation of the main interactions in the system being modelled.

Although the system dynamics framework was originally developed for understanding the dynamics of industrial processes, it has been widely applied in understanding the dynamic behaviour of ecosystems, particularly in evaluating the impacts of alternative management regimes on ecosystem functioning, ecosystem services' supply and human well-being.

For example, Van Beukering *et al*. (2003) developed and applied a system dynamics model to examine the economic consequences of alternative management options of a national park in Indonesia. They developed ecological and economic modules to predict the impacts of alternative management regimes on ecosystem functioning and ecosystem services provided by the national park. Three management regimes for the national park were considered: deforestation; conservation; and selective use. Selected ecosystem services were considered in the model, which are: water supply; fisheries; flood prevention; agriculture and plantation; hydroelectricity; timber and non-timber products; tourism; biodiversity; fire prevention; and carbon sequestration. The economic valuation module was used as an intermediate step in the modelling process to estimate the economic (monetary) value associated with each management option. The study found that conservation of the national park spreads the benefits of the national park equally among all stakeholders and therefore prevents potential social conflicts while deforestation widened the income gap between the rich and the poor.

In a study in the Brazilian Amazon forests, Portela and Rademacher (2001) used a dynamic simulation model to investigate the value of forest ecosystem services under farming and ranching uses. They developed a model with three modules: i) deforestation drivers module, which considered the socio-economic drivers of forest clearing; ii) the ecosystem services for quantifying the impacts of land use patterns on forest ecosystem services; and iii) ecosystem valuation module for calculating the economic value of changes in forest ecosystem services. The key forest ecosystem services considered in the model are: hydrological regulation; nutrient cycling; carbon sequestration; and species diversity. The losses in the value of ecosystem services due to different land use practices (farming and rangeland management) were compared to the forest reference value, which was based on a global average value of forest ecosystems to find the net welfare impacts of land use practices. Portela and Rademacher (2001) showed that there are significant losses in the value of ecosystem services under farming and rangeland management regimes compared to the forest reference value.

Gambiza *et al*. (2000) examined the ecological and economic impacts of changing stock rates, tree removals, fire regimes and woodland structures for the Miombo woodland ecosystems of Zimbabwe. A dynamic simulation model with the following five interactive modules was developed: rainfall; grass production; fuel load; fire occurrence; and tree dynamics. The economic impacts of alternative woodland management regimes were explored by comparing the net present values accruing to the state authority that manages the forest and communal dwellers dependent on the forest under different management regimes (grazing pressure, high or reduced impact logging, varying proportion of harvestable timber cut). Their study concluded that the net present value to the state authority managing the forest remained constant under the different management regimes despite the marked ecological response.

Higgins *et al*. (1997) developed a dynamic simulation model to examine the value of ecosystem services provided by mountain *fynbos* ecosystems under alternative management regimes in South Africa. Three management regimes were considered: pristine management (uninvaded, no clearing required); present management (invaded, no alien clearing); and proactive management (invaded, intense clearing). Like the other studies discussed above, they divided their model into modules and used economic valuation as an intermediate step in the modelling process. Their model has five modules: hydrological; fire; plant; management; and economic valuation modules. The first three modules were used to quantify the impacts of management regimes on the *fynbos* ecosystem and the supply of selected ecosystem services while the economic valuation module estimated the value of the services under each management regime. By considering key ecosystem services provided by forests they were able to demonstrate that the costs of clearing invasive alien plants were a small proportion of the value of *fynbos* ecosystem services thus justifying an investment in clearing alien plants in *fynbos* ecosystems.

Application of system dynamics models to model dynamic behaviour of wetland ecosystems has recently gained prominence. For example, Chopra and Adhikari (2004) developed and applied an ecological-economic model to simulate effects of alternative regimes on ecological health and incomes derived from a wetland system in Northern India. Their model has three environmental modules which examine changes in three environmental variables that affect the ecological health of the wetland water, biomass and birds modules and a net income module, which sums up the impact of changes in each of the environmental modules on income derived from tourism and resource extraction. Upstream agricultural activities were assumed to cause pressures that affect stock of water and biodiversity (biomass and birds), which in turn determine the ecological health and hence amenity value of the wetland. The number of tourist visits to the wetland was considered to be a function of ecological health fir the wetland. The sensitivity of tourist visits to wetland ecological health indices were derived through simulation of scenarios with respect to future pressures on the wetland. The travel cost method was applied to estimate demand functions and consumer surplus accruing as welfare gain to tourists from amenity values derived from the wetland. They concluded that direct and indirect income obtained from the wetland is positively related to the ecological health of the wetland demonstrating a positive incentive to conserve the wetland.

Eppink *et al*. (2004) presented a general dynamic simulation model for analysing interactions between land use and wetland biodiversity. The model comprises of four modules: a land accounting module, which tracks changes in agricultural and urban land use; a biodiversity module describing the impacts of land use on biodiversity (measured in terms of species richness and evenness); a land use decision module describing the process that leads to decisions on urban expansion; and a social evaluation module in which social welfare is modelled as a function of income per capita, population density and wetland biodiversity was used to assess scenario outcomes. Using different scenarios for population, agricultural and urban growth, simulation experiments were performed to assess the effects of these scenarios on wetland biodiversity and social well-being. The study showed that there may be conflicts between urban growth and the conservation of wetland biodiversity.

Güneralp and Barlas (2003), working on a lake ecosystem in Turkey, developed and applied a system dynamics model to assess the impacts of different scenarios on ecosystem and economic activities. The objective of the model was to find a balance between improving the well-being of inhabitants living around the lake and maintaining ecological integrity of the lake ecosystem. They simulated dynamics of: ecological elements of the lake ecosystem; economic activities such as crop production, industrial activities and fishing; and the demographics of inhabitants in the study area. Their study concluded that there is no threat of a shift in algal dominance in the lake although there is potential for a decline in the welfare of inhabitants due to an increase in population.

In southern Africa, there is limited empirical work on evaluating the impacts of alternative management and policy regimes on wetland functioning, ecosystem services supply and human well-being. Apparently, one study by Turpie *et al*. (1999) attempted to assess the economic and ecological impacts of various management options of wetland systems in the Zambezi basin using a dynamic simulation model. Although the study does not give a detailed description of the model the information available shows that four management scenarios were simulated, which are: the maintenance of the status quo; implementing wise use practices; delimiting protected areas; and commercial agricultural development. The model integrated ecological submodels describing the impacts of management scenarios on wetland functioning and selected ecosystem services (fish, wild animals, palms, reeds and papyrus production, flood plain grazing and crop production) and an economic valuation module for estimating values of ecosystem services under each management scenario. Their results showed that the status quo management practices will result in reduced wetland benefits in future, while wise use practices maximise future wetland benefits to the community.

5.3 Approaches and methods of the study

This study adopts the system dynamics framework to establish the linkages between ecological and economic systems in the Ga-Mampa wetland area. This framework is chosen, because of its ability to take into consideration the feedback effects between ecological and economic systems and also its ability to capture the intertemporal effects of interventions on ecosystem dynamics (Costanza *et al*. 1993; Costanza, 1996).

In developing the system dynamics model one can draw upon earlier studies on the systems modelling interactions between ecological and economic systems in wetland systems presented by Eppink *et al*. (2004); Güneralp and Barlas (2003) and Chopra and Adhikari (2004).

The adapted analytical framework is presented in Figure 5.2. The framework involves three steps: (i) evaluating the impacts of management scenarios on wetland ecosystem functioning; (ii) quantifying the effects of changes in ecosystem functioning on the supply of ecosystem services; and (iii) measuring the effects of the change in ecosystem services on human well-being. The bulk of the work involves quantifying the biophysical relationships along a causality chain. This involves integrating models from different disciplines.

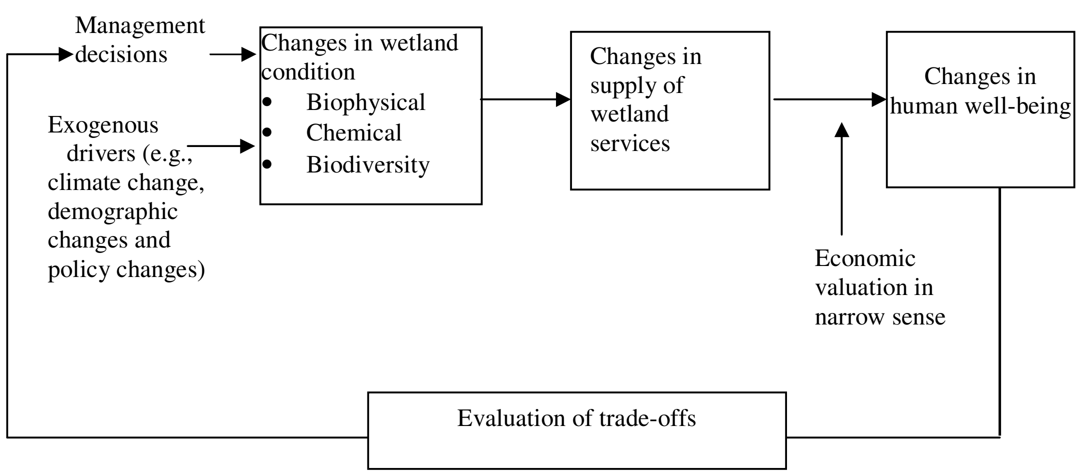


Figure 5.2: Analytical framework for evaluating the impacts of alternative wetland ecosystem management and policy regimes on ecosystem functioning, ecosystem services and human well-being (Adapted from: MEA, 2003)

5.4 Concluding Summary

This chapter reviewed the main analytical approaches used for evaluating the impacts of alternative management and policy regimes on ecosystem functioning, the supply of ecosystem services and human well-being. The review showed that three main analytical approaches are used for this purpose, which are: economic valuation; multi-criteria analysis; and integrated ecological-economic models (heuristic and systems dynamics models). Due to its ability to capture economic and ecological systems as integral components of one system and the feedbacks between them, the system dynamics approach in developing an ecological-economic model was chosen. The model is developed and applied to simulate the impacts of alternative management and policy scenarios in the next chapter.

CHAPTER 6

EMPIRICAL MODEL AND RESULTS FROM ANALYISIS OF THE IMPACTS OF ALTERNATIVE MANAGEMENT REGIMES ON WETLAND FUNCTIONING AND ECONOMIC WELL-BEING

6.1 Introduction

This chapter develops an empirical ecological-economic model for evaluating the impacts of alternative policy and management regimes on the wetland system and economic well-being. The first section of the chapter presents a generalised conceptual framework highlighting the main components in the system and their interactions. Section two discusses in detail the components of the empirical model and the assumptions behind their specification. The section that follows presents the entire system of the empirical model showing the linkages between ecological and economic systems and parameters used in the model. The fourth section validates the model. The model is then used to perform simulations of alternative wetland management and policy regimes the results of which are presented and discussed in the fifth section. A concluding summary of the chapter is presented at the end of the chapter.

6.2 Conceptual framework

This study attempts to develop an ecological-economic model based on the system dynamics framework. As highlighted in the previous chapter, the said framework takes into consideration feedback effects between ecological and economic systems as well as involved tradeoffs in the supply of individual constituents of the bundle of multiple services provided by wetlands. This framework also captures the intertemporal effects of interventions on ecosystem dynamics. In order to understand the ecological-economic interactions in the wetland system under study it is important to first identify the main components of the system and their interactions. The adapted framework consists of five subsystems: socio-economic; wetland hydrology; natural wetland vegetation; crop production; and land use change trade-offs. These subsystems are interlinked and changes in one subsystem impact on others with some feedbacks among them (Figure 6.1). Crop production and livestock production as well as natural wetland vegetation subsystems are linked to the wetland hydrological module through changes in water use. Crop and livestock activities abstract water from the wetland thereby affecting the wetland system's hydrology and water budget. Water use on the other hand influences the productivity of crops, livestock and natural wetland vegetation, which in turn affects the economic welfare component of the socio-economic subsystem. Crops and natural wetland vegetation also influence the wetland water budget as they lose water through evapotranspiration.

Crop and livestock production and natural wetland vegetation subsystems are also interrelated through competition for land and labour resources. For example, conversion of the wetland for crop cultivation reduces the wetland area and consequently the availability of its natural products, including vegetation for livestock grazing. There are therefore trade-offs involved between these activities, which also require the use of labour and other inputs supplied by the communities and hence competition for these inputs.

A positive relationship between growth in biomass of natural wetland vegetation and wetland groundwater level links the natural wetland vegetation to the underlying hydrological system and captures the trade-offs between crop and wetland biomass production due to competition for water. For instance, as groundwater levels are lowered through wetland conversion to agriculture, natural wetland vegetation is adversely affected by competition with non-wetland plant species (Eppink *et al.* 2004). As biomass increases the actual growth rate is expected to decrease due to competition for limited resources (e.g. light, water, nutrients and space). This is also true the other way around, when biomass is removed from the wetland (e.g. through biomass harvesting) the actual growth rate will increase.

The economic welfare component of the system is influenced by benefits derived from exploiting the wetland ecosystem (i.e. crop, livestock and natural products as well as domestic water supply) and income derived from other sources (i.e. off-farm employment and social transfers). This socio-economic subsystem on the other hand supplies labour and other inputs for which various crop, livestock, natural product harvesting and off-farm activities compete.

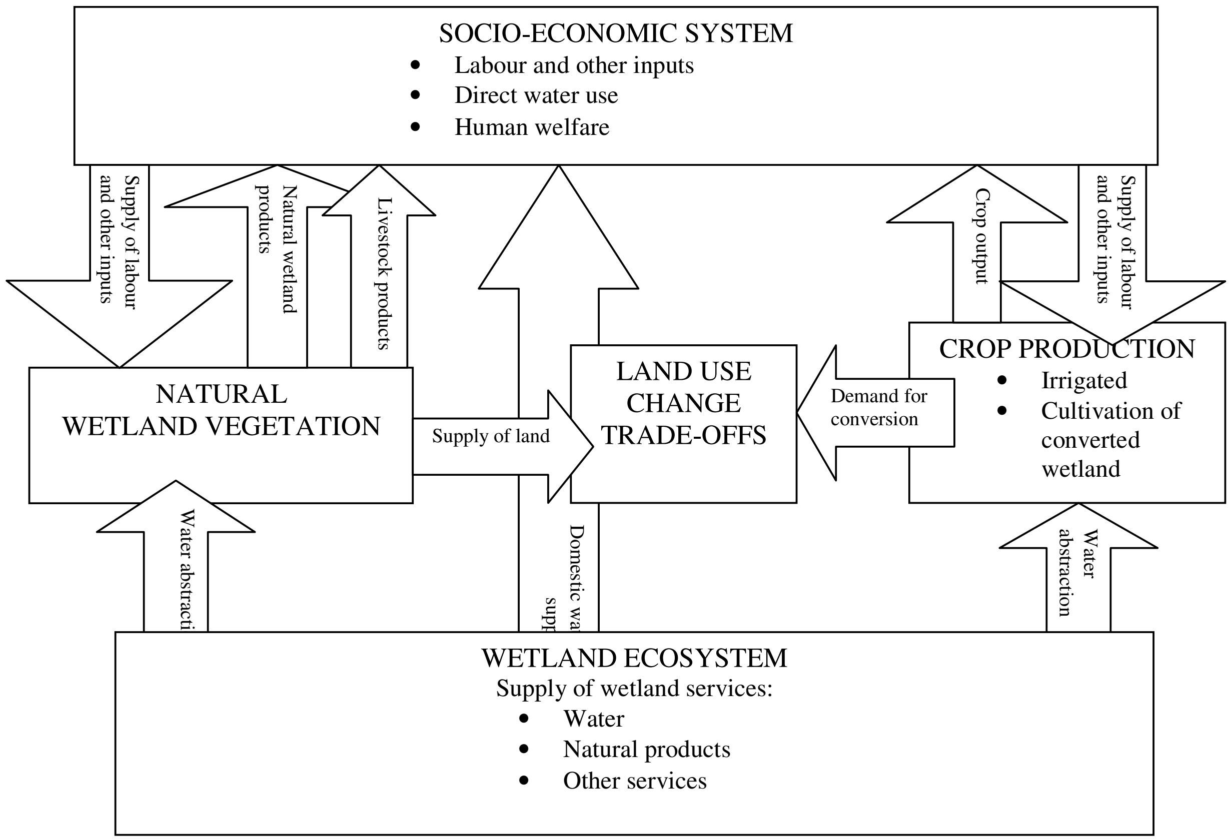


Figure 6.1: Conceptual framework showing the interactions between components of the system (Adapted from: Güneralp and Barlas, 2003)

6.3 The empirical model components and assumptions

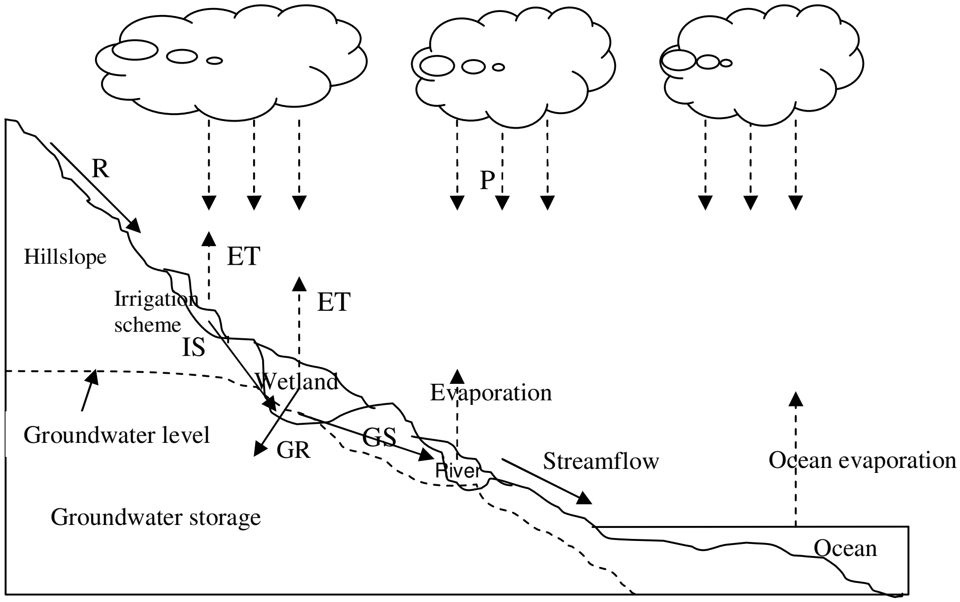
Although the wetland system under study provides several direct services, crop production and natural products harvesting[12] are the most important services supporting the well-being of the population in the study area (Adekola, 2007). Therefore, this study's empirical model focuses on these two services. The model integrates five modules which are discussed in detail below.

[12] Livestock production and domestic water supply have been excluded from the empirical model due to lack of data for estimating livestock products and domestic water supply and input demand system.

6.3.1 Hydrology module

Wetland hydrology is the primary driver of wetland ecosystem dynamics and many important functions of wetlands are directly linked to wetland hydrological processes (Eppink *et al*., 2004; Zhang and Mitsch, 2005; Mitsch and Gosselink, 2000). The objective of this module is to assess the impacts of wetland uses (crop production and natural wetland vegetation products) on the wetland water budget. The module is modelled in just enough detail to reflect the fundamental system dynamics and have input-output exchanges with the other modules. Standard stock-flow equations are used to relate the different wetland water budget components including inflows, and outflows from the wetland, which are mainly groundwater recharge and discharge processes and their link to soil water.

This study's wetland hydrological system comprises of five linked sub-systems: the upper catchment; the hillslopes; the irrigation scheme; the wetland aquifer; and the river system. The wetland is fed primarily by recharge from precipitation and irrigation schemes and losses through the evapotranspiration of crops and natural vegetation and seepage from the wetland to the river (Masiyandima *et al*., 2006).



Where: P is precipitation; IS refers to irrigation scheme seepage; GS is groundwater seepage from the wetland to the river; GR is recharge from wetland soil to groundwater; R is surface runoff; and ET refers to evapotranspiration losses.

Figure 6.2: Schematic representation of the main hydrological fluxes of the wetland (Adapted from: Bullock and Acreman, 2003)

The main surface flow through the wetland is the river, which passes through the edge of the wetland. The river inflow is influenced mainly by runoff generated in the catchment upstream. Although the bare soils in the wetland can generate significant runoff this is assumed to be minimal, as water infiltrates into the wetland due to the high permeability of peat soils in the wetland (McCartney, 2005).

Although it is believed that the lateral flow of groundwater from the hillslopes contributes to wetland recharge through seepage, this has not been validated through an empirical analysis. Therefore, this component is not included in the model. Discharge of wetland groundwater occurs through outflow of groundwater from the wetland to the river through seepage. The discharge of groundwater from the wetland is also influenced by artificial drainage activities as farmers drain groundwater from wetland plots to lower the water table and increase crop yields. In the studied wetland, 5% of the wetland represents the open drain area and much of the drained water is lost through evaporation before reaching the river system. However, to simplify the model and also due to lack of data, artificial drainage was not considered in the model.

In addition to groundwater seepage from the wetland to the river, wetland groundwater level is also influenced by groundwater recharge from saturated wetland soils (GR) and recharge from irrigation (IS). Recharge from wetland soils is influenced by soil moisture dynamics, which are in turn influenced by rainfall and evapotranspiration. Upstream of the wetland is a water diversion for the irrigation scheme on the perimeter of the wetland. The diversion from the river is channelled to the irrigated fields via a primary canal and several secondary canals, all of which leak severely. A principal canal transports water to the primary and secondary canals, which then feeds into the fields.

It is assumed that some water seepage from the irrigation area into the wetland groundwater storage occurs, recharging the wetland. The volume of diverted irrigated water for irrigation depends on the geometry of the canal as well as the water level in the weir. The canal's capacity is 130 litres per second (l/s). An estimated 94% of the diverted water is lost through seepage in the network of canals from the primary to field canals leaving only 6% available for crops (Chiron, 2005). It was assumed that the seepage losses from irrigated area recharge wetland groundwater.

Crop and natural vegetation evapotranspiration is the major component of water loss from the studied wetland system[13] (McCartney, 2005). Evapotranspiration consists of actual evapotranspiration from natural vegetation (ETv_t^i) and actual crop evapotranspiration from cultivated area (ETc_t^i). Therefore, the total evapotranspiration (ET_t^i) is given by the following equation:

$$ET_t^i = ETc_t^i + ETv_t^i \quad (6.1)$$

$$ETc_t^i = ET_{a,t}^i * AC_t^i$$

[13] Abstraction of water for domestic uses and watering of livestock is limited.

Where i refers to the two systems: irrigation; or wetland system that is to say i(r,w). $ET^{i}_{a,t}$ is actual evapotranspiration per hectare of cultivated area in system i at the time period t (mm/ha) and AC^{i}_{t} is the area cultivated in system i (ha) at the time period t.

Equation 6.1 is only true for the wetland since there is no natural vegetation in the irrigation system. Also, since our primary interest is to model the hydrological dynamics in the wetland system, equations 6.2-6.4 focus on the wetland system (i.e. i = w = wetland system). For the wetland system, the rate of evapotranspiration from natural vegetation varies with every season and is as high as 5mm per day during the rainy season and is approximately 1mm to 2mm per day during the winter season (Dye *et al*. 2008; Von der Heyden and New, 2003; Kleynhans, 2004). Using these values, it is assumed that actual evapotranspiration from natural wetland vegetation (ETv^{w}) is approximately 1100mm per unit area of wetland per year. Thus, evapotranspiration from natural vegetation in the wetland system is given by the following equation:

$$ETv^{w}_{t} = \eta * TA^{w}_{t} \qquad w = \text{wetland system} \qquad (6.2)$$

Where η is a parameter showing the rate of evapotranspiration from natural vegetation per hectare per year and TA^{w}_{t} refers to the total wetland area.

For the area cultivated in the wetland system, we considered that recharge to groundwater occurs when the water content of the root zone is above field capacity. The water holding capacity for the type of soil texture found in the study area ranges from 140mm to 170mm per metre of soil depth (Saxton and Rawls, 2006). Therefore, we assume that the field capacity of the soil is 140mm.

Given the earlier description of the wetland hydrological system and the fact that run-off is limited in the wetland, the soil moisture content in the root zone can be expressed as a water balance equation as follows:

$$MC_{t+1} - MC_{t} = P_{t} + CR_{t} - GR_{t} - ET^{w}_{t} \qquad (6.3)$$

w = wetland system

Where MC_t and CR_t refer to soil moisture content and capillary rise from the shallow groundwater, respectively.

The wetland hydrological fluxes discussed above impact on the wetland groundwater level through recharge and discharge processes. The equation for the change in the wetland groundwater level is given by[14]:

$$GWL_{t+1} = GWL_t + [GR_t + IS_t - GS_t - CR_t]/10^3 \qquad (6.4a)$$

Where GWL_t wetland is groundwater level (in metres) and the other variables are as defined earlier.

Since recharge to groundwater from saturated wetland soils is assumed to occur only if the soil water content is above field capacity, groundwater recharge from wetland soils is modelled using a logical if-then-else statement as follows[15]:

$$GR = \text{If } (MC_t + P_t + CR_t - ET_t^w \succ WHC) \text{ then } (MC_t + P_t + CR_t - ET_t^w - WHC) * (AC_t^w/120) \text{ else } 0 \qquad (6.4b)$$

Where WHC is a parameter for the water holding capacity of the wetland soil.

The hydrological components GS_t, IS_t, and CR_t were also modelled using: if-then-else logical statements; the information known about these processes at the study sites; and reasonable assumptions where necessary and these are presented in Appendix A2.

[14] We divide the expression by 10^3 to convert it from millimetres to metres since the wetland groundwater level (GWL) is measured in metres.
[15] To take into account the relative area of wetland and cultivated wetland, groundwater recharge is weighted by the proportion of wetland under cultivation $AC_t^w/120 = (1 - TA_t^w/120)$

6.3.2 Crop production module

This module assesses grain dynamics and their link to the other modules. Based on the grain supply function specified in equation 4.1, grain supply is a function of socio-economic variables. The parameter estimates for the grain supply function are presented in Chapter 4 (Table 4.5).

The crop production module is linked to the hydrology module through crop water use. Crops abstract water from the wetland thereby affecting the hydrology of the wetland, and in turn crop water use influences crop yields. To estimate crop water use we employ a linear crop yield-water response function based on the CROPWAT model developed by FAO (Doorenbos and Kassam, 1979) and widely applied in estimating crop water use (e.g. Igbadun *et al.*, 2007; Raes *et al.*, 2006; Ringler and Cai, 2003).

The model is specified as:

$$Y^{i}_{a,t} = Y^{i}_{m} \left[1 - k_{y} * \left(1 - ET^{i}_{a,t} / ET^{i}_{m,t}\right)\right] \quad (6.5)$$

Where: i, represents a wetland or irrigation system; $Y_{a,t}$ = actual yield (tonnes/ha) at the time period t; Y_{m} = maximum yield (tonnes/ha); $ET_{a,t}$ = actual crop evapotranspiration per hectare over the cropping season (mm/ha); $ET_{m,t}$ = maximum crop evapotranspiration over the cropping season (mm); and k_{y} = crop yield response factor

To link the crop yield-water response function (equation 6.5) and the grain supply function specified in the agricultural household model of Chapter 4 with the slope parameter adjusted with the average values of the variables of household characteristics (equation 4.1) a two-step process is followed. First, the grain supply and the area cultivated are aggregated across all households in irrigated and wetland systems to get a total grain supply (TG^{i}_{t}) and total area cultivated in system i (AC^{i}_{t}) as follows:

$$TG_t^i = \left(\sum_{q=1}^{Q_i} G_{q,t}^i \Big/ 10^3 \right) \quad (6.6a)$$

$$AC_t^i = \sum_{q=1}^{Q_i} A_{q,t}^i$$

Where: $G_{q,t}^i$ is grain supply per household in system (in kgs); $A_{q,t}^i$ is the area cultivated per household in system i at the time period t (in ha); and q is the number of households in system i where total households in that system ranges from 1 to Q.

The number of households in the irrigation system (Q_r) is constant (see Table 6.4) while the number of households cultivating in the wetland system (Q_w) is computed by dividing the total wetland area under cultivation by the cultivated wetland area per household. Therefore, the equation for Q_w is given as:

$$Q_w = AC_t^w / wc_0 \quad (6.6b)$$

Where AC_t^w is the total wetland area under cultivation and wc_0 is the cultivated wetland area per household.

The second step computes average yield in system i (Y_a^i) as:

$$Y_{a,t}^i = TG_t^i / AC_t^i \quad (6.7)$$

The average yield is substituted for actual yield (Y_a) in equation 6.5 to solve for ET_a^i (this corresponds to crop water use per hectare in system i).

The parameters used to solve $ET_{a,t}^i$ using equation 6.5 are given in Table 6.1. Values for parameters k_y and ET_m were taken from the work of Durand (2008) on crop water use for the 19 water management areas in South Africa based on the CROPWAT model. Values of Y_m in the irrigated and wetland area were obtained from the work done in the study area by Chiron (2005).

Table 6.1 Parameters used in the CROPWAT model for maize grain

	Wetland	Irrigation
k_y (a)	1.25	1.25
Y_m (b)	3	2.5
ET_m (a)	490	490

Sources: (a) Durand (2008); (b) Chiron (2005)

It is assumed that the demand levels for local production and agricultural input are too small to influence market prices, therefore crop output and input prices are considered exogenous. The producer price series of grain, derived from national statistics (Department of Agriculture, 2009) and local observations in 2006 were used for valuing maize output[16].

Two inputs are considered in the specification of the grain supply system: water and labour. Crop water use (which corresponds to ET_a calculated from equation 6.5) is used as the proxy for quantity of water used in wetland grain production. As the actual quantity of water used for irrigated maize production is difficult to determine since the irrigation system in the study area uses gravity to convey water directly from the river into the fields through canals the ET_a for maize grain under irrigation is used as an alternative.

Since rainwater is not supplied by an economic agent at a cost, the price of water used in wetland maize grain production does not exist. We accordingly used water tariff figures for agricultural water in South Africa for 2009 to attach a cost to water. Although, there are other costs related to labour for canalisation for irrigated crops, these were not included due to data limitations. In addition, water losses due to the low efficiency of water distribution systems from river to irrigation plots was not accounted for in the model.

[16] All production is valued irrespective of whether it is self-consumed, sold or retained.

The labour costs associated with grain production are calculated based on the labour demand for grain production given in Chapter 4 (equation 4.2 of the agricultural household model with the slope parameter adjusted with the average values of the variables of household characteristics) the parameters of which are presented in Table 4.5. The net value of grain (R_t), which links this module to the human well-being module is calculated using the following equation:

$$R_t = P_{G,t}\sum_{i}\left(Y^i_{a,t}AC^i_t\right) - P_{W,t}\sum_{i}\left(ET^i_a AC^i_t\right) - W_t * L_{G,t} * \sum_{i} Q_i \qquad (6.8)$$

Where: $P_{G,t}$ is the price of grain at the time period t (Rand/tonne); $P_{W,t}$ is the price of water at the time period t (Rand/mm); W_t is the wage rate (Rands/hour); $L_{G,t}$ is the labour time used in grain production per household in the time period t (hours/household/year) and Q_i is the total number of households in system i.

6.3.3 Land use change module

This module captures the dynamics in the area cultivated with grains in the wetland and under irrigation. Three land use systems are present in the area under study: irrigated area; natural wetland area; and area of wetland converted to crop production. Based on information from key informant interviews in the study area, the irrigated area is assumed to be constant over time and is estimated to be equal to 170 ha (Chiron, 2005). However, the area of wetland converted to cultivation grows over time whereas the natural wetland area is cleared for crop production causing the total wetland area to decline.

Therefore, the dynamics of the total wetland area are modelled using the following equation:

$$TA^w_{t+1} = TA^w_t - WCA_t \qquad (6.9)$$

Where TA^w_t represents the total wetland area and WCA_t is the area of wetland converted to cultivation in time period t.

Based on focus group discussions conducted in the study area, it is assumed that changes in the total area of wetland under cultivation are a function of three sets of factors: (i) the changes in population, which increase consumption, demand for food grain; (ii) crop output prices and input prices, which provide incentives (or disincentive) to convert the wetland to crop production; and (iii) a decline in annual precipitation, which results in new farmers moving into the wetland to cultivate because of its ability to retain soil moisture throughout the year. To predict the effect of these factors (precipitation, agricultural prices for output and inputs and population) on the total wetland area under cultivation (AC_t^w) we fitted historical annual time series data for these variables on area of wetland cultivated in the past, using a multiple regression analysis[17]. As the population in the study area is only known for the year 2006, we used the district average annual population growth of 1.7% (Statistics South Africa, 2004) to extrapolate the population for additional years corresponding to the periods for which historical data on the area of wetland under cultivation is available and use that for the regression estimation.

The regression equation for area of wetland under cultivation in period t is given by:

$$AC_t^w = a_1 P_t + a_{2,} P_{G,t} + a_3 P_{Y,t} + a_4 Pop_t \qquad (6.10a)$$

Where: a_1, a_2, a_3 and a_4 are parameters; and P_t, P_G, P_Y and Pop_t represent precipitation, price of grain, price of agricultural input and population at time period t, respectively.

Thus the area of wetland converted to cultivation in period t (WCA_t) is given by the following equation:

$$AC_{t+1}^w - AC_t = WCA_t \qquad (6.10b)$$

[17] The Consumer Price Index, which we use as the proxy for the price of market goods as will be explained later, was excluded from the regression due to its high collinearity with the price of agricultural inputs. As discussed in Chapter 4, the price of maize seed is used as the proxy for the price of agricultural inputs as this is the main input cost in grain production.

The initial value of the total area of wetland under cultivation starting in year 1990 was set up in such a way as to reach the levels in 2006 that were estimated to be 66 ha (Adekola, 2007).

6.3.4 Natural wetland vegetation module

This module describes the dynamics of wetland natural biomass. Due to limited data on the study site, the formulation of this module relied mainly on literature. Reeds (*Phragmites australis* and *Phragmites mauritanus*) are the major constituents of biomass in the studied wetland system (Kotze, 2005). Following Hellden (2008), a simplified S-shaped growth curve (logistic growth function) is employed to model biomass growth dynamics. Biomass per hectare of wetland area is specified by the following equation:

$$B_{t+1} = B_t(1 + r_t) \qquad (6.11)$$

Where B_t is biomass per hectare at time period t (tons/ha) and r_t is the actual growth rate of biomass stock at time period t.

Wetland biomass per hectare was set to a maximum of 70 tons per annum, which is the maximum annual productivity of reeds or carrying capacity (Finlayson and Moser, 1991 cited in Turpie *et al*. 1999). One can expect that as biomass increases the actual growth rate decreases due to competition for limited resources (e.g. light, water, nutrients and space). This is also true the other way around, when biomass is removed from the wetland (e.g. through biomass harvesting) the actual growth rate will increase. To capture the changes in actual growth rate as biomass stock changes we multiply the intrinsic growth rate by a density dependent factor (or growth rate multiplier) in computing the actual growth rate. Thenya (2006) estimated that the annual intrinsic growth rate (s_0) of wetland *phragmites* species (common reeds) can be as high as 300% after harvest during the rainy season. We assume a very moderate estimate for the intrinsic growth rate of 0.3. This rate applies when there are no limitations to biomass growth.

However, to capture the limitations caused by competition for resources as biomass stock grows, the intrinsic rate is adjusted by the growth rate multiplier. The growth rate multiplier is equal to 1 (100%) when biomass stock is close to zero and the rate decreases to close to zero when biomass stock is in full growth and is reaching carrying capacity. Thus, the growth rate multiplier is negatively related to the ratio of biomass stock in each time period to the carrying capacity (which is set at the maximum biomass per hectare). This is modelled as a graphical relationship based on the work of Hellden (2008). Following this work, the growth rate multiplier is a graphical function of the following form:

$$\sigma_t = \text{GRAPH}\,(B_t / k_B)\,;\ 0 < \sigma_t < 1 \qquad (6.12)$$

Where σ_t is the growth rate multiplier, k_B is carrying capacity and B_t is biomass per hectare at time period t (tons/ha), as defined earlier.

Although little is known on the effects of water regimes or the productivity of wetland plant species, changes in wetland groundwater are bound to affect wetland biomass production. For instance, as the groundwater level is lowered through the wetland's conversion to agriculture, wetland vegetation is adversely affected and loses the competitive struggle with non-wetland plant species (Eppink *et al*. 2004). Therefore, the actual growth rate of biomass is linked to changes in wetland groundwater level in a linear form. This relationship links this module to the hydrology module and captures the trade-offs between crop production and wetland natural resources production due to competition for water. Given that there is very limited literature on the relationship between the below ground groundwater level and biomass growth, the above ground water depth-reeds growth correlations done by Tarr *et al*. (2004) is relied upon to obtain a gross parameter estimate on the wetland groundwater level effects on biomass growth.

Therefore, the actual growth rate is given by:

$$r_t = s_0 * \sigma_t + \mu_1 GWL_t \qquad (6.13)$$

Where s_0 is the intrinsic growth rate, μ_1 is a parameter, σ_t is the growth rate multiplier and GWL is the wetland groundwater level as defined earlier.

Total biomass stock (TB_t) (measured in tons) is calculated as a product of biomass per hectare (B_t) and wetland area (TA_t^w) minus quantity of biomass harvested (h_t):

$$TB_t = TA_t^w * B_t - h_t \qquad w = \text{wetland system} \qquad (6.14)$$

The quantity of biomass harvested (h_t) is a product of the reduced form household biomass supply function (X_H^H) (measured in tons per household per year) which is derived from an agricultural household model in equation 4.1 in Chapter 4 with the slope parameter adjusted with the average values of the variables of household characteristics and the number of biomass harvesting households (NH_t):

$$h_t = NH_t * X_H^H \qquad (6.15)$$

The number of biomass harvesting households varies over time and is influenced by the total biomass stock. It is assumed that the number of households that harvest households is positively related to the total biomass stock. For as the total biomass stock declines, so does the number of households that harvest biomass and the efforts required to meet the required biomass needs, increases. As time series data on the total biomass stock for the study area does not exist, the author resorted to fitting historical annual time series data on the natural wetland area (which is used as a proxy for total biomass stock) and the number of wetland harvesting households using a simple linear regression in order to estimate the parameter (c). The relationship between the number of biomass harvesting households and the total wetland area is given by the following equation:

$$NH_t = c * TA_t^w \qquad (6.16)$$

Where c is a parameter.

Given that the actual number of wetland biomass harvesting households is known for the survey year, the other years we extapolated by assuming that it is 24% of the total number of households (which is the proportion of households engaged in harvesting obtained from the survey). As the wetland area is used as a proxy for wetland biomass, the parameter c was adjusted to take into account the average biomass per hectare.

The biomass supply function is influenced by several exogenous factors as shown in equation 4.1 in chapter 4. The labour used in biomass harvesting (equation 4.2 with the slope parameter adjusted with the average values of the variables of household characteristics) is used to compute the labour costs incurred in biomass harvesting. The labour cost function for biomass harvesting (b_t) is given as:

$$b_t = W_t * L_H * NH_t \tag{6.17}$$

Where L_H is the labour used in biomass harvesting, measured in hours per harvesting household per year.

Therefore, the net value of biomass harvested (V_t) is given by:

$$V_t = h_t * P_{H,t} - b_t \tag{6.18}$$

$P_{H,t}$ is the market price of harvested biomass at time period t.

6.3.5 The economic well-being module

This module deals with the welfare of the human population in the study area, which influences the demand for grain and wetland natural products for their own consumption and sales for cash income. Communities living in the area also supply labour for these activities. Following Woodwell (1998) and Hellden (2008) this study used an exponential population growth function where population growth is assumed to vary with natural growth rate, g (birth and death rate) and out-migration (EM_t). Although both death rate and birth rate are dependent on a number of factors (e.g.

family policies, access to markets and health services,) these are not considered in the model. However, it is assumed that emigration rates (e_t) vary over time and are influenced by the availability of off-farm employment opportunities (the proxy for this is GDP per capita) and rainfall. Low rainfall reduces agricultural productivity, which results in more people migrating to urban areas to seek off-farm income opportunities to cushion themselves from income shocks. Therefore, the population in the study area is linked to GDP per capita and rainfall through the emigration rate equation (equation 6.21).

The initial population was set in such a way as to reach the population levels of the study area in 2006 that were estimated to be approximately 2700 people (Adekola, 2007). The average annual population growth rate for the area is set at the district average which is estimated at 1.7% (Statistics South Africa, 2004). Focus group discussions conducted in the study area showed that immigration (in-migration) is minimal and therefore we assume that there is no in-migration in the area so the immigration rate is set at zero.

Therefore, the population dynamics are given by:

$$Pop_{t+1} = Pop_t(1+g) - EM_t \qquad (6.19)$$

Where Pop_t is as defined earlier, g is the natural population growth rate and EM_t is the number of emigrants at time t

The number of emigrants is estimated using the following equation:

$$EM_t = e_t * Pop_t \qquad (6.20)$$

Where e_t is the emigration rate.

The equation for emigration rate is specified as follows:

$$e_t = f_0 + f_1 GDP_{k,t} + f_2 P_t \qquad (6.21)$$

Where f_0, f_1 and f_2 are parameters; GDP_k and P_t represent GDP per capita and precipitation, respectively.

The parameters for equation 6.21 were derived from estimating a regression of historical emigration rates. These rates were for a typical rural area in South Africa for the midpoint years of a five-year period given by Kok and Collison (2006) with national the GDP per capita figures and the annual rainfall data corresponding to these years for the area.

In each given period, population determines the total labour supply and hence the total available labour (LS_t) (measured in hours per year) is specified as follows:

$$LS_t = (\kappa_1 m_1 + \kappa_2 m_2) * Pop_t \qquad (6.22)$$

Where κ_1 and κ_2 are parameters representing the proportion of adults and children in the population, respectively; m_1 and m_2 are also parameters representing the total labour supply per adult and child, respectively (measured in hours/person/year).

Labour demand (LD_t) is given by summing the labour demand for each of the livelihood activities taking into account the number of households involved in each of the activities:

$$LD_t = L_{o,t} * NO_t + L_{H,t} * NH_t + L_{G,t} * \sum_i Q_i \qquad (6.23)$$

Where L_o, L_H and L_G represent the labour used in off-farm work, biomass harvesting and grain production (measured in hours/household/year), respectively; NO_t and NH_t represent the number of households engaged in off-farm work and biomass harvesting, respectively.

It is assumed that labour is free to move between the different livelihood activities. Thus, the market clearing condition was imposed to solve the equilibrium wage rate as follows:

$$LS_t = LD_t + L_{z,t} * TH_t \tag{6.24a}$$

Where $L_{z,t}$ represents the labour time used in leisure (hours per household per year) and TH_t the total number of households.

The total number of households (TH_t) is equal to the population divided by the average household size (hs_0):

$$TH_t = Pop_t / hs_0 \tag{6.24b}$$

This module also derives the value of services of the wetland ecosystem and income from different sources. Four main forms of income are considered in the model: the net value of grain production; the net value of biomass harvested; off-farm wage income; and exogenous income (income from government social grants)[18]. The net values of grain and biomass harvested are shown by equations 6.8 and 6.18, respectively.

Off-farm wage income is a function of labour time used in off-farm work and the wage rate. The labour time used in off-farm work per household (L_o) (in hours/household/year) is also a function of exogenous factors as shown in equation 4.2 in chapter 4.

Therefore, the off-farm income function (O_t) is specified as:

$$O_t = NO_t * W_t * L_{o,t} \tag{6.25}$$

Where NO_t is the number of households engaged in off-farm work.

[18] Crop income and natural resource income gives the net value of all productions and harvested biomass at market prices including productions or harvests sold, consumed and retained.

The number of households engaged in off-farm work assumedly changes over time and is influenced by national economic performances measured in terms of GDP per capita (which is used as a proxy for availability of off-farm employment opportunities). Historical employment figures from ward level census data in the study area and the national GDP per capita figures were used for a regression analysis to establish the relationship between the number of households engaged in off-farm work and the GDP per capita. The equation for NO_t is given by:

$$NO_t = d_0 + d_1 GDP_{k,t} \tag{6.26}$$

Where d_0 and d_1 are parameters and GDP_k is GDP per capita.

The main form of exogenous income in the study area is government transfers through child grants given for children under the age of 14. The equation for exogenous income (social transfers) (E_t) is specified as:

$$E_t = z_t * NS_t \tag{6.27}$$

Where z_t is the social grant rate (Rand/beneficiary/year) and NS_t is the number of households that benefit from social grants.

The National Treasury of South Africa (2008) highlighted that the social grant rate has been increasing over the years in line with inflation, mainly to protect its purchasing power. Based on this observation, the author assumes that the social grant rate is a function of the consumer price index (CPI) and used historical social grants rates and CPI values to regress these two variables and find parameters for their relationship. The social grant rate can be expressed as:

$$z_t = k_0 + k_1 CPI_t \tag{6.28a}$$

Where k_0 and k_1 are parameters and CPI is the consumer price index.

The number of households benefiting from social grants (NS_t) is assumed to be a proportion of the total number of households at each time period and is given by the following relationship:

$$NS_t = n_0 * TH_t \qquad (6.28b)$$

Where n_0 is a parameter.

The total net income for the population in time period t, NI_t, is the summation of income derived from off-farm wage work, exogenous sources (social grants) and net value of maize production and biomass harvested:

$$NI_t = R_t + V_t + O_t + E_t \qquad (6.29)$$

It is assumed that the economic well-being of the targeted population in time t measured as net income per capita (SW_t) is a function of total net income such that the economic well-being function is given by:

$$SW_t = \frac{NI_t}{Pop_t} \qquad (6.30)$$

The net income per capita is the measure (index) of economic well-being that is used to assess scenario outcomes.

6.4 The full system of equations showing the linkages between modelled ecological-economic systems

In order to clearly show the linkages between economic and ecological processes in the system being modeled we present the full system of equations and the model variables to solve for endogenously are defined in Table 6.2. The model is specified and solved in STELLA[19], a simulation software which is well suited for simulating dynamics of ecological-economic systems (Costanza and Gottlieb, 1998). The model is run on an annual time step.

(A) Hydrology module

Total evapotranspiration (mm): (i = r, w) $ET_t^i = ETc_t^i + ETv_t^i$ (6.1)

Actual crop evapotranspiration from cultivated area (mm): $ETc_t^i = ET_{a,t}^i * AC_t^i$

Actual evapotranspiration from natural vegetation (mm): $ETv_t^w = \eta * TA_t^w$

(6.2)

Soil moisture content (w = wetland) (mm): $MC_{t+1} - MC_t = P_t + CR_t - GR_t - ET_t^w$

(6.3)

Wetland groundwater level (m): $GWL_{t+1} = GWL_t + [GR_t + IS_t - GS_t - CR_t]/10^3$

(6.4a)

Groundwater recharge from wetland soils (mm):

$$GR = \text{If } (MC_t + P_t + CR_t - ET_t^w \succ WHC) \text{ then } (MC_t + P_t + CR_t - ET_t^w - WHC) * (AC_t^w/120) \text{ else } 0$$

(6.4b)

(B) Crop production module

Actual crop yield (tons/ha): $Y_a^i = Y_m^i \left[1 - k_y * \left(1 - ET_a^i / ET_m^i\right)\right]$ (6.5)

Household grain supply function (kg/household/year):

$$G_{q,t} = \alpha_0 + \alpha_1 E_t + \alpha_2 W_t + \alpha_3 P_{G,t} + \alpha_4 P_{H,t} + \alpha_5 P_{M,t} + \alpha_6 P_{Y,t} \quad (4.1)$$

Household labour used in grain production (hours/household/year):

$$L_{G,t} = \beta_0 + \beta_1 E_t + \beta_2 W_t + \beta_3 P_{G,t} + \beta_4 P_{H,t} + \beta_5 P_{M,t} + \beta_6 P_{Y,t} \quad (4.2)$$

[19] The software requires that the variables in the system are categorised into stocks (state variables), flows (rate of change of stock variables) and converters (intermediate variables used for miscellaneous calculations). The linkages between these through difference equations represent the links between the ecological and economic components in the integrated model. The model state variables are presented in Table 6.3.

Total grain supply (tons):

$$TG_t^i = \left(\sum_{q=1}^{Q_i} G_{q,t}^i \Big/ 10^3 \right) \qquad (6.6a)$$

Total area cultivated (ha):

$$AC_t^i = \sum_{q=1}^{Q_i} A_{q,t}^i$$

Households cultivating the wetland system: $Q_w = AC_t^w / wc_0$ (6.6b)

Average yield (tons/ha): $Y_{a,t}^i = TG_t^i / AC_t^i$ (6.7)

Net value of grain (Rands):

$$R_t = P_{G,t} \sum_i \left(Y_{a,t}^i AC_t^i \right) - P_{W,t} \sum_i \left(ET_a^i AC_t^i \right) - W_t * L_{G,t} * \sum_i Q_i \qquad (6.8)$$

(C) Land use change module

Total wetland area (ha): $TA_{t+1}^w = TA_t^w - WCA_t$ (6.9)

Total area of wetland under cultivation (ha): $AC_t^w = a_1 P_t + a_{2,} P_{G,t} + a_3 P_{Y,t} + a_4 Pop_t$

(6.10a)

Area of wetland converted to cultivation (ha):

$$AC_{t+1}^w - AC_t = WCA_t \qquad (6.10b)$$

(D) Natural wetland vegetation module

Biomass per hectare (tons/ha): $B_{t+1} = B_t (1 + r_t)$ (6.11)

Growth rate multiplier: $\sigma_t = GRAPH\,(B_t / k_B)\,;\, 0 < \sigma_t < 1$ (6.12)

Actual growth rate: $r_t = s_0 * \sigma_t + \mu_1 GWL_t$ (6.13)

Total biomass stock (tons): $TB_t = TA_t^w * B_t - h_t$ (6.14)

Total biomass harvested (tons): $h_t = NH_t * X_{H,t}^H$ (6.15)

Number of biomass harvesting households: $NH_t = c * TA_t^w$ (6.16)

Household biomass supply function (tons/household/year):

$$X^{H}_{H,t} = \theta_0 + \theta_1 E_t + \theta_2 W_t + \theta_3 P_{G,t} + \theta_4 P_{H,t} + \theta_5 P_{M,t} + \theta_6 P_{Y,t} \qquad (4.1)$$

Labour cost for biomass harvesting (Rands):

$$b_t = W_t * L_{H,t} * NH_t \qquad (6.17)$$

Household labour used in biomass harvesting (hours/household/ year):

$$L_{H,t} = \rho_0 + \rho_1 E_t + \rho_2 W_t + \rho_3 P_{G,t} + \rho_4 P_{H,t} + \rho_5 P_{M,t} + \rho_6 P_{Y,t} \qquad (4.2)$$

Net value of harvested biomass (Rands):

$$V_t = h_t * P_{H,t} - b_t \qquad (6.18)$$

(E) Economic well-being module

Population (No. of people): $Pop_{t+1} = Pop_t (1 + g) - EM_t$ (6.19)

Number of Emigrants (No. of people): $EM_t = e_t * Pop_t$ (6.20)

Emigration rate: $e_t = f_0 + f_1 GDP_{k,t} + f_2 P_t$ (6.21)

Total labour supply (hours/year): $LS_t = (\kappa_1 m_1 + \kappa_2 m_2) * Pop_t$ (6.22)

Total labour used in livelihood activities (hours/year):

$$LD_t = L_{o,t} * NO_t + L_{H,t} * NH_t + L_{G,t} * \sum_i Q_i \qquad (6.23)$$

Labour market equilibrium: $LS_t = LD_t + L_{z,t} * TH_t$ (6.24a)

Total number of households (hhlds): $TH_t = Pop_t / hs_0$ (6.24b)

Off-farm income (Rands/year): $O_t = NO_t * W_t * L_{o,t}$ (6.25)

Household labour used in off-farm work (hours/household/year):

$$L_{o,t} = \delta_0 + \delta_1 E_t + \delta_2 W_t + \delta_3 P_{G,t} + \delta_4 P_{H,t} + \delta_5 P_{M,t} + \delta_6 P_{Y,t} \qquad (4.2)$$

Number of households engaged in off-farm work (households):

$$NO_t = d_0 + d_1 GDP_{k,t} \qquad (6.26)$$

Exogenous income (Rands/year): $E_t = z_t * NS_t$ (6.27)

Social grant rate (Rand/beneficiary/year): $z_t = k_0 + k_1 CPI_t$ (6.28a)

Number of social grants beneficiaries (hhlds): $NS_t = n_0 * TH_t$ (6.28b)

Total net income (Rands/year): $NI_t = R_t + V_t + O_t + E_t$ (6.29)

Economic well-being (Rands/capita): $SW_t = \dfrac{NI_t}{Pop_t}$ (6.30)

Table 6.2: Definition of endogenous model variables

Variable	Definition	Units
ET_t^i	Total evapotranspiration for system i (i = wetland or irrigation system) at the time period t	Millimetres
ETc_t^i	Actual total crop evapotranspiration from cultivated area from system i (i = wetland or irrigation system) at the time period t	Millimetres
ET_a^i	Actual crop evapotranspiration per hectare of cultivated area in system i (i = wetland or irrigation system)	Millimetres/ha
ET_v^w	Actual evapotranspiration from natural wetland vegetation	Millimetres
GWL_t	Wetland groundwater level at the time period t	Metres
GS_t	Groundwater discharge from wetland at the time period t	Millimetres
CR_t	Capillary rise at the time period t	Millimetres
GR_t	Groundwater recharge from wetland soils	Millimetres
MC_t	Wetland soil water content	Millimetres
TA_t^w	Total wetland area at the time period t	Hectares
AC_t^w	Total area of wetland under cultivation	Hectares
WCA_t	Area of wetland converted to cultivation	Hectares
Q_w	Number of households in the wetland system	Households
Y_a^i	Actual crop yield (i= wetland or irrigation system)	Tons/ha
$G_{q,t}$	Household grain supply at the time period t	kg/household/year
$L_{G,t}$	Household labour used in grain production at the time period t	Hours/household/year
TG_t^i	Total grain supply from system i (i= wetland or irrigation system) at the time period t	Tons
R_t	Net value of grain at the time period t	Rands/year
B_t	Biomass per ha at the time period t	Tons/ha
TB_t	Total biomass stock	Tons
V_t	Net value of harvested biomass at the time period t	Rands/year
r_t	Actual growth rate at the time period t	Non-dimensional
σ_t	Growth rate multiplier at the time period t	Non-dimensional
TB_t	Total biomass stock at the time period t	Tons
h_t	Total biomass harvested at the time period t	Tons
NH_t	Number of biomass harvesters at the time period t	Households
$X_{H,t}^H$	Household biomass supply at the time period t	Tons/household/year
b_t	Labour costs for biomass harvesting at the time period t	Rands/year

Table 6.2 (continued): Definition of endogenous model variables

Variable	Definition	Units
$L_{H,t}$	Household labour used in biomass harvesting at the time period t	Hours/household/year
Pop_t	Population at the time period t	People
EM_t	Number of emigrants at the time period t	People
e_t	Emigration rate at the time period t	Non-dimensional
TH_t	Total number of households at the time period t	Households
NS_t	Number of social grants beneficiaries	Households
LS_t	Total labour supply at the time period t	Hours/year
O_t	Off-farm income at the time period t	Rands/year
NO_t	Number of households engaged in off-farm work at the time period t	Households
$L_{o,t}$	Household labour time used in off-farm work at the time period t	Hours/household/year
LD_t	Total labour demand by livelihood activities at the time period t	Hours/year
E_t	Exogenous income at the time period t	Rands/year
z_t	Social grant rate at the time period t	Rands/person/year
NI_t	Total net income at the time period t	Rands/year
SW_t	Human well-being at the time period t	Rands/capita

Table 6.3: State variables (stocks) in the model

Module variable	Definition	Units
GWL_t	Wetland groundwater level	Metres
MC_t	Wetland soil water content	Millimetres
AC_t^w	Total area of wetland under cultivation	Hectares
TA_t^w	Total wetland area	Hectares
B_t	Biomass per hectare	Tons/ha
Pop_t	Population at the time period t	People

6.5 Specification of model parameters and validation

Data for model parameters were obtained from a wide range of sources. Table 6.4 presents the full model parameter values and their sources.

Table 6.4: Parameter values and sources

Parameter label	Symbol	Value	Source
Crop yield response to water factor for maize	k_y	1.25	Durand (2008)
Constant in the grain supply function	α_0	6.47	Agricultural household model grain supply function estimates from Chapter 4; adjusted by the average values of household size and education.
Coefficient for exogenous income in the grain supply function	α_1	0.01	Agricultural household model grain supply function estimates from Chapter 4
Coefficient for wage rate in the grain supply function	α_2	-0.013	Agricultural household model grain supply function estimates from Chapter 4
Coefficient for the price of grain in the grain supply function	α_3	0.06	Agricultural household model grain supply function estimates from Chapter 4
Coefficient for the price of wetland biomass in the grain supply function	α_4	-0.01	Agricultural household model grain supply function estimates from Chapter 4
Coefficient for the price of market goods in the grain supply function	α_5	-0.08	Agricultural household model grain supply function estimates from Chapter 4
Coefficient for the price of agricultural inputs in the grain supply function	α_6	-0.08	Agricultural household model grain supply function estimates from Chapter 4
Constant in the labour use equation for grain production	β_0	8.38	Agricultural household model estimates of labour use in grain production from Chapter 4 adjusted by the average values of household size and education.
Coefficient for exogenous income in the labour use for grain production	β_1	-0.016	Agricultural household model estimates of labour use in grain production from Chapter 4.
Coefficient for wage rate in the labour use equation for grain production	β_2	-0.039	Agricultural household model estimates of labour use in grain production from Chapter 4.
Coefficient for the price of grain in the labour use equation for grain production	β_3	0.054	Agricultural household model estimates of labour use in grain production from Chapter 4.
Coefficient for the price of wetland biomass in the labour use equation for grain production	β_4	-0.01	Agricultural household model estimates of labour use in grain production from Chapter 4.
Coefficient for the price of market goods in the labour use equation for grain production	β_5	-0.001	Agricultural household model estimates of labour use in grain production from Chapter 4.
Coefficient for the price of agricultural inputs in the labour use equation for grain production	β_6	-0.01	Agricultural household model estimates of labour use in grain production from Chapter 4.
Constant in the biomass supply function	θ_0	82.81	Agricultural household model estimates of the wetland biomass supply function from Chapter 4; adjusted by the average values of household size and education.
Coefficient for exogenous income in the biomass supply function	θ_1	-0.09	Agricultural household model estimates of the wetland biomass supply function from Chapter 4
Coefficient for wage rate in the biomass supply function	θ_2	-0.036	Agricultural household model estimates of the wetland biomass supply function from Chapter 4
Coefficient for the price of grain in the wetland biomass supply function	θ_3	-0.13	Agricultural household model estimates of the wetland biomass supply function from Chapter 4
Coefficient for the price of wetland biomass in the wetland biomass supply function	θ_4	0.01	Agricultural household model estimates of the wetland biomass supply function from Chapter 4
Coefficient for the price of market goods in the wetland biomass supply function	θ_5	-0.37	Agricultural household model estimates of the wetland biomass supply function from Chapter 4

Table 6.4 (Continued): Parameter values and sources

Parameter label	Symbol	Value	Source
Coefficient for the price of agricultural inputs in the wetland biomass supply function	θ_6	0.11	Agricultural household model estimates of the wetland biomass supply function from Chapter 4
Constant in the labour use equation for wetland biomass harvesting	ρ_0	13.41	Agricultural household model estimates of labour use in wetland biomass collection from Chapter 4; adjusted by the average values of household size and education.
Coefficient for exogenous income in the labour use equation for biomass collection	ρ_1	-0.02	Agricultural household model estimates of labour use in wetland biomass collection from Chapter 4
Coefficient for wage rate in the labour use equation for biomass collection	ρ_2	-0.086	Agricultural household model estimates of labour use in wetland biomass collection from Chapter 4
Coefficient for the price of grain in the labour use equation for biomass collection	ρ_3	-0.45	Agricultural household model estimates of labour use in wetland biomass collection from Chapter 4
Coefficient for the price of wetland biomass in the labour use equation for biomass collection	ρ_4	0.02	Agricultural household model estimates of labour use in wetland biomass collection from Chapter 4
Coefficient for the price of market goods in the labour use equation for biomass collection	ρ_5	-0.12	Agricultural household model estimates from Chapter 4
Coefficient for the price of agricultural inputs in the labour use equation for biomass collection	ρ_6	0.34	Agricultural household model estimates of labour use in wetland biomass collection from Chapter 4
Constant in off-farm labour use equation	δ_0	-6.60	Agricultural household model estimates of labour use in off-farm work from Chapter 4; adjusted by the average values of household size and education.
Coefficient for exogenous income in off-farm labour use equation	δ_1	-0.74	Agricultural household model estimates of labour use in off-farm work from Chapter 4
Coefficient for wage rate in off-farm labour use equation	δ_2	0.014	Agricultural household model estimates of labour use in off-farm work from Chapter 4
Coefficient for the price of grain in off-farm labour use equation	δ_3	-0.12	Agricultural household model estimates of labour use in off-farm work from Chapter 4
Coefficient for the price of wetland biomass in off-farm labour use equation	δ_4	-0.01	Agricultural household model estimates of labour use in off-farm work from Chapter 4
Coefficient for the price of market goods in off-farm labour use equation	δ_5	-0.93	Agricultural household model estimates of labour use in off-farm work from Chapter 4
Coefficient for the price of agricultural inputs in off-farm labour use equation	δ_6	0.64	Agricultural household model estimates of labour use in off-farm work from Chapter 4
Natural population growth rate	g	0.017	Statistics South Africa (2004)
Constant in the number of people employed off-farm-GDP per capita regression	d_0	-3.62	Regression analysis of the number of people employed in off-farm work and the GDP per capita
Coefficient for GDP per capita effect on number of people employed in off-farm work	d_1	0.01	Regression analysis of the number of people employed in off-farm work and the GDP per capita
Constant in the emigration rate equation	f_0	-4.17 e(-03)	Multiple regression analysis of the emigration rate, GDP per capita and rainfall
Coefficient for GDP per capita effect on emigration rate	f_1	2.70e(-07)	Multiple regression analysis of the emigration rate, GDP per capita and rainfall
Coefficient for rainfall effect on emigration rate	f_2	-6.9e(-07)	Multiple regression analysis of the emigration rate, GDP per capita and rainfall

Table 6.4 (Continued): Parameter values and sources

Parameter label	Symbol	Value	Source
Coefficient for the effect of CPI on social grant rate	k_1	1.58	Social grant rate-consumer price index regression analysis
Biomass carrying capacity	k_B	70tons/ha/year	Finlayson and Moser, 1991 cited in Turpie *et al*.1999
Constant for the CPI effect on social grant rate	k_0	-48.35	Social grant rate-consumer price index regression analysis
Coefficient of rainfall in cultivated wetland area regression	a_1	-0.042	Multiple regression estimates of wetland cultivated area and rainfall, grain price, agricultural input price and population
Coefficient of grain price in cultivated wetland area regression	a_2	0.021	Multiple regression estimates of wetland cultivated area and rainfall, grain price, agricultural input price and population
Coefficient of the price of agricultural input (seed maize) in the cultivated wetland area regression	a_3	-0.041	Multiple regression estimates of wetland cultivated area and rainfall, grain price, agricultural input price and population
Coefficient of the population in the cultivated wetland area regression	a_4	0.032	Multiple regression estimates of wetland cultivated area and rainfall, grain price, agricultural input price and population
Proportion of working adults (aged 15-64years) in the population	κ_1	0.5	Statistics South Africa (2004)
Proportion of children (aged 4-15years) in the population	κ_2	0.3	Statistics South Africa (2004)
Total labour supplied per adult per year (hours)	m_1	1600	Stephenne and Lambin (2001)
Total labour supplied per child per year (hours)	m_2	400	Stephenne and Lambin (2001); adjusted to take into account the fact that most of children go to school
Intrinsic growth rate for wetland biomass	s_0	0.3	Thenya (2006)
Coefficient for biomass stock in the regression for the number of biomass harvesters	c	0.0042	Regression analysis of the number of biomass harvested and natural wetland area historical time series data
Field capacity of the soil	WHC	140mm/m	Saxton and Rawls (2006)
Area under irrigation	AC^r	170ha	Chiron (2005)
Total number of households under irrigation	Q_r	283 households	Computed by dividing the area under irrigation (from Chiron, 2005) by the irrigated area per household, which is 0.6 ha per household (from household survey data)
Cultivated wetland area per household	wc_0	0.66	Household survey
Proportion of households that obtain social grants	n_0	0.64	Household survey
Coefficient of the effect of the groundwater level on wetland biomass growth rate	μ_1	0.0001	Estimate based on the reeds yield-water depth correlations by Tarr *et al*. (2004)
Average household size	hs_0	7.3 people	Household survey
Actual evapotranspiration from natural wetland vegetation per year	η	1100mm/ha/year	Dye *et al*. (2008); Von der Heyden and New (2003); Kleynhans (2004).
Precipitation	P_t	500mm/year	McCartney (2005)
Maximum grain yield in wetland	Y_m^w	3tons/ha	Chiron (2005)

Table 6.4 (Continued): Parameter values and sources

Parameter label	Symbol	Value	Source
Maximum grain yield in irrigation	Y_m^w	2.5 tons/ha	Chiron (2005)
Maximum crop evapotranspiration per season	ET_m	490mm/year	Durand (2008)
Wage rate	W_t	R8/hour	Adekola (2007)
Price of grain	$P_{G,t}$	R1.58/kg	Household survey
Price of wetland biomass	$P_{H,t}$	R2/kg	Adekola (2007)
Price of agricultural inputs	$P_{Y,t}$	R5.29/kg	Household survey
Price of water	$P_{W,t}$	R0.13/mm	Department of Water Affairs
Price of market goods	$P_{M,t}$	R345	Household survey
Consumer Price Index	CPI_t	138	SARB (2009)
GDP per capita	$GDP_{k,t}$	R34234/capita/annum	SARB (2009)

In system dynamic modelling, the ultimate objective of the validation process is to establish the structural validity of the model with respect to the modelling purpose. Confidence in the model simulation results is high only if the model has robust predictive ability in reproducing historical trends. Dynamic simulation models are validated by comparing model predicted versus observed past trends for selected variables. However, the validity tests should place emphasis on pattern prediction of key variables rather than point predictions, mainly because of the long-term orientation of these models (Güneralp and Barlas, 2003). Because of the limited availability of observed time series data for most of the variables in the model, the validation exercise was done for a few variables for which past trend data could be obtained. The period used for the validation is 1990 to 2006. After validation the model will be used to conduct policy simulations for a 14-year post validation period, (i.e. 2006 to 2020).

Figures 6.3 and 6.4 compare the observed versus the model predicted values for the wetland area converted to agriculture and social grant rates, respectively. Figure 6.3 shows that the wetland area converted to agriculture has been increasing with a corresponding decrease in the wetland area. This has been primarily driven by the increasing frequency of droughts, which increases wetland conversion rates due to its fertile soils and ability to retain soil moisture.

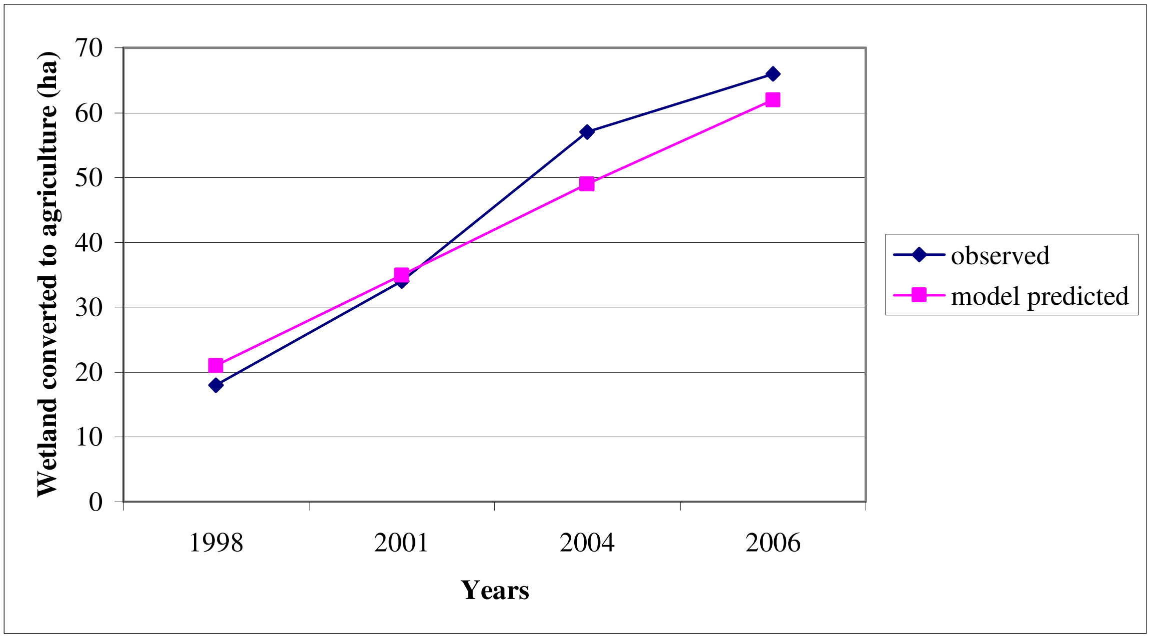


Figure 6.3: Comparison of model predicted and actual wetland area converted to agriculture (Observed data obtained from: Sarron, 2005; Adekola, 2007)

The predicted social grant rate follows an increasing trend in line with the observed trend due to an increase in inflation (Figure 6.4). Whilst the model predicted values are not exactly equal to the observed values in both cases, the model does well in predicting the observed pattern of these two variables. The correlation between the model predicted and the observed values is more than 0.9 in both cases, suggesting that the model can be used with confidence.

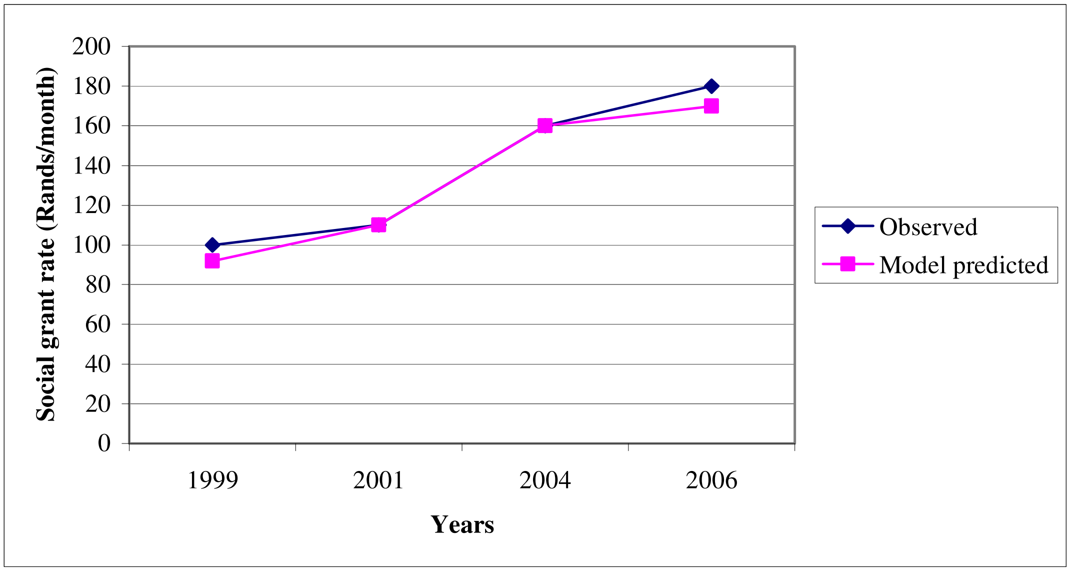


Figure 6.4: Comparison of model predicted versus actual social grant rate (Observed data obtained from: National Treasury, 2008)

Clearly it would be possible to establish a much stronger case if more numerical time series data were available for more variables in the model. Lack of past trend data on most variables severely restricted the study's validation options and collecting new dynamic data necessitates long time periods. However, it should be kept in mind that the main purpose of this model is to capture broad dynamic behaviour patterns of the real system, not provide point predictions.

6.6 Simulation of impacts of alternative wetland management and policy regimes

The first step in performing a simulation experiment is to run the baseline scenario, which becomes the benchmark against which simulated scenarios are compared. Scenario simulations are performed by changing values of exogenous variables in the model and comparing the outcomes with the base scenario. Policy scenarios considered for simulations are selected on the basis of possible government policy interventions. The policy scenarios simulated include: tax and subsidy policy regimes that work through changing effective prices of agricultural outputs, inputs, and market goods; as well as government policy instruments such as direct income transfers and changes in availability of off-farm work which are driven by changes in social policy and economic growth trends.

In order to maintain a functional wetland ecosystem in which biodiversity protection is maximal it is necessary to put part of the wetland area under protection. However, total protection is not always necessary in order to maintain high levels of diversity, but would be necessary if the goal is to maintain an ecosystem intact in its natural state, which in most cases is done for promoting ecotourism. In this study's simulation experiments the author considered a scenario of partial protection through placing some percentage of the wetland under conservation.

Although climate change predictions for precipitation are less consistent, most simulations for southern Africa indicate that rainfall will decline in the next 100 years. Predictions for 2050 show that rainfall in southern Africa could be 10% to 20% lower than the 1950 to 2000 averages (IPCC, 2001). Based on these predictions, a scenario of a 10% reduction in annual precipitation is considered in the simulation experiments.

To evaluate the social desirability of simulated intervention scenarios, final outcome values are compared (values at the end of the simulation period, which is the year 2020) for selected indicators with the baseline scenario as done in other studies (Eppink *et al*., 2004; Saysel *et al*. 2002). As the primary purpose of this study is to investigate the impacts of alternative policy regimes on wetland functioning, ecosystem services and human well-being, the key variables considered in the evaluations are: (1) wetland crop (grain) production and harvested biomass and their values (the two wetland services considered in the model); (2) the total wetland area and the total biomass stock (indicators of wetland conservation status), (3) wetland soil water content and groundwater level (indicators of wetland hydrological regulation services) and (4) net income per capita (a proxy for human well-being). The specific policy scenarios evaluated and results of the simulation experiments are given in Table 6.5.

Table 6.5: Changes in value of selected indicator variables, expressed as percentages of baseline values

Percentage change in indicator variables compared to their baseline levels									
Policy scenarios	Total biomass harvested (tons)	Total biomass stock (tons)	Total wetland grain supply (tons)	Wetland ground water level (m)	Soil water content (mm)	Net value of wetland grain (Rands)	Net value of harvested biomass (Rands)	Total wetland area (ha)	Net income per capita (Rands/capita/year)
(1) Taxing grain production (30% on price)	0.11	0.04	-0.01	0.26	0.01	-10.06	4.29	0.43	-0.21
(2) Taxing biomass products (30% on price)	-0.11	0.06	0.01	-0.01	-0.01	0.04	-17.79	-0.12	0.02
(3) Combined tax on grain and biomass (30% each)	-0.85	0.15	-0.01	0.45	0.07	-10.07	-10.15	0.46	-0.23
(4) 30% increase in agricultural input prices[a]	0.12	0.14	-0.21	1.76	5.1	-0.19	3.6	1.15	-0.28
(5) 30% increase in the off-farm wage rate	-0.55	0.01	-0.01	0.04	0.01	-39.58	-26.65	0.14	6.59
(6) Increased availability of off-farm opportunities (5% increase in GDP per capita)	0.10	0.29	-0.81	0.27	1.42	-0.01	0.03	2.72	6.40
(7) Putting 30% of wetland area under protection	-0.22	38.63	-22.45	0.06	43.77	-22.45	-0.45	92.98	-0.46
(8) 10% reduction in precipitation	-0.89	-33.01	1.60	-0.91	-13.6	-4.10	-2.24	-76.58	-0.13

[a]Price of maize seed is used as this is the key variable input used in wetland grain production.

A total of eight policy experiments have been simulated. Simulation results show that taxing wetland conversion to agriculture through reduced grain output prices (scenario 1) weakens the incentive for expanding the cultivated area in the wetland, leading to decreases in wetland crop production. This leads to an increase in the total wetland area and thus lowers evapotranspiration from cultivated land (crop water use), reducing the total evapotranspiration from the system. As a result, soil water content in the wetland increases lifting the wetland groundwater level as the recharge to groundwater is increased. In response, the actual growth rate of wetland biomass increases (equation 6.13) causing an increase in wetland biomass per hectare (equation 6.11).

The total biomass stock is consequently higher due to increases in the actual growth rate of biomass and total wetland area, and the number of biomass harvesters increases as a result. The net income per capita decreases due to the substantial reduction in the net value of grain production, which by far exceeds the increase in net value of biomass harvested. In a nutshell, taxing grain output production discourages wetland conversion to agriculture, which negatively impacts human well-being to the advantage of maintaining wetland ecological integrity.

Taxing the excessive harvesting of biomass products (scenario 2) through lowering the product prices, reduces the total biomass harvested and increase biomass stock. The wetland grain supply increases (equation 4.1) causing an increase in crop water use (ET_a) with consequent reductions in soil water content and wetland groundwater level. Although the reduction in the groundwater level reduces the natural wetland biomass growth (equation 6.13), the total biomass stock increases due to a reduction in the total of harvested biomass. The net value of harvested biomass decreases substantially due to a reduction in the total of harvested biomass. On the one hand, the incentive for grain production improves leading to a higher conversion of wetland area for agriculture, which in turn causes the net income per capita to increase. On the other hand, the result of this tax scenario also shows that increasing the price of harvested biomass increases returns to biomass products relative to that of wetland grain and therefore reduces conversion of wetland to agriculture.

These results demonstrate the trade-offs that need to be managed between improving human well-being in the short-run and conserving the wetland ecosystem (long-term sustainability goals), and between supply of the two wetland services (crop production and biomass harvesting) competing for water, labour and land resources.

A combined tax on both grain and biomass products (scenario 3) is found to be more effective in conserving the wetland and maintaining hydrological integrity than levying separate taxes on biomass and grain production. This of course comes at a higher welfare cost.

An alternative way of taxing wetland conversion is through increasing agricultural input prices (scenario 4), which has similar but stronger effects compared to increasing grain prices. It increases agricultural production costs and reduces returns to agricultural production and therefore reduces the rate of conversion of the wetland area to cultivated agriculture. As can be seen from Table 6.5, a much higher growth in total wetland area is obtained under the input price policy interventions than with the grain price tax policy (scenario 1). Also a much larger impact on water levels and wetland hydrology are realised. This, however, comes at a higher loss in the economic welfare measured in net income per capita. The above results suggest that, while policy interventions such as agricultural prices, support policies (e.g. subsidies) have the potential to improve the welfare of poor rural farmers they can also lead to agricultural intensification and environmental degradation.

Like taxing prices of other inputs, intervention through the urban wage rate policy instrument (scenario 5) reduces wetland grain supply (equation 4.1) and its value. Improving off-farm wages, however, results in substantial decreases in production and the net value of harvested biomass since labour is the main input in biomass harvesting and hence the high sensitivity to movements in wages. Despite this, the net income per capita increases due to a substantial increase in the off-farm income (equation 6.25) component of total net income (equation 6.29). At the same time the wage rate option achieves conservation objectives, but at lower levels compared to commodity price (tax/subsidy) regimes. This makes clear the importance of understanding the important distinctions carefully weighing the potential net impacts of alternative policy intervention choices and instruments.

The wetland area and net income per capita grow with the highest percentage through an increase in off-farm income opportunities (scenario 6). This result derives from the fact that an increase in off-farm income opportunities (through increasing GDP per capita) causes an increase in the emigration rate (equation 6.21). This leads to a reduction in the population, which in turn reduces the rate of wetland conversion to agriculture as demands for land and food is reduced. Accordingly, wetland grain supply and the net value of grain decline. Income from off-farm employment opportunities increases as the number of households engaged in off-farm work increases. The increase in off-farm income totally offsets reductions in net value of harvested biomass and grain resulting in a significant increase in net income per capita. Like improved off-farm wages, this scenario has a double dividend effect as it simultaneously improves economic well-being and conserves the wetland ecosystem.

This result demonstrates the potential for indirect economic incentive measures such as improving off-farm employment and income opportunities to contribute towards improving both human well-being and wetland conservation. However, as demonstrated by Brandon and Wells (1992) and Ferraro and Kramer (1997) such measures do not automatically lead to sustainable resource management and in some cases the availability of alternative income sources leads to the intensification of resource use activities. For alternative livelihood and income sources to spur conservation of wetland resources, it is important to emphasise the overall economic development in the area to increase the availability of off-farm employment opportunities outside of the natural resources or agriculture-based economy. Promoting livelihood diversification out of agriculture becomes an important strategy for enhancing sustainable wetland management.

The results of the wetland conservation strategy (scenario 7) show that the economic well-being of the local population declines considerably due to substantial reductions in the value of biomass harvested and grain produced in the wetland, as harvesting of natural products and the conversion of the wetland to cropland are restricted. However, the reduction in the economic welfare to the local community only takes into account direct use benefits of the wetland without considering its non-use values and indirect benefits of maintaining biodiversity intactness and hydrological regulation services.

The predicted reduction in precipitation (scenario 8) produces by far the worst results in terms of conserving the wetland. The wetland area declines by close to 90% due to an increased rate of conversion of the wetland to cultivation and total cultivated wetland area as rainfall declines (equations 6.10a and 6.10b). The rate of wetland conversion to cultivation increases as more households move into the wetland due to its ability to retain soil moisture throughout the year. As a consequence, the total area of wetland under cultivation expands and, accordingly, the total wetland area declines.

A reduction in precipitation adversely affects wetland soil moisture content and the groundwater level, which in conjunction with the recession of the total wetland area leads to a reduction in total biomass.

6.7 Concluding Summary

This chapter developed and applied a dynamic ecological-economic model to analyse the linkages between the economic and ecological elements in the wetland system under study. The model was used to analyse the impacts of various policy and management regimes on wetland functioning and economic well-being.

The model showed that economic and ecological systems are intricately linked with important feedback effects. Changes in the socio-economic system influence wetland ecosystem processes while changes in ecosystem processes influences the economic system through provision of services, which influence economic well-being.

The results of the policy simulations suggest that wetland ecosystem services (crop production and natural resource harvesting) are interlinked with subtle trade-offs involved through their competition for labour, water and land resources. Some policy interventions such as improving profitability of cultivation through supporting agricultural output prices and/or subsidizing input prices may improve economic well-being, but at the expense of wetland conservation.

Results also suggest that increasing off-farm income and employment opportunities has a double dividend effect, because it simultaneously improves economic well-being and enhances wetland conservation. Therefore, promoting livelihood diversification out of agriculture becomes an important strategy for enhancing sustainable wetland management.

A pure conservation strategy that aims at protecting the wetland leads to substantial reductions in economic welfare of the local population unless their livelihood sources are diversified into alternative non-farm employment and income options. This study also confirms that the predicted reduction in rainfall in southern Africa is likely to accelerate wetland conversion to agriculture and undermine wetland conservation efforts.

CHAPTER 7

SUMMARY, CONCLUSIONS AND IMPLICATIONS FOR POLICY AND RESEARCH

7.1 Introduction

This chapter summarises the key findings of this study and draw conclusions and policy insights from the research results. The first section of the chapter summarises the main findings of the study and draws policy implications. The section that follows articulates the limitations of the study and suggests possible areas for further research.

7.2 Summary of key findings and policy implications

This study developed an empirical model to analyse the determinants of rural household labour allocation and supply decisions for competing livelihood activities including the production of agricultural and wetland products. The study also developed a dynamic ecological-economic model based on the system dynamics framework and applied it to evaluate the trade-offs between provisions of various components of a bundle of multiple wetland services through simulation of the impacts of alternative management and policy regimes on wetland functioning, the services they provide and economic well-being. This aspect is largely ignored in the literature on wetlands in Africa. Most studies on wetlands in Africa have dwelled much on static economic valuation approaches aimed at valuing the contribution of wetland services to human welfare at a given time and do not consider the intertemporal nature of the interaction between ecological and economic systems. The results of the study are useful for designing effective policies to enhance sustainable management of wetland resources in developing countries.

Results of the study showed that improved household education level enhances diversification into off-farm work. The policy implication of this result is that the government needs to promote investments in education and skills development for the rural population to enhance diversification of their livelihoods out of agriculture and reduce pressure on wetlands.

The results also indicate that household exogenous income and wealth status (asset endowment) enhance farm production and reduce dependence on harvesting wetland products for livelihood. This result implies that government should pursue policy measures that reduce rural household liquidity constraints and enhance investment in productive assets (e.g. improving rural household access to credit and off-farm income opportunities) to boost farm production and provide positive incentives for the rural population to conserve wetlands.

Findings also suggest that asset-poor households with limited non-farm incomes, most of whom are female-headed, rely heavily on wetland products for their livelihood. This finding is consistent with the hypothesis that poorer households are more reliant on local environmental resources than wealthy households are. This also suggests that wetlands play an important role as livelihood safety nets for rural poor households by reducing their vulnerability to shocks such as droughts and other income shocks.

Two main policy implications can be drawn from this result. The first one is that the government, policy-makers and natural resource managers need to acknowledge the livelihood safety net role wetlands play in rural livelihoods and recognise that environmental protection policies limiting or banning access and use of wetland resources can deepen rural poverty, as the poor suffer more from the deprivation of these resources. Therefore, instead of adopting strict wetland protection policies, there is need to invest in the development and promotion of use of sustainable wetland management practices (in particular crop, livestock and natural products management practices) that allow the poor to utilise wetlands to enhance their economic well-being with minimum adverse effects on the wetland ecological condition. The second policy implication that can also be drawn from this result is the importance of the provision of safety nets for the poor through the promotion of government programmes and policies that support diversification into off-farm livelihood and income sources to provide positive incentives for wetland conservation and sustainable use. This suggests that sustainable wetland management has to be integrated within the broader rural development programmes aimed at reducing poverty in order to provide the necessary incentives for the poor to adopt sustainable wetland management options.

The dynamic ecological-economic model developed in this study demonstrated the importance of considering feedback effects between ecological and economic systems. Due to its modularity, the model developed in this study can easily be adapted to similar small-scale wetlands in southern Africa.

Policy scenario simulations using the model showed that policy interventions such as improving the profitability of cultivation through supporting agricultural output prices and/or subsidising input prices may improve economic well-being, but at the expense of wetland conservation.

Simulation results also suggest that increasing off-farm income opportunities has a double dividend effect because it simultaneously improves economic well-being and enhances wetland conservation. Therefore, promoting livelihood diversification out of agriculture becomes an important strategy for enhancing sustainable wetland management as also suggested earlier. Livelihood diversification can be supported through increased government investment in rural infrastructure, downstream value chains, health and education.

The simulation results further suggest that increasing returns to the collection of wetland natural products reduces wetland conversion. This implies that the development of a competitive marketing system for harvested biomass products, which increases returns to wetland biomass products relative to that of wetland grain, has the potential to reduce the conversion of wetlands to agriculture, which poses a major threat to the ecological integrity of the wetland than the harvesting of natural products.

The results also showed that a pure conservation strategy that aims at protecting the wetland leads to substantial loss in the economic welfare of the local population unless their livelihood sources are diversified into alternative non-farm employment and income options. This again emphasises the need to diversify the livelihood options for rural populations and also identify and promote local level sustainable wetland management strategies rather than putting wetlands under strict protection.

This study also confirms that the predicted reduction in annual rainfall in southern Africa is likely to accelerate wetland conversion to agriculture and undermine wetland conservation efforts. The implication of this result is that improving the capacity of rural farmers to adapt to climate change, especially droughts, is important to reduce pressure on wetland resources. Strategies that reduce the dependence on wetlands for agriculture should be promoted, such as: investments in water harvesting and storage; efficient irrigation methods; and promoting the use of drought tolerant crops and diversifying out of agriculture.

7.3 Limitations of the study and areas for further research

The agricultural household model presented in this study does not consider risk and uncertainty, which is a common feature in the environment under which rural households make decisions. Therefore, a possible extension of the present study is the development of a household model based on expected utility theory taking into account risk and uncertainty. In addition, the agricultural household model can also be improved by including institutional (property rights) and social factors that influence access and use of wetland resources.

Although the dynamic ecological-economic model that was developed generated useful results and policy insights for wetland management it has a number of limitations, which could be the basis for further research. The main challenges in the development of the model were the limited availability of data to validate the model and insufficient understanding of several feedback mechanisms in the modelled system. Possible improvements in the model include:

- including groundwater flow from hillslope to wetland, which is a key component of the hydrology of the wetland and artificial drainage activities which affect groundwater levels;
- modelling the hydrological processes at a monthly or seasonal time step instead of an annual time step to capture the seasonal variations of wetland water;

- adding a module sector on wetland soil organic matter, which is linked to wetland soil moisture; and
- including feedbacks from well-being to population dynamics and also capture the feedbacks of emigration on total net income through remittances.

As some of the components of the wetland hydrology were not included in the model due to data limitations the results of the hydrological effects of the simulated scenarios have to be considered with caution. There is also scope to extend the model by going beyond the two wetland services considered in this study (crop production and biomass harvesting) and include other provisioning and regulating services provided by the wetland.

Because of the limitations imposed by the structure of the ecological-economic model, it was not possible to consider some important wetland management strategies in the simulation analysis. In light of the evidence shown by the given results that wetlands are a key resource for the livelihood of the poor especially in managing the effects of climate variability on agriculture, it is important to identify local level sustainable wetland management practices that farmers can use with minimum effects on wetland ecosystem conditions. Therefore, instead of focusing on external drivers and macro policies, there is need to improve the ecological-economic model presented here and expand the simulation analysis to include local level wetland management scenarios. The scenarios would then include alternative wetland crop and livestock management practices, which enables the identification of management practices that the rural people can use to enhance their economic well-being with minimum impacts on wetland ecological conditions.

The ecological-economic model can also be further improved by integrating social and institutional aspects with the presently modelled environmental and economic systems. Last but not least, future research can also consider the spatial aspects into the dynamic analysis presented here by looking at the ecological and economic effects of the alternative management regimes beyond the local level, to be able to understand the full consequences (off-site effects) of these regimes at a broader scale.

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APPENDICES

Appendix A1: First order conditions for the household optimisation model

$$\partial\ell/\partial L_H = \lambda_1 \, \partial X_H^H/\partial L_H - \lambda_5 = 0 \quad \text{(A1.1)}$$

$$\partial\ell/\partial L_G = \lambda_2 \, \partial G_q/\partial L_G - \lambda_5 = 0 \quad \text{(A1.2)}$$

$$\partial\ell/\partial L_V = \lambda_3 \, \partial V_N/\partial L_V - \lambda_5 = 0 \quad \text{(A1.3)}$$

$$\partial\ell/\partial L_o = \lambda_4 W_o - \lambda_5 = 0 \quad \text{(A1.4)}$$

$$\partial\ell/\partial Y_G = \lambda_2 \, \partial G_q/\partial Y_G - \lambda_4 P_Y = 0 \quad \text{(A1.5)}$$

$$\partial\ell/\partial N = \lambda_3 \, \partial V_N/\partial N - \lambda_4 P_N = 0 \quad \text{(A1.6)}$$

$$\partial\ell/\partial X_M = \partial U/\partial X_M - \lambda_4 P_M = 0 \quad \text{(A1.7)}$$

$$\partial\ell/\partial X_H^H = \partial U/\partial X_H \, \partial X_H/\partial X_H^H - \lambda_1 = 0 \quad \text{(A1.8)}$$

$$\partial\ell/\partial X_H^S = \partial U/\partial X_H \, \partial X_H/\partial X_H^S + \lambda_4 P_H = 0 \quad \text{(A1.9)}$$

$$\partial\ell/\partial X_H^P = \partial U/\partial X_H \, \partial X_H/\partial X_H^P - \lambda_4 P_H = 0 \quad \text{(A1.10)}$$

$$\partial\ell/\partial G_q = \partial U/\partial X_G \, \partial X_G/\partial G_q - \lambda_2 = 0 \quad \text{(A1.11)}$$

$$\partial\ell/\partial V_N = \partial U/\partial X_N \, \partial X_N/\partial V_N - \lambda_3 = 0 \quad \text{(A1.12)}$$

$$\partial\ell/\partial G_q^P = \partial U/\partial X_G \, \partial X_G/\partial G_q^P - \lambda_4 P_G = 0 \quad \text{(A1.13)}$$

$$\partial\ell/\partial G_q^S = \partial U/\partial X_G \, \partial X_G/\partial G_q^S + \lambda_4 P_G = 0 \quad \text{(A1.14)}$$

$$\partial\ell/\partial V_N^P = \partial U/\partial X_N \, \partial X_N/\partial V_N^P - \lambda_4 P_V = 0 \quad \text{(A1.15)}$$

$$\partial\ell/\partial V_N^S = \partial U/\partial X_N \, \partial X_N/\partial V_N^S + \lambda_4 P_V = 0 \quad \text{(A1.16)}$$

$$\partial\ell/\partial \lambda_1 = X_H^H(L_H, \beta; \Omega) - X_H^H = 0 \quad \text{(A1.17)}$$

$$\partial\ell/\partial \lambda_2 = G_q(L_G, K_G, Y_G, \alpha) - G_q = 0 \quad \text{(A1.18)}$$

$$\partial \ell / \partial \lambda_3 = V_N(L_V, N, \theta) - V_N = 0 \tag{A1.19}$$

$$\partial \ell / \partial \lambda_4 = P_H X_H^S + P_G G_q^S + P_V V_N^S + L_o W_o + E - P_M X_M - P_H X_H^P - P_G G_q^p - P_V V_N^P - P_Y Y_G - P_N N = 0 \tag{A1.20}$$

$$\partial \ell / \partial \lambda_5 = L_T - L_H - L_o - L_G - L_V - L_Z \tag{A1.21}$$

Appendix A2: Logical rules for hydrological dynamics in the modelled wetland

Capillarity (CR_t): Based on knowledge and reasonable assumptions by hydrologists working in the studied wetland, it is assumed that capillary rise only occurs when the groundwater level is less than 1m below ground level (ge = 719m) and capillarity is estimated at 30mm/month. Therefore the equation for capillarity is as follows:

$$CR_t = \text{If } (GWL_t \succ \text{ge} - 1) \text{ then } (1*30*12) \text{ else } 0 \qquad \text{(A2.1)}$$

Groundwater seepage (GS_t): Groundwater seepage is assumed to occur only if the wetland groundwater level is higher than the water level in the river and is modelled as follows:

$$GS_t = \text{If } (GWL_t \prec 718.5) \text{ then } (0) \text{ else } (2*2.5*30(((GWL_t - 710)\text{^}2 - (Rs - 710)\text{^}2)))/400 \qquad \text{(A2.2)}$$

Recharge from irrigation (IS): It is assumed that diverted irrigation water (DW) depends on the geometry of the diversion canal. According to Chiron (2005) the diverted irrigation water is estimated at 0.13 cubic metres per second, which we convert to cubic metres per year. As 94% of the diverted irrigation water is assumed to recharge the wetland, IS is modelled as:

$$IS_t = 0.94 * DW/(120*10) \qquad \text{(A2.3)}$$

DW=diverted irrigation water (in cubic metres per year) = (0.13*3600*24*30)*12

Appendix A3: Wetlands-based livelihoods agronomic and socio-economic household questionnaire

Interview No: ____

Name of Respondent ____

Name of Village: ____

Village Head ____

Ward ____

Date: ____

Name of interviewer**:** ____

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Section A: GENERAL [20]HOUSEHOLD INFORMATION (Human Assets)

A1 Please state the relationship of the respondent to the head of the household: ___
KEY 1 1.Head of household; 2.Wife; 3.Child; 4. Grandchild; 5.Parents; 6.Siblings; 7.Farm laborer; 8.Other members (includes household helpers)

A2 Household size:________________
A3 Can you please give the following information for all the household members starting with the household head

	Gender	Age	Relation to household head	Marital status	Number of years in education	Professional qualification/ training	Occupation/ activity	Residential status 1-stays home permanently 2-stays away permanently 3. stays home and away	Reason why member is not staying within the household
1									
2									
3									
4									
5									
6									
7									
8									
9									
10									
11									
12									
	Key 1.Male *2.Female*	In years	use key 1 above	1: Married or living together 2: Never married 3: Previously married (divorced, separated, widowed 4: Not applicable (child < 16 years)		1.none 2. farming 3.carpentry 4.brickmaking 5.knitting and sewing 6.teacher 7. other (specify)	1. Permanently employed 2. Not permanently employed 3. Self employed 4. Full-time farmer 5. Farm laborer 6. Unemployed 7.student 8.Other (specify)		*1.Married* *2. Working in farm, town or city* *3. Working abroad* *4. other*

[20]A **household** is defined as all the persons registered on the same residential site. Children (even when older then 18) not staying at home anymore, but being registered at their parents address should be considered.

Section B: Physical and Natural Asset Ownership and Access

B1. Productive assets

List productive assets that you have   No productive asset ☐

Type of productive asset Use key 2	Number owned and working	How was it acquired? 1. Purchased 2.donated 3.inherited 4. other (specify)	When was it acquired? (year of acquisition)

Key 2: 1.Hand hoes, 2.Shovel, 3.Plough, 4.Harrow, 5.Wheelbarrow 6.Sledge 7.Trailer/cart 8.Tractor 9.car, truck, lorry 10. Water storage 11. Fishing equipment 12.irrigation equipment 13 other (specify)

B2. Domestic assets

List domestic assets that you own

Type of domestic asset Use key 3	Number owned and working	How was it acquired? 1. purchased 2.donated 3.inherited 4. other (specify)	When was it acquired? (year of acquisition)

Key 3: 1.Motorcycle 2.Bicycle 3.Radio 4.Television 5.Telephone 6.Sewing machine 7.Stove 8.Solar power 9.Fridge 10.Other (specify)

B3. Housing

What type of housing do you have?

☐ Mud bricks and iron roofed
☐ Mud bricks and grass thatched
☐ Mud bricks asbestos roofed
☐ Pole and dagga and grass thatched

☐ Cement bricks, iron roofed

How many rooms do you have in your homestead?_____________

B4. Sanitation

What type of toilet do you have at your homestead?

1. No toilet 2. Pit latrine 3.ventilated pit latrine/blair toilet 4.flush toilet with septic tank

5. Water use

Which source of water do you use for the following activities during each season ?

i) Dry season:

Water for	Source (use key 4)	Location 1.homestead 2.dryland 3. wetland 4. downstream	Distance from homestead (in metres)	Water use on the spot at home elsewhere diverted
Drinking				
Cooking				
Washing clothes				
Bathing				
Sanitary use or ablutions				
Washing household utensils				
Building purposes				
Watering of small livestock(eg rabbits, poultry)				
Watering of large livestock				
Watering gardens				
Other specify				

Key 4 1.private tap within homestead or yard 2.neighbors tap 3. communal tap 4. borehole 5.spring 6.dam 7.well/pond/stagnant water 8.river/stream 9. other

(ii) Wet season

Water for	Source (use key 4)	Location 1.homestead 2.dryland 3. wetland 4. downstream	Distance from homestead (in metres)	Water use on the spot at home 3.elsewhere 4.diverted
Drinking				
Cooking				
Washing clothes				
Bathing				
Sanitary use or ablutions				
Washing household utensils				
Building purposes				
Watering of small livestock (eg rabbits, poultry)				
Watering of large livestock				
Watering gardens				
Other specify				

How do you perceive the quality of water that you use for drinking and cooking? (ask the question for each source used for drinking and cooking)?

Very safe ☐ moderately safe ☐ not safe ☐

If not safe, why do you think it is not safe? Smell ☐ Colour ☐ Upstream pollution ☐ Unsafe use of the source ☐ Lack of protection ☐ Other (specify)________________________________

Do you treat the water (e.g. for drinking, or for other uses?) in any way? How?
Filtering through cloth ☐ Chloride ☐ Sand filter ☐ Boiling ☐ Other (specify)_______________________

4. Do you experience any disease, which you think is related to the poor quality of water? Yes ☐ No ☐

If yes, list the diseases____
____
_

Who is affected in the family?__ Children under 5years ☐ School going children (between 5 and 15years of age) ☐ Adult females (>18years) ☐ Adult males (>18years) ☐ Everyone in the family ☐

How often did this happen during the last month? 6 months? Year?

How many days is the affected person (and family members) absent from income generating activities due to the illness in the past month?_____________6months?___________year?____________________

Do you use any protective measures against malaria or diarrhoea? Yes ☐ No ☐

If yes, what protective measures do you use?_______________________________________
____
____

How many plots do you us… …ock production), their location, area, uses e.tc for the table below)

If yes specify

Location of plot 1. homestead 2. wetland 3. dryland 4. irrigation scheme 5. other	Number of plots	Total area (in acres and hectares)	What are the plots used for? (Key 5)	Mode of acquisition (Key 6)	Who in the household has access to this land?(use Key 1)

Key 5.Plots used as 1.Arable land 2.Grazing land 3.Garden 4.other
Key 6. Mode of acquisition 1. Purchase 2. Resettled under Government program 3. Inherited land 4. Land for all community members 5.other

Section C: Use of Wetland Resources

C1. Wetland goods collection
Did you collect some plant materials or catch some animals in the wetland during the past cropping season?

Type of material	Yes	No	If yes specify which plants or animals (or for which use in case of water)	If yes, was it for own consumption?		Was it for selling?	
				Yes	No	Yes	No
1. Domestic fire wood							
2. Edible plants							
3. Building material							
4. Medicinal plants							
5. Craft material							
6. Fish							
7. Animals							
8. Water							
9. Other							

How did you get permission to undertake these activities?

____
____
____________Did you notice any changes in the availability of wetland resources in the last 5 years?

Yes ☐ No ☐

If yes, for which resources?

Resources	Changes in supply of resource?		Changes in time spent on collection?	
	Increase	Decrease	Increase	Decrease
1. Domestic fire wood				
2. Edible plants (wild) specify which plant______________				
3. Building material				
4. Medicinal plants				
5. Craft material				
6. Fish				
7. Game				
8. Water				
9.Other				

[indicate with one, two or three stars * the importance of the change]

C3. Conflict about wetland use

Are there any conflicts or tensions about wetland use during the last 5 years?

Yes ☐ No ☐

If yes, elaborate (Who was involved? What was the reason of the conflict? Which resources are concerned?)

____
____
____

Have some of these conflict/tensions been resolved?

Yes ☐ No ☐

If yes, elaborate (Who was involved? What was the reason of the conflict? Which resources are concerned? How was it resolved?)____

Are you satisfied with the way the conflict was resolved?

If not satisfied, how best do you think this could have been resolved?

Section D: Livestock production

Do you keep any livestock in your farm? Yes ☐ No ☐

If yes, answer the following questions

D1. Livestock products

Living animals

Livestock categories	How many at the beginning of the last cropping season	How many born?	How many dead?	How many purchased?	How many sold?	How many used for own consumption?	How many exchanged? (+/-)	How many at the end of the last cropping season?
Cattle								
Donkeys								
Sheep								
Goats								
Poultry								
Rabbits								
Pigs								

Milk production

Do you produce milk? Yes ☐ No ☐

If yes, how many cows or goats that produce milk do you have at present?
Cows_______________Goats______________________

How much milk do they produce per day at present?
Cows_______________Goats______________________

Does the number of cows or goats producing milk vary over the year?
Cows Yes ☐ No ☐ Goats Yes ☐ No ☐

If yes fill the table below

	Oct	Nov	Dec	Jan	Feb	March	April	May	June	July	Aug	Sept
Cows												
Goats												

Does the quantity of milk per cow or goat vary over the year?
Cows Yes ☐ No ☐ Goats Yes ☐ No ☐

If yes indicate in the table below the quantity produced per cow or goat
(specify unit____________)

	Oct	Nov	Dec	Jan	Feb	March	April	May	June	July	Aug	Sept
Cows												
Goats												

What are the causes of the variation?

Which quantity of milk do you use each day for household consumption?
___________Unit_____

Is the production enough all over the year to cover your needs? Yes ☐ No ☐

If not, when do you experience shortages?

Oct	Nov	Dec	Jan	Feb	March	April	May	June	July	Aug	Sept

How do you cope with milk shortages?
Reduce or suppress milk consumption ☐
Buy milk from other farmers ☐ quantity bought__________price_________
Buy milk from shop ☐ quantity bought__________price_________
Other ☐ specify_______________________________

Draught power

Do you use some of your livestock for plowing or transport? Yes ☐ No ☐

If yes, how many animals and of which type do you use for this?

Type of animals	Number	Use 1.Plowing 2.transport 3. Other (specify)
Cows		
Oxen		
Donkeys		

How many days did you use them the last cropping season for your own needs and what area did you plough with your own animals?

Type of animals	Days used for transport	Plowing	
		days	area
Cows			
Oxen			
Donkeys			

(Specify unit________)

Do you rent or lend your animal for plowing or transport? Yes ☐ No ☐

If yes specify how many days in the last cropping season and the area plowed?

Type of animals	Days used for transport	Plowing	
		days	area
Cows			
Oxen			
Donkeys			

What did you receive in exchange?
Cash ☐ How much for one day?________________
Labour ☐ How many man-days for one day of work?
other ☐ specify

Manure production

Do you collect the manure produced by your animals for fertilizing your plots?
Yes ☐ No ☐

If yes, from which animals a … e, collect manure produced at night in the kraal)

- ☐ Cattle
- ☐ Goats/sheep
- ☐ Donkeys
- ☐ Pigs
- ☐ Poultry

How many carts (or other mean of measure) of manure did you collect the last cropping season?____

On which crop and what area did you apply the manure?

Do you exchange or give away manure to your relatives or neighbors? Yes ☐ No ☐

If yes, how many carts during the last cropping season?_________________________

What did you receive in exchange?

Cash ☐ How much for one cart?
Labour ☐ How many man-days for one cart?
other ☐ specify

Other livestock products

Did you get other animal product in the last cropping season? Yes ☐ No ☐

If yes, specify,
Which product?______________________________
From which animal?__________________________
The quantity produced?_______________________
For which use (sale, own consumption, exchange)_______
If sold or exchanged specify price or against what?_______

D2. Source of feed / grazing

D11. Do you let your livestock graze in the wetlands? Yes ☐ No ☐

D12. If yes, indicate the periods when you let your livestock graze/browse in the wetlands?

	Oct	Nov	Dec	Jan	Feb	March	April	May	June	July	Aug	Sept
Cattle												
Donkeys												
Goats												
Sheep												

Indicate on the map which part of the wetland you use for livestock grazing?

D13. If no, why?____
____

D14. Which other grazing area do you use for your livestock? (locate them on the map)

D15. Indicate the periods w[illegible]e in this area?

	Oct	Nov	Dec	Jan	Feb	March	April	May	June	July	Aug	Sept
Cattle												
Donkeys												
Goats												
Sheep												

Do you control grazing? Yes ☐ No ☐

If yes, how?____

____

D16. Do you cut grasses or bushes to feed your livestock? Yes ☐ No ☐

If yes specify
Which plants?____

Where did you collect them? (dryland, wetland, irrigation scheme; locate on a map)_____________________________________

At what time of the year?

Oct	Nov	Dec	Jan	Feb	March	April	May	June	July	Aug	Sept

For which and how many animals?__________________________________

What quantity did you collect?____________________________________

How much time did you spent in collection? (indicate units)____________________

Who in the household did it?____

D17. Do you cultivate forage to feed your livestock? Yes ☐ No ☐
If yes specify
Which crops?____

Where did you cultivate them? Dryland ☐, wetland ☐, irrigation scheme ☐ [locate on a map]

At what time of the year?

Oct	Nov	Dec	Jan	Feb	March	April	May	June	July	Aug	Sept

For which and how many animals?__________________________________

What quantity did you harvest?____________________________________

For which and how many animals was the forage used?____________________

What is the mode of distribution? (free grazing, in the kraal…)____________________

[for agricultural practices fill in a crop information sheet]

D18. Do you use crop residue for feeding your livestock? Yes ☐ No ☐
If yes specify
From which crops?____

On which plot? Dryland ☐, wetland ☐, irrigation scheme ☐
[locate on a map]

For which and how many animals?________________________________

What is the mode of distribution? (free grazing, in the kraal…)___________

What quantity did you use?____

At what time of the year is it used?

Oct	Nov	Dec	Jan	Feb	March	April	May	June	July	Aug	Sept

How much time do you spent in harvesting and distribution? (State units)_____________

Who in the household does it?________________________________

D19. Do you experience feed shortages? Yes ☐ No ☐

If yes when?

Livestock type	Oct	Nov	Dec	Jan	Feb	March	April	May	June	July	Aug	Sept

How do you cope with feed shortages?

Keep same number of animals ☐
Sell animals ☐
Buy feed ☐
Other (specify) ____

D3. Livestock water
Which source(s) of water do you use for watering your livestock during the last cropping season? (locate on a map or indicate distance from homestead)
____

How do you have access to this source?_____________________________________
____

Is this water source sufficient for your needs? Yes ☐ No ☐

If not sufficient, when do you experience shortages?

Oct	Nov	Dec	Jan	Feb	March	April	May	June	July	Aug	Sept

How do you cope with water shortages?____
____
____

Is the quality of water appropriate for livestock watering? Yes ☐ No ☐

If no, what are the consequences for the animals?______________________________
____

D4. Livestock production costs

Did you buy feed for your livestock during the last cropping season? (including complement, salt…)

What do you buy?	For which animals?	When?	Quantity	Price	From whom?

How much did you spend during the last cropping season on veterinary expenses?

	Dry season	Wet season	Total
Cattle			
Donkeys			
Goats			
Sheep			

When was the last time you build a new fence?________________________
Do you recall the length of fence you built?__________________________
Do you recall the total cost of implement?_____________________________
How many days of family labor did you spent?_________________________
Did you hire labor for that? ____
If yes how many days and what was the cost?_________________________

How many days of family labor did you spend during the last cropping season repairing fences? ______________________________
Did you hire labor to repair fences?____________________
If yes how many man-days? And what was the cost?_______________
Did you buy some inputs to maintain the fence? If yes specify what and at what cost?
____

Did you have any other costs for your livestock?

D5. Livestock labor

How many persons of your household took care of livestock during the last cropping season? (if necessary distinguish per categories of livestock)

Categories of livestock	How many people?	Who in the household? [use key 1]	How many hours / day?	How many days / months?
Cattle				
Donkeys				
Sheep				
Goats				
Poultry				
Rabbits				
Pigs				
Total				

Did you hire other people to take care of your livestock? Yes ☐ No ☐

If yes, specify for which activity? _____________________

How many people? ______________________

How many days per person?__________________

When? [indicate number of man-days per month]

Oct	Nov	Dec	Jan	Feb	March	April	May	June	July	Aug	Sept

At what price or exchanged against what?

Section E: Crop production

E1. Which crop did you grow during the last cropping season

Type of land 1. wetland 2. dryland 3. irrigation scheme 4. backyard garden 5. other (specify)	Type of crop (use key 7) [1]	Area planted (ha) [2]	Total output (kg) [3]	Qty sold (kg) [3]	What was the price last season?	Qty consumed (kg) [3]	Qty retained (kg) [3]

[1] If the same crop is grown in several types of land use as many rows as type of land where the crop is cultivated
[2] locate the plot on the map
[3] if the respondent cannot express the quantity in kg use any appropriate container (grade, basket, cart…) and then assess the weight of an average container

Key 7: Types of crops grown – adapt the list of crops to the site

1. Rice	5.Bambara-nuts	9. Leafy vegetables	13. Peas	17. Madhumbe
2. Maize	6. Groundnuts	10. Onions	14. Sweet potatoes	18. Sugarcane
3. Sorghum	7. Soybean	11. Tomato	15. Potatoes	19. Citrus fruit
4. Barley	8. Rapoko	12. Sugar beans	16. Pumpkins	20. Banana
				21.other

E2. Crop management practices

Repeat this sheet for each plot/crop and cropping season

Type of land:

Crop: Plot number (refere

Cropping calendar: indicate with a line the time and duration of each operation

Operation	Oct.	Nov.	Dec.	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.

[operations: 1. land preparation 2. sowing or planting,3. weeding 4. fertility management 5. pest control, 6. Harvesting 7. post-harvest]

How did you prepare the land for the last wet season?
Tractor ☐ donkey ☐ hoe ☐

Which seed did you use? Farm seed ☐ bought normal seeds ☐
bought improved variety ☐

How did you do the weeding? Manual ☐ chemical ☐

Did you use fertilizers? Yes ☐ No ☐

If yes which type? mineral ☐ organic ☐ both ☐

Did you experience any problems of pests? Yes ☐ No ☐

If Yes, please state the type of pests and how you did control them

Type of pest	Method of control used	Severity of problem *1.very severe* *2.moderate* *3.not severe*

Did you rotate the use of pesticides? Yes ☐ No ☐

Did you experience any problems of crop diseases? Yes ☐ No ☐
If Yes state the type of diseases and how you did control them

Type of disease	Method of control used	Severity of problem *1.very severe* *2.moderate* *3.not severe*

Input use [use one row for each

Input category [use key 8]	Input name	Quantity used for the total area	Unit	Price / unit	Origin [use key 9]

Key 8: 1.seeds or seedlings; 2. mineral fertilizers; 3. organic fertilizers; 4. pesticides; 5. containers; 6. packaging; 7.transport
Key 9: 1. farm production; 2. purchase; 3. gift from family or neighbor; 4. gift from government, NGOs

Labour use

Task	How many family members	Who in the family? [use key 1]	How many days per family member?	How many hired laborers?	How many days per hired laborer?
Land preparation					
Planting, sowing					
Weeding [*]					
Fertility management [*]					
Pest control [*]					
Harvest [*]					
Post harvest processing, shelling, threshing					
Other (specify)					
Other (specify)					

[*] if several operations of the same type indicate the total number of days

What was the total production for this plot the last cropping season? (specify the unit)

What quantity did you keep for household consumption?

What quantity did you retain for next planting season?
What quantity did you sell?

To whom did you sell?
At what price did you sell?

Section F. Access to Markets, credit and support services

F.1. Access to credit
Do you have any access to credit facilities? Yes ☐ No ☐

If no, what is the major factor (s) hindering your access to credit facilities? ________________
____
____

If yes, identify your major source (s) of credit in the past 5 years in the table below.

Source of credit	Major source of credit in the past 5 years (*tick*)	Amount borrowed per annum	When was credit taken (year)	Purpose of credit? (key 10)	Form of repayment (key 11)	Interest rate (additional amount paid back or %)
1. Individual lenders (relatives and friends)						
1. Individual lenders (not related to you)						
2. Farmer groups/organization						
3. Commercial banks						
4. Retailers						
5. NGO						
6. Government department						
7.Local municipality						
8. Other (specify)						

Key 10: 1. Purchase agricultural inputs 2. Purchase farm equipment 3. Purchase of livestock assets 4. Purchase building materials 5. domestic assets 6. family events 7. Other (specify)
Key 11: 1. Cash 2. Livestock 3. Labor 4. Other (specify)

For the sources of credit not used, what factors hinder you from using this credit facility? (key 12)

Key 12: 1. No credit is given by this source 2. Credit from this source is not easily accessible 3. Delays in processing of money 4. Lack of information on how the credit facility operates 5. Lack of trust 6. Lack of collateral 7. high interest rate 8. Length of credit not adapted 9. Other (specify)

F.2. Access to Markets

	Do you have access to markets for these items? 1. Yes 2. No	Main market used in the past 5 years (Key 13)	Distance of market from the village?	Do you have access to market information? (*) 1. Yes 2. No	What are the sources of market information? (Key 14)
Agricultural outputs					
Field crops					
in wetland					
in other land					
Horticultural crops					
in wetland					
in other land					
Other crops (specify)					
in wetland					
in other land					
Non-agricultural wetland resources					
Fish					
Reeds (including their processed products)					
Thatching grass					
Wild edible fruits					
Wild animals					

(*) prices, where and when to get supplies, product characteristics

Key 13: 1. Consumers in the village 2. Consumers in other villages in the locality 3. Local retailers 4. wholesalers/supermarkets 5. Farmer cooperatives/groups 6. Hotels and restaurants 7. Collection centres (GMB) 8. Processors 9. Others (specify)

Key 14: 1.Other people in the village 2. Farmer organizations/co-operatives 3. Local retailers 4. Radio programs 5. Newspapers 6. Extension officers 7. Wholesalers/supermarkets 8 Other (specify)

What are the major advantages of using these markets compared to others?___________
____

What are the main problems /limitations of using these markets?

List the markets you use for the following agricultural inputs

Agricultural inputs	Do you have access to markets for these items? 1. Yes 2. No	Main market used in the past 5 years (Key 15)	Distance of market from the village?	Do you have access to market information? (*) 1. Yes 2. No	What are the sources of market information? (use key 14)
Seeds					
Pesticides					
Fertilizers					
Animal feeds					
Farm implements					

(*) prices, where and when to get supplies, product characteristics

Key 15: 1. Other farmers in the village 2. Local retailers 3. Farmer cooperatives/groups 4. wholesalers/supermarkets 5. NGOs 6. Government 7. Other (specify)

What are the major advantages of using these markets compared to others?

____

What are the main problems /limitations of using these markets?
____
____

F3. Access to extension and other support services

Do you have access to extension services? Yes ☐ No ☐

If no, explain why?____
____

____

If yes, how many times did the extension agent visit you in the last six months?

What kind of advice do you get from the extension agents?_____________________________
____

Do the extension agents advice you on specific aspects on wetland management?
Yes ☐ *No* ☐

If yes, what aspects of wetland management do they advice on?

Fill in the table below on household access to other support services

Services	Is the service available in the area? 1. Yes 2. No	Do you use it or have you used it in the past 5 years? 1. Yes 2. No	Reasons for not using the service (Key 16)
Public transport			
Private transport			
Savings			
Health services			
Educational services			
Other government support services (specify) …………………			
Private (NGO) service support programs (specify) ……………….			
Other (specify)			

Key 16: 1. I don't require the s… and I am not part of the group 3. Service is too expensive 4. Quality of service not to standard 5. Other (specify)

F.4. Membership to social groups
Is there any member of the household belonging to a social group or network?
Yes ☐ No ☐

Who in the household is a member of this group and what is his/her relationship to household head?
(repeat questions which follow for every household member who belongs to a social group)

Type of social group the household member belongs to?
Farmer association ☐
Credit or savings group ☐
Professional association ☐
Wetlands committee ☐
Other village committee ☐
Burial society ☐
Other (specify) ____

Does the person hold a particular position within the social group?
Yes ☐ No ☐

If yes, what is the position held?

How active is the member in the social grouping? How many times per year does the person participate in the meetings of the social group?

What are the benefits of joining this social group?___________________________________
____
____

When there is a decision to be made in this organisation/group, how does this usually come about?
Leader imposes decision without consultation of other group members ☐
Leader decides and informs other group members ☐
Leader consults other members of the group first and then makes a decision ☐
Group members make a decision together ☐
Other (specify) ☐

Section G: Income, budge

G1. What are the different sources of income available to your household? State the amount you receive from every source per month or during the last cropping season.

Key 1. 1.Head of household; 2.Spouse; 3.Child; 4. Grandchild; 5.Parents; 6.Siblings; 7.Farm laborer; 8.Other members (includes household helpers)

Source	Form of income 1.cash 2.kind	Who earns the income? Use key 1.	How long have they been engaged in this activity?	Average amount per month	Average amount for the last cropping season	Is it a regular or once-off income? If once-off what is the period of earning?
1. Crop production						
2. Paid job						
3. Non agricultural independent (self)activities e.g brick making, fishing						
4. Informal activities (e.g gold panning)						
5. Remittances						
6. Social grants						
7. Other (specify)						

Among these sources of income which ones are the most variable?

What are the main causes of variability?

G2. Household budget

How is the average annual income (in cash) distributed among the following categories of expenses?

[use 25 or 50 stones or sticks to represent the total annual income and ask the respondent to distribute them among seasons and then among categories of expenses. Use cards with drawing to represent the various categories of expenses]

Categories of expenses	Wet season	Dry season
Basic food (oil, salt…)		
Other food		
House		
Clothing		
House		
Religious expenses		
Family & social events		
School fees & uniforms		
Health		
Crop inputs		
Livestock inputs		
Livestock		
Farm implements		
Domestic assets (specify)		
Electricity		
Water		
Savings		
Misc.		

G.3 Food supply and security

These questions should preferably be asked of the person responsible for food preparation or of another adult who was present permanently and ate in the household during the reference period

F3.1. Number of eating occasions

During the previous 24-hour period, did you or anyone in your household consume...

Eating Occasion	Yes	No
Any food before a morning meal		
A morning meal		
Any food between morning and midday meals		
A midday meal		
Any food between midday and evening meals		
An evening meal		
Any food after the evening meal		
Number of eating occasions for the household (per day)		

G3.2 Food diversity

These questions refer to the household as a whole, not any single member of the household

Now I would like to ask you about the types of food that you or anyone else in your household ate yesterday <u>during the day and at night</u>. Please include the food prepared and consumed at home and the food prepared at home and consumed outside.

G3.3.1 Was yesterday a normal day for the household (e.g., no funeral or feast or special event)? Yes ☐ No ☐

If No, choose another day of the previous week that was normal

G3.3.2 Did you or anyone else in the household ate yesterday…
Read the list of food groups. Place a 1 in the box if anyone in the household ate the food in question; place a 0 in the box if no one in the household ate the food

1. Any bread, rice noodles, biscuits or any other food made from millet, sorghum, maize, rice, wheat? [Cereals] ☐
2. Any potatoes, yams, manioc, cassava, or any other foods made from roots or tubers? [Roots and tubers] ☐
3. Any vegetables? ☐
4. Any fruits? ☐
5. Any beef, pork, lamb, goat, rabbit wild game, chicken, duck, or other birds, liver, kidney, heart, or other organ meats? [Meat] ☐
6. Any eggs? ☐
7. Any fresh or dried fish or shellfish? ☐
8. Any foods made from beans, peas, lentils or nuts? [Pulses / legumes / nuts] ☐
9. Any cheese, yoghurt, milk or other milk products? ☐
10. Any foods made with oil, fat or butter? ☐
11. Any sugar or honey? ☐
12. Any other foods, such as condiments, coffee, tea? ☐

Total number of food groups [from 0 to 12]

G3.4. For each type of food indicate how much you require for your household per month. Then indicate the main sources of this type of food during the last cropping season

[Give the respondent ten stones or sticks and ask him/her to distribute them according to the main sources of food for cereals. Then repeat the question for each type of food. Use a table with explicit drawings to represent the different sources of food]

Type of food	How much do you require for the household per month	Unit	01. Purchase	02. Household production from wetland	03. Household production from other land	04. Wild food from wetland	05. Wild food from other land	06. Gift	07. Government or NGO program	08. Other	99. Don't know
1. Cereals											
2. Roots/tubers											
3. Legumes											
4. Fruits											
5. Vegetables											
6. Milk/milk products											
7. Eggs											
8. Meat											
9. Fish											

G3.5 Now I would like to ask you about your household's food supply during different months of the year. When responding to these questions, please think back over the last 12 months.

G3.5.1. In the past 12 months were there months in which you did not have enough food to meet your family's needs? Yes ☐ No ☐

G3.5.2. If yes, which were the months (in the last 12 months) in which you did not have enough food to meet your family's needs?

Aug.	Sept	Oct	Nov	Dec	Jan	Feb	March	April	May	June	July	Total nb of months

Working backward from the current month, put a 1 in the box if the respondent identifies that month as one in which the household did not have enough food to meet their needs

G3.5.3. How does your household cope with food shortages?

____

____

Section H. Household Perceptions on Wetland Management and Human Well-Being

In your own opinion, do you think people have sufficient understanding on management of wetlands?

Yes ☐ No ☐

If yes, what are the main sources of information on wetland management in the area?

____

____

____

What aspects of wetland management do these sources cover?

____

____

____

Do you think this information adequately covers the wetland management issues people need to understand? Yes ☐ No ☐

If no, what aspects of wetland management do you think people need further elaboration on?

____

____

____

In your own opinion, do you think degradation of wetland resources is a problem in the area?

Yes ☐ No ☐

If yes, what do you think are the proximate causes of degradation of wetland resources in your area?

In what ways is degradation of wetland ecosystems affecting the well-being of people in your area?

How do you cope with the effects of wetland degradation on your well-being?

In general, what are the major factors constraining the use of wetlands for supporting livelihoods in your area?

What do you think should be done to improve management of wetlands so that the community continues to derive benefits from them?

Is there any information that you think would be useful for the research project?

Thank you for your cooperation

Appendix A4: Household questionnaire used for economic valuation of provisioning services of the Ga-Mampa wetland

Source: Adekola (2007)

Section 1
Interview No: ____

Name of Respondent: ____

Sex: Male [ ] Female [ ]

Age/ Year of Birth: ____

Marital Status: Married [ ] Single [ ] Divorced [ ] Widowed [ ] Living together

Educational Level: ____

Main Occupation: ____

Number in Household: ____

Monthly Household Income ____

Position in Household: ____
(In relation to head of household)

Name of Village: ____

Date/ Time Begin: ____

Section 2

1. How long have you been staying in this village? From Birth [ ] Years [ ]
2. Do you derive any benefits from the wetland? Yes [ ] No [ ]
3. Do you own a plot in the wetland? Yes [ ] No [ ]
4. Which of the following activities have you ever used the wetland for in the past?

[ ] Cropping
[ ] Grazing
[ ] Edible plant collection
[ ] Building material collection
[ ] Arts and craft materials collection
[ ] Fuelwood collection
[ ] Fishing
[ ] Hunting
[ ] Drinking water
[ ] Water for washing
[ ] Water for bathing
[ ] Others (Specify)____

5. Which of these have you used the wetland for in the last one year?

[ ] Cropping
[ ] Grazing
[ ] Edible plant collection
[ ] Building material collection
[ ] Arts and craft materials collection
[ ] Fuelwood collection
[ ] Fishing
[ ] Hunting
[ ] Drinking water
[ ] Water for washing
[ ] Water for bathing
[ ] Others (Specify)____

6. Did you give out your plot (all or part) to another person to use either for cropping or grazing in the last year? Yes [ ] No [ ]
7. If yes for what purpose? ____________________
8. How much/ what did you collect in exchange? ______________________________

If yes to any in 5 above, then please go to the relevant section in Appendix.

9. Which other benefit(s) (apart from those listed above) do you derive from the wetland?

Regulation	**Supporting**	**Cultural**

10. Which benefits apart from those listed above are you aware of?

Regulation	Supporting	Cultural

11. Apart from livelihood resource generated from wetland use, what other sources of income do you have? (List)

Livelihood Resource Source	Importance	Livelihood Resource Source	Importance

12. From list above indicate importance in terms of contribution to household resources with asterisk (pebbles or beans)

13. Are you satisfied with the current benefits you derive from the wetland? Yes [ ] No[ ]

14. Please explain your answer____

____

____

15. Have you received information on how to use the wetland so you can derive **better** benefits? Yes[ ] No [ ]

16. If yes, who provided the information? ____

17. Through which medium? ____

18. Have you received any training on how to best use the wetland to benefit you? Yes [ ] No [ ]

19. If yes, explain ____

20. Overall, how important is the wetland to you?

[ ] Extremely Important (5)
[ ] Very Important (4)
[ ] Important (3)
[ ] Fairly Important (2)
[ ] Not Important (1)

21. Please, can you kindly provide name(s) of other person(s) known to you using the wetland for the following purpose(s).

[ ] Cropping ____
[ ] Grazing ____
[ ] Wild plant collection ___________________________________
[ ] Building material collection ______________________________
[ ] Arts and craft materials collection _________________________
[ ] Fuelwood collection ____________________________________
[ ] Fishing ____
[ ] Hunting ____
[ ] Drinking water ____
[ ] Water for washing ______________________________________
[ ] Water for bathing
[ ] Others (Specify)____

20. Time End ______________________________________

Section 3

A. Cropping

1. How long have you been involved in cropping activity in the wetland? __________ Years
2. How many households do you know to be involved in cropping activity in the wetland in?

Mashushu ____, Mapagane ____, Mantlane ____, Moila ____, General ____

3. What is the size of the land you use for cropping?
   Wetland _______________________ *Bambas*
   Others (Specify) _________________ *Bambas*
4. Has your wetland farmland size changed in the last two cropping seasons? Yes [ ] No [ ]
5. Did the size of your farmland in the wetland change in the last five Years? Yes [ ] No [ ]
6. Locate on a map where your farmland(s) is/are presently located in the wetland?
7. How do you get there (wetland cropping land from home)?

[ ] Walking, [ ] Cycle, [ ] Personal Transport, [ ] Public Transport

8. How long does it take to the farm from your home? _________________________(Hours)
9. Is cropping your main occupation? Yes [] No [ ]
10. Why do you crop in the wetland? ____
11. Are there other locations available for you to crop besides the wetland area? Yes [ ] No [
12. If yes, what is what/where is this alternative? (describe) ___________________________
13. How accessible is this alternative to you? Free [ ] I pay [ ] ______ (ZAR)
14. Do you have possibility to do what you do in the wetland elsewhere? Yes [ ] No [ ]
15. If yes, what is what/where is this alternative? (describe) ___________________________
16. How accessible/available is this alternative? Free [ ] I pay [ ] _(ZAR)
17. In the absence of the wetland, how will you meet the cropping contribution of the wetland to your household?____
18. In the past years have you ever experienced crop shortage in the wetland? Yes [ ] No [ ]
19. If yes, when was this and how did you adjust, what did you do?_____________________
20. Which crops did you cultivate in the last 3 years per farming seasons?

Year 1 (2003/2004)		Year 2 (2004/2005)		Year 3 (2005/2006)	
Wet Season	Dry Season	Wet Season	Dry Season	Wet Season	Dry Season

21. What was your yield for these crops?

Crop	Year 1 (2003/2004)		Year 2 (2004/2005)		Year 3 (2005/2006)	
	Wet Season	Dry Season	Wet Season	Dry Season	Wet Season	Dry Season

22. How much are you willing to be paid to in *lieu* of your cropping right in the wetland
23. Once payment ____ (ZAR)
24. Over a period of time (indicate below)

Year					
Amount					

Repeat this sheet for each plot/crop for each cropping season in the last year.

Crop type: **Size of plot used** **Cropping season:**

1. How did you prepare the land for the season?
Tractor ☐ donkey ☐ hoe ☐ did not cultivate ☐

2. Which seed did you use?
Farm seed ☐ bought normal seeds ☐ bought improved variety ☐

3. Did you do weeding? Yes ☐ No ☐

4. How did you do the weeding? Manual ☐ Chemical ☐

5. Did you use fertilizers? Yes ☐ No ☐

6. If yes which type? Mineral ☐ Organic ☐ Both ☐

7. Did you experience any problems of pests? Yes ☐ No ☐

8. If Yes, please state the type of pests and how you did control them

Type of pest	Crop affected	Method of control used	Estimated cost of control	Severity of problem *1.very severe, 2.moderate, 3.not severe*

9. Did you experience any problems of crop diseases? Yes ☐ No ☐

10. If yes state the type of diseases and how you did control them

Type of disease	Crop affected	Method of control used	Estimated cost of control	Severity of problem *1.very severe, 2.moderate, 3.not severe*

11. Input used [use one row for each type of input]

Input category [use key 2]	Input name	Quantity used for the total area	Unit	Price / unit	Source [use key 3]

Key 2: 1.seeds or seedlings; 2. mineral fertilizers; 3. organic fertilizers; 4. pesticides; 5. containers; 6. packaging; 7.transport; 8. Others

Key 3: 1. farm production; 2. purchase; 3. gift from family or neighbor; 4. gift from government, NGOs

12. Implement used [use one row for each type of input]

Implement category [use key 4]	Input name	Quantity used for the total area	Source [use key 5]	Price / unit	Length of Use	Estimated Life length of Implement

Key 4: 1.Tractors; 2. Hoes; 3. Cutlass; 4. Wheel Barrow: 5. Spade: 6. others ;

Key 5: 1. Farm production; 2. Purchase; 3. Gift from family or neighbor; 4. Gift from government, 5. NGOs, 6. Hire (from who? _________________________) 7 Borrow

13. Labor use

Task	Period operation was done	How many family members	Who in the family? [use key 1]	How many days per family member?	How many hired laborers?	How many days per hired laborer?	Cost of labor
Land preparation							
Planting, sowing							
Weeding [*]							
Fertility management [*]							
Pest control [*]							
Disease Control							
Harvest [*]							
Transport of Harvest							
Post harvest processing, shelling, threshing							
Other (specify)							

Key 1 1.Head of household; 2.Spouse; 3.Child; 4. Grandchild; 5.Parents; 6.Siblings; 7.Farm laborer; 8.Other members (includes household helpers)

[*] if several operations of the same type indicate the total number of days

14. Can you indicate average time you personally spend on your farm in the following months?

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept
Time Per Person												
Average number of persons												

15. Did you loose any part of your yield to flood, thieves etc before harvesting? Yes [] No[]

16. If yes, what quantity?

Crop (Type)	Reason for Lost	Quantity Lost

17. What was the total yield for this crop? (specify the unit)

Crop (Type)	Size of plot used	Quantity of yield

18. Did you loose any part of your yield after harvesting? Yes [ ] No [ ]
19. If yes, what quantity?

Crop (Type)	Reason for Lost	Quantity Lost

20. What quantity of this yield did you use for household consumption?

Crop type	Quantity

21. What quantity did you give out?

Crop type	Quantity

22. What quantity did you retain for next planting season?

Crop type	Quantity

23. What quantity did you exchange?

Crop type	Quantity exchanged	Exchanged for

24. With whom did you exchange? ___________________________________
25. Did you pay any other cost for this exchange? Yes [ ] No [ ]

26. If yes how much and for what? ____
27. What quantity did you sell?

Crop type	Quantity	Price per unit

28. To whom did you sell? ____
29. Where did you sell it (i.e. local market, outside market)?
30. Did you transport to the market? Yes [ ] No [ ]
31. If yes, how much did the transport cost? ________________________________
32. In the last one year what is the highest and lowest price you sold this crop

Crop type	Highest Price	When (Period)	Lowest Price	When (Period)

33. Can you provide price you sold this crop in the last five years?.

Period	Price	Period	Price

34. What other products did you make from your crops? (list)[21]

Product	Product	Product

35. What else do you do with part of your yield? ___________________________

General Questions

1. How will you describe benefits from cropping in the wetland in the past five years?
[ ] Increasing, [ ] Decreasing, [ ] Not changing, [ ] No Idea
2. What (indicator) did you use to suggest this change? (explain) ____
3. Are you aware of impacts your cropping activity is having on the wetland? Yes [ ] No [ ]
4. If yes, please explain____
5. In the last 2 years (and maybe years prior) have you done anything to ameliorate this impact(s)? Yes [ ] No [ ]
6. If yes what action have you taken (personally) to reduce impact so you could continue to have these benefits? ____
7. What did you do? ____
8. How much did the action cost you? ____

[21] If any ascertain cost and amount made from this.

9. In the last 2 years has the community taken any action to ameliorate this impact? Yes [] No []
10. If yes what has been done to reduce impact so you could continue to have this benefit? ____
11. How much did this activity cost the community? ________________________
12. In the last 2 years has any external organization taken any action to ameliorate these impacts? Yes[ ] No[ ]
13. Which organization? ______________________________________
14. What did they do? ______________________________________
15. How much did it cost them? ____________________________________

B. Collection of Edible Plants

1. How long have you been involved in collection of edible plants from the wetland? ________
2. How many households do you know to be involved in this activity in the wetland?
3. Mashushu ____, Mapagane ____, Mantlane ____, Moila ____, General ____, I don't know __
4. Which type of plants do you collect from the wetland? (List)

Plant Type	Plant Type	Plant Type

5. How often do you collect this type of plant in a month/year? __________________
6. How many people involved in the collection per month for your household? ___________
7. How long do each spend? ________________________
8. What is the total quantity you collect a month/year?______________________
9. How long does it take to collect this quantity? _______________________persons/month
10. In the last one year what quantity of each of these plants did you collect? (Optional)

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept
Freq. of Collection												
Quantity collected												

11. Describe availability of each type of plant in the wetland relation to farming seasons (for each plant)?

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept
Availability												
Harvesting period												

12. Which part of the wetland do you get these plants? Show it on the map for each type.
13. How long is it from your homestead to the place of collection? _________________ (time)
14. How do you transport from the homestead to and from the place of collection

[ ] Walking, [ ] Cycle, [ ] Private car, [ ] Public transport

15. Why do you choose the wetland as a place to collect wild plants? ____________________
16. Is/are these plants available in other places outside the wetland? Yes [ ] No [ ]
17. If yes, where are they located? (describe or show on map.__________________________
18. Do you also get these plants from this source(s)? Yes [ ] No [ ]
19. How accessible (right) is this source to you? ______________________________________
20. Is collection of wild plant your main occupation? ______________________________
21. Which of these sources do you use the most? ____________________________________
22. How many people collect wild plant for your household? _________________________
23. Who are they? ____
24. Do you hire external labor to collect wild plant? Yes [ ] No [ ]
25. If yes, how many per collection ____
26. Do you pay for the right to collect wild plant? Yes [ ] No [ ]
27. If yes how much do you pay to collect these materials?
28. Do you use specific tools for collection of plants? Yes [ ] No [ ]
29. If yes, fill table below

Type of tool	Number	Source (Rent, gift, inheritance etc.)	When did you acquire it	Averagely how long does it work	How much do you pay for it

30. What quantity (of each type of plant) do you use personally? (Per time month)

Type (Plant)	Quantity	Price

31. What quantity did you give out? (Per time month)

Type (Plant)	Quantity	Price

32. What quantity did you give out in exchange? (Per time month)

Type (Plant)	Quantity	Exchange for

33. What quantity did you sell? (Per month)

Type (Plant)	Quantity	Price

34. Where did you sell them? ___________________________________
35. To whom did you sell them? ______________________________________
36. Did you incur transport cost to sell? Yes [ ] No [ ]
37. If yes, how much? _____________________________
38. In the last one year what is the highest and lowest price you sold wild plants

Type	Highest Price	When (Period)	Lowest Price	When (Period)

39. Can you provide price you sold this wild plants in the last five years?.

Period	Price	Period	Price

40. Do you make other product from wild plants? Yes [ ] No [ ]
41. If yes, what other products do you make from wild plants? (List)

Product	Product

42. In the last one year what is the highest and lowest price you sold these products?

Type	Highest Price	When	Lowest Price	When

43. What else do you use collected wild plants for?____________________________________
44. How will you describe possibility to collect wild plant in the wetlands in the past five years?
[ ] Increasing, [ ] Decreasing, [ ] Not changing, [ ] No Idea
45. Are you aware of impacts your plant collection activity is having on the wetland? Yes [ ] No [ ]
46. If yes list/explain ____
47. In the last 2 years (and maybe years prior) have you done anything to ameliorate this impact(s)? Yes [ ] No [ ]
48. If yes what action have you taken (personally) to reduce impact so you could continue to have these benefits? ____
49. What did u do?____
50. How much did the action cost you? ____

51. In the last 2 years has the community taken any action to ameliorate this impact? Yes [ ] No []
52. If yes what has been done to reduce impact so you could continue to have this benefit? ____
53. In the last 2 years has any **external organization** taken any action to ameliorate these impacts? Yes[ ] No[ ] I don't know [ ]
54. Which organization? ____
55. What did they do? ____

C. Collection of Building Material

1. How long have you been involved in collection of building materials from the wetland? ________

2. How many households do you know to be involved in this activity in the wetland?
Mashushu ____, Mapagane ____, Mantlane ____, Moila ____, General ____, I don't know ____

3. Which type of building materials do you collect from the wetland? (List)

Plant Type	Plant Type	Plant Type

4. Have you collected these materials in the last one year? Yes [ ] No [ ]

5. How often do you collect each of these materials in a month/year? __________________

6. How many people involved in the collection per month for your household? _______________

7. How long do each spend? ___________________________________

8. What quantity do you collect a month/year? ___________________________

9. How long does it take to collect this quantity? __________________________persons/month

10. In the last one year what quantity of each of these materials did you collect? (Optional)

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept
Freq. of Collection												
Quantity collected												

11. Can you describe availability of each material in relation to farming seasons (for each plant)?

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept
Availability												
Harvesting period												

12. Which part of the wetland do you get these building materials? Show it on the map for each.

13. How long is it from your homestead to the place of collection? ____________________ (time)

14. How do you transport from the homestead to and from the place of collection
[ ] Walking, [ ] Cycle, [ ] Private car, [ ] Public transport

15. Why do you choose the wetland as a place to collect building materials? _________________

16. Is/are these materials available in other places outside the wetland? Yes [ ] No [ ]

17. If yes, where are they located? (describe or show on map.____________________________

18. Do you also get these materials from this source(s)? Yes [ ] No [ ]

19. How accessible is this source to you? ____

20. Which of these sources do you use the most? ______________________________________

20. Is collection of building material your main occupation? _____________________________

21. How many people collect building material for you? ________________________
22. Who are they? ____
23. Do you hire external labor to collect building material? Yes [ ] No [ ]
24. If yes, how many per collection _______________________________________
25. Do you pay to collect building materials? Yes [ ] No [ ]
26. If yes how much do you pay to collect these materials?
27. Do you use specific tools for collection of building materials? Yes [ ] No [ ]
28. If yes, fill table below

Type of tool	Number	Source (Rent, gift, inheritance etc.)	When did you acquire it	Averagely how long does it work	How much do you pay for it

29. What quantity (of each type of material) do you use personally? (Per time month)

Type (Plant)	Quantity	Price

30. What quantity did you give out? (Per time month)

Type (Plant)	Quantity	Price

31. What quantity did you give out in exchange? (Per time month)

Type (Plant)	Quantity	Exchange for

32. What quantity did you sell? (Per month)

Type (Plant)	Quantity	Price

33. Where did you sell them? _________________________________
34. To whom did you sell them? ___________________________________
35. Did you incur transport cost? Yes [ ] No [ ]
36. If yes, how much? ___________________________
37. In the last one year what is the highest and lowest price you sold building materials

Type	Highest Price	When (Period)	Lowest Price	When (Period)

38. Can you provide price you sold this building materials in the last five years?.

Period	Price	Period	Price

39. Do you make other product from collected materials? Yes [ ] No [ ]

40. If yes, what other products? (List)

Product	Product

41. In the last one year what is the highest and lowest price you sold these products?[i]

Type	Highest Price	When	Lowest Price	When

42. What else do you use collected materials for?
43. How will you describe possibility to collect building materials in the wetlands in the past five years? [ ] Increasing, [ ] Decreasing, [ ] Not changing, [ ] No Idea
44. Are you aware of impacts your collection activity is having on the wetland? Yes [ ] No [ ]
45. If yes list/explain ____
46. In the last 2 years (and maybe years prior) have you done anything to ameliorate this impact(s)? Yes [ ]No
47. If yes what action have you taken (personally) to reduce impact so you could continue to have these benefits? ____
48. What did you do?____
49. How much did the action cost you? ____
50. In the last 2 years has the community taken any action to ameliorate this impact? Yes [ ] No []
51. If yes what has been done to reduce impact so you could continue to have this benefit?
____
52. In the last 2 years has any external organization taken any action to ameliorate these impacts? Yes[ ] No[ ] I don't know [ ]
53. Which organization? ____
54. What did they do?____

D. Arts and Craft Material Collection

1. How long have you been involved in collection of craft materials from the wetland? _____
2. How many households do you know to be involved in this activity in the wetland?

Mashushu ____, Mapagane ____, Mantlane ____, Moila ____, General ____, I don't know __

3. Which type of art and craft materials do you collect from the wetland? (List)

Plant Type	Plant Type	Plant Type

4. How often do you collect each of these materials in a month/year? ___________________
5. How many people involved in the collection per month for you? ________________
6. How long do each spend? ____________________________________
7. What quantity do you collect a month/year? _____________________________
8. How long does it take to collect this quantity? ________________________persons/month
9. In the last one year what quantity of each of these materials did you collect? (Optional)

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept
Freq. of Collection												
Quantity collected												

10. Can you describe availability of each material in relation to farming seasons (for each)?

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept
Availability												
Harvesting period												

11. Which part of the wetland do you get these art and craft materials? Show it on the map for each type.
12. How long is it from your homestead to the place of collection? __________________ (time)
13. How do you transport from the homestead to and from the place of collection

[ ] Walking, [ ] Cycle, [ ] Private car, [ ] Public transport

14. Why do you choose the wetland as a place to collect art and craft materials? ___________
15. Is/are these materials available in other places outside the wetland? Yes [ ] No [ ]
16. If yes, where are they located? (describe or show on map.__________________________
17. Do you also get these materials from this source(s)? Yes [ ] No [ ]
18. How accessible is this source to you?____
19. Which of these sources do you use the most (rank)_________________________________
20. Is collection of art and craft material your main occupation? __________________________
21. How many people collect art and craft material for you? __________________________
22. Who are they? ____
23. Do you hire external labor to collect material? Yes [ ] No [ ]
24. If yes, how many per collection ____
25. Do you pay to collect art and craft materials? Yes [ ] No [ ]
26. If yes how much do you pay to collect these materials?
27. Do you use specific tools for collection of art and craft materials? Yes [ ] No [ ]

28. If yes, fill table below

Type of tool	Number	Source (Rent, gift, inheritance etc.)	When did you acquire it	Averagely how long does it work	How much do you pay for it

29. What quantity (of each type of material) do you use personally? (Per time month)

Type (Plant)	Quantity	Price

30. What quantity did you give out? (Per time month)

Type (Plant)	Quantity	Price

31. What quantity did you give out in exchange? (Per time month)

Type (Plant)	Quantity	Exchange for

32. What quantity did you sell? (Per month)

Type (Plant)	Quantity	Price

33. Where did you sell them? ___________________________________
34. To whom did you sell them? ______________________________________
35. Did you incur transport cost to sell? Yes [ ] No [ ]
36. If yes, how much? _____________________________
37. In the last one year what is the highest and lowest price you sold art and craft materials

Type	Highest Price	When (Period)	Lowest Price	When (Period)

38. Can you provide price you sold these materials in the last five years?

Period	Price	Period	Price

39. Do you make other product from collected materials? Yes [ ] No [ ]
40. If yes, what other products? (List)

Product	Product

41. In the last one year what is the highest and lowest price you sold these products?[ii]

Type	Highest Price	When	Lowest Price	When

42. What else do you use collected materials for?
43. How will you describe possibility to collect art materials in the wetlands in the past five years?

[ ] Increasing, [ ] Decreasing, [ ] Not changing, [ ] No Idea

44. Are you aware of impacts your collection activity is having on the wetland? Yes [ ] No [ ]

45. If yes list/explain ____
46. In the last 2 years (and maybe years prior) have you done anything to ameliorate this impact(s)? Yes [ ] No [ ]
47. If yes what action have you taken (personally) to reduce impact so you could continue to have these benefits? ____
48. What did u do? ____
49. How much did the action cost you? ____________________________________
50. In the last 2 years has the community taken any action to ameliorate this impact? Yes [ ] No []
51. If yes what has been done to reduce impact so you could continue to have this benefit? ____
52. In the last 2 years has any external organization taken any action to ameliorate these impacts? Yes[ ] No[ ] I don't know [ ]
53. Which organization? ____
54. What did they do?____

E. Fuelwood Collection

1. How long have you been involved in collection of fuelwood from the wetland? ________

How many households do you know to be involved in this activity in the wetland?

2. Mashushu ____, Mapagane ____, Mantlane ____, Moila ____, General ____, I don't know __
3. Which type of fuelwood materials do you collect from the wetland? (List)

Plant Type	Plant Type	Plant Type

4. How often do you collect each of these materials in a month/year? _________________
5. How many people involved in the collection per month for your household? ___________
6. How long do each spend? __________________________________
7. What quantity do you collect a month/year? ___________________________
8. How long does it take to collect this quantity? ____________________________ Hours
9. In the last one year what quantity of each of these materials did you collect? (Optional)

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept
Freq. of Collection												
Quantity collected												

10. Can you describe availability of each material in relation to farming seasons (for each plant)?

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept
Availability												
Harvesting period												

11. Which part of the wetland do you get these fuelwoods? Show it on the map for each type.
12. How long is it from your homestead to the place of collection? ___________________
13. How do you transport from the homestead to and from the place of collection

[ ] Walking, [ ] Cycle, [ ] Private car, [ ] Public transport

14. Why do you choose the wetland as a place to collect fuelwood? ____________________

15. Is/are these materials available in other places outside the wetland? Yes [ ] No [ ]
16. If yes, where are they located? (describe or show on map.___________________________
17. Do you also get these materials from this source(s)? Yes [ ] No [ ]
18. How accessible is this source to you? ____
19. Which of these sources do you use the most (rank)_________________________________
20. Is collection of fuelwood your main occupation? ________________________________
21. How many people collect fuelwood for you? __________________________
22. Who are they? ____
23. Do you hire external labor to collect fuelwood? Yes [ ] No [ ]
24. If yes, how many per collection ____
25. Do you pay to collect fuelwood? Yes [ ] No [ ]
26. If yes how much do you pay to collect these materials?
27. Do you use specific tools for collection of fuelwood? Yes [ ] No [ ]
28. If yes, fill table below

Type of tool	Number	Source (Rent, gift, inheritance etc.)	When did you acquire it	Averagely how long does it work	How much do you pay for it

29. What quantity (of each type of material) do you use personally? (Per time month)

Type (Plant)	Quantity	Price

30. What quantity did you give out? (Per time month)

Type (Plant)	Quantity	Price

31. What quantity did you give out in exchange? (Per time month)

Type (Plant)	Quantity	Exchange for

32. What quantity did you sell? (Per month)

Type (Plant)	Quantity	Price

33. Where did you sell them? ___________________________________
34. To whom did you sell them? ____
35. Did you incur transport cost? Yes [ ] No [ ]
36. If yes, how much? ______________________________
37. In the last one year what is the highest and lowest price you sold fuelwood?

Type	Highest Price	When (Period)	Lowest Price	When (Period)

38. Can you provide price you sold fuelwood in the last five years?.

Period	Price	Period	Price

39. Do you make other product from collected materials? Yes [ ] No [ ]
40. If yes, what other products? (List)

Product	Product

41. In the last one year what is the highest and lowest price you sold these products?[iii]

Type	Highest Price	When	Lowest Price	When

42. What else do you use collected materials for?
43. How will you describe possibility to collect fuelwood in the wetlands in the past five years? [ ] Increasing, [ ] Decreasing, [ ] Not changing, [ ] No Idea
44. Are you aware of impacts your collection activity is having on the wetland? Yes [ ] No [ ]
45. If yes list/explain ____
46. In the last 2 years (and maybe years prior) have you done anything to ameliorate this impact(s)? Yes [ ] No [ ]
47. If yes what action have you taken (personally) to reduce impact so you could continue to have these benefits? ____
48. What did you do? ____
49. How much did the action cost you? ________________________________
50. In the last 2 years has the community taken any action to ameliorate this impact? Yes [ ] No []
51. If yes what has been done to reduce impact so you could continue to have this benefit? ____
52. In the last 2 years has any external organization taken any action to ameliorate these impacts? Yes[ ] No[ ] I don't know [ ]
53. Which organization? ____
54. What did they do? ____

F. Fishing (only relevant if actual fishing is done in the wetland)

1. How long have you been involved in fishing from the wetland? ________
2. How many households do you know to be involved in this activity in the wetland?

Mashushu ____, Mapagane ____, Mantlane ____, Moila ____, General ____, I don't know __

3. Which type of fish do you collect from the wetland? (List)

Plant Type	Plant Type	Plant Type

4. How often do you fish in a month/year? ________________
5. How many people involved in fishing per month for your household? ______________
6. How long do each spend? ______________________________
7. What quantity do you collect a month/year? ________________________
8. How long does it take to collect this quantity? ____________________ persons/week
9. In the last one year what quantity of each fish type did you collect? (Optional)

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept
Freq. of												

Collection												
Quantity collected												

10. Can you describe availability of fish in relation to farming seasons (for each plant)?

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept
Availability												
Harvesting period												

11. Which part of the wetland do you get these fishes? Show it on the map for each type.
12. How long is it from your homestead to the place of fishing? ____________________
13. How do you transport from the homestead to and from this place?
[ ] Walking, [ ] Cycle, [ ] Private car, [ ] Public transport
14. Why do you choose the wetland as a place to fish? _____________________
15. Is/are there alternative places outside the wetland you can fish? Yes [ ] No [ ]
16. If yes, where are they located? (describe or show on map._________________________
17. Do you also get fish from this source(s)? Yes [ ] No [ ]
18. How accessible is this source to you? ____
19. Which of these sources do you use the most (rank)_______________________________
20. Is fishing your main occupation? _____________________________
21. How many people fish for you? ________________________
22. Who are they? ____
23. Do you hire external labor to fish for you? Yes [ ] No [ ]
24. If yes, how many per collection _______________________________________
25. Do you pay to fish in the wetland? Yes [ ] No [ ]
26. If yes how much do you pay?
27. Do you use specific tools for fishing in the wetland? Yes [ ] No [ ]
28. If yes, fill table below

Type of tool	Number	Source (Rent, gift, inheritance etc.)	When did you acquire it	Averagely how long does it work	How much do you pay for it

29. What quantity (of each type of material) do you use personally? (Per time month)

Type (Fish)	Quantity	Price

30. What quantity did you give out? (Per time month)

Type (Fish)	Quantity	Price

31. What quantity did you give out in exchange? (Per time month)

Type (Fish)	Quantity	Exchange for

32. What quantity did you sell? (Per month)

Type (Fish)	Quantity	Price

33. Where did you sell them? ___________________________________
34. To whom did you sell them? ______________________________________
35. Did you incur transport cost? Yes [ ] No [ ]
36. If yes, how much? ______________________________
37. In the last one year what is the highest and lowest price you sold fishes?

Type	Highest Price	When (Period)	Lowest Price	When (Period)

38. Can you provide price you sold fish in the last five years?.

Period	Price	Period	Price

39. Do you make other product from fish? Yes [ ] No [ ]
40. If yes, what other products? (List)

Product	Product

41. In the last one year what is the highest and lowest price you sold these products?[iv]

Type	Highest Price	When	Lowest Price	When

42. What else do you use fish for?
43. How will you describe possibility to fish in the wetlands in the past five years?
[ ] Increasing, [ ] Decreasing, [ ] Not changing, [ ] No Idea
44. Are you aware of impacts your fishing is having on the wetland? Yes [ ] No [ ]
45. If yes list/explain ____
46. In the last 2 years (and maybe years prior) have you done anything to ameliorate this impact(s)? Yes [ ] No [ ]
47. If yes what action have you taken (personally) to reduce impact so you could continue to have these benefits? ____
48. What did u do? ____
49. How much did the action cost you? ____
50. In the last 2 years has the community taken any action to ameliorate this impact? Yes [ ] No []
51. If yes what has been done to reduce impact so you could continue to have this benefit?
____
52. In the last 2 years has any external organization taken any action to ameliorate these impacts? Yes[ ] No[ ] I don't know [ ]
53. Which organization? ____
54. What did they do? ____

G. Hunting

1. How long have you been involved in hunting from the wetland? _________
2. How many households do you know to be involved in this activity in the wetland?
Mashushu ____, Mapagane ____, Mantlane ____, Moila ____, General ____, I don't know ____
3. Which type of games do you collect from the wetland? (List)

Plant Type	Plant Type	Plant Type

5. How often do you hunt in a month/year? ___________________
6. How many people involved in hunting for you per month? ________________
7. How long do each spend? ____________________________________
8. What quantity do you collect a month/year? _____________________________
9. How long does it take to collect this quantity? ______________________________ Hours
10. In the last one year what quantity of each game type did you collect? (Optional)

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept
Freq. of Collection												
Quantity collected												

11. Can you describe availability of games in relation to farming seasons (for each plant)?

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept
Availability												
Harvesting period												

12. Which part of the wetland do you get these games? Show it on the map for each type.
13. How long is it from your homestead to the place of hunting? _____________________
14. How do you transport from the homestead to and from this place?
[ ] Walking, [ ] Cycle, [ ] Private car, [ ] Public transport
15. Why do you choose the wetland as a place to hunt? ______________________
16. Is/are there alternative places outside the wetland you can hunt? Yes [ ] No [ ]
17. If yes, where are they located? (describe or show on map.______________________________
18. Do you also get hunt from this source(s)? Yes [ ] No [ ]
19. How accessible is this source to you? ____
20. Which of these sources do you use the most (rank)____________________________________
20. Is hunting your main occupation? _______________________________
21. How many people hunt for you? __________________________
22. Who are they? ____
23. Do you hire external labor to hunt for you? Yes [ ] No [ ]
24. If yes, how many per collection ____
25. Do you pay to hunt in the wetland? Yes [ ] No [ ]
26. If yes how much do you pay?
27. Do you use specific tools for hunting in the wetland? Yes [ ] No [ ]

28. If yes, fill table below

Type of tool	Number	Source (Rent, gift, inheritance etc.)	When did you acquire it	Averagely how long does it work	How much do you pay for it

29. What quantity (of each type of material) do you use personally? (Per time month)

Type (game)	Quantity	Price

30. What quantity did you give out? (Per time month)

Type (game)	Quantity	Price

31. What quantity did you give out in exchange? (Per time month)

Type (game)	Quantity	Exchange for

32. What quantity did you sell? (Per month)

Type (Fish)	Quantity	Price

33. Where did you sell them? ________________________________
34. To whom did you sell them? ___________________________________
35. Did you incur transport cost? Yes [ ] No [ ]
36. If yes, how much? ___________________________
37. In the last one year what is the highest and lowest price you sold games?

Type	Highest Price	When (Period)	Lowest Price	When (Period)

38. Can you provide price you sold game in the last five years?.

Period	Price	Period	Price

39. Do you make other product from games? Yes [ ] No [ ]
40. If yes, what other products? (List)

Product	Product

41. In the last one year what is the highest and lowest price you sold these products?[v]

Type	Highest Price	When	Lowest Price	When

42. What else do you use games for?
43. How will you describe possibility to games in the wetlands in the past five years?
[ ] Increasing, [ ] Decreasing, [ ] Not changing, [ ] No Idea

44. Are you aware of impacts your hunting is having on the wetland? Yes [ ] No [ ]
45. If yes list/explain ____
46. In the last 2 years (and maybe years prior) have you done anything to ameliorate this impact(s)? Yes [ ] No [ ]
47. If yes what action have you taken (personally) to reduce impact so you could continue to have these benefits? ____
48. What did you do? ____
49. How much did the action cost you? ____
50. In the last 2 years has the community taken any action to ameliorate this impact? Yes [ ] No []
51. If yes what has been done to reduce impact so you could continue to have this benefit?
____
52. In the last 2 years has any external organization taken any action to ameliorate these impacts? Yes[ ] No[ ] I don't know [ ]
53. Which organization? ____
54. What did they do? ____

H. Water

1. How long have you been collecting water from the wetland? ________
2. How many households do you know to be involved in this activity in the wetland? Mashushu ____, Mapagane ____, Mantlane ____, Moila ____, General ____, I don't know ____
3. Which quantity of water for the following activities do you collect from the wetland during the week?

Water for	Source	Location on the map	Quantity Collected per day	Frequency of collection	Length of time using wetland for this purpose	Number of households
Drinking and cooking						
Washing clothes						
Bathing						
Building purposes						
Watering of small livestock(eg rabbits)						
Watering gardens						
Other specify						

4. Why do you collect water from the wetlands? ______________________________________
5. Do you have alternative to this? ____
6. If yes, do you also use this source(s)
7. How accessible is this alternative source to you? _________________________________
8. Which of these sources do you use most (rank) _____________________________________
8. How many people collect water for your household? ________________________
9. Who are they? ____
10. Do you hire external labor to collect water? Yes [ ] No [ ]
11. If yes, how many per collection ____
12. How much do you pay them? ____________________________________
13. Do you pay to collect water? Yes [ ] No [ ]
14. If yes how much do you pay to collect water?

15. Do you use specific tools for collecting water? Yes [ ] No [ ]
16. If yes, fill table below

Type of tool	Number	Source	When did you acquire it	Averagely how long does it work	How much do you pay for it

17. How do you transport to and from the place of collection
[ ] Walking, [ ] Cycle, [ ] Private car, [ ] Public transport
18. What quantity of water collected do you use personally? (Per time mentioned above)
19. What quantity do you give out?
20. What quantity do you sell?
21. What else do you use collected water for?
22. How will you describe possibility to collect water in the wetlands in the past five years?
[ ] Increasing, [ ] Decreasing, [ ] Not changing, [ ] I don't know
23. Are you aware of impacts your water collection activity is having on the wetland?
Yes [ ] No [ ]
24. If yes list/explain ____
25. In the last 2 years (and maybe years prior) have you done anything to ameliorate this impact(s)? Yes [ ] No [ ]
26. If yes what action have you taken (personally) to reduce impact so you could continue to have these benefits? ____
27. What did you do? ____
28. How much did the action cost you? ____
29. In the last 2 years has the community taken any action to ameliorate this impact? Yes [ ] No [ ]
30. If yes what has been done to reduce impact so you could continue to have this benefit?
____
31. In the last 2 years has any external organization taken any action to ameliorate these impacts?
Yes[ ] No[ ] I don't know [ ]
32. Which organization? ____
33. What did they do? ______________________________
34. Did you experience any water related disease in the last year?
35. If yes, explain (ascertain cost of treatment)

I. Livestock

1. How long have you been involved in livestock grazing activity in the wetland area?
____

2. How many households are do you know to be involved in livestock grazing?
Mashushu ____, Mapagane ____, Mantlane ____, Moila ____, General ____, I don't know ____
3. Is livestock rearing your main occupation? Yes [ ] No [ ]
4. Fill for each season (last two seasons)

Livestock categories	How many the season	How many born?	How many dead?	How many purchased?	How many sold?	How many used for own consumption?	How many do you give out as gift?	How many exchanged? (+/-)	How many today?
Cattle/ Cow									
Donkeys									
Sheep									
Goats									
Poultry									
Rabbits									
Pigs									

Milk production
5. How many cows or goats that produce milk do you have in the season? Cows ____ Goats____
6. How much milk do each produce per week? Cows ____________, Goats ______________
7. What quantity of milk do you use for household consumption per week? ___________
8. What do you do with the rest? ____
Draught power
9. Did you use some of your livestock for plowing or transport in cropping season? Yes ☐ No ☐
10. If yes, how many animals and of which type did you use for this?

Type of animals	Number	Use [plowing, transport]
Cows		
Donkeys		

11. How many days did you use them last cropping season for your own needs and what area did you plow with your own animals?

Type of animals	Days used for transport	Plowing	
		days	Area
Cows			
Donkey			

(Specify unit________)

12. Did you rent or lend your animal for plowing or transport last cropping season? Yes ☐ No ☐

13. If yes specify how many days and the area plowed?

Type of animals	Days used for transport	Plowing	
		days	area
Cows			
Donkey			

14. What did you receive in exchange?
Cash ☐ How much for one day?
Labour ☐How many man-days for one day of work?
other ☐specify

Manure production

15. Did you collect the manure produced by your animals for fertilizing your plots last cropping season?
Yes ☐ No ☐

16. If yes, from which animals and how did you collect it? (for example, collect manure produced at night in the kraal)

- Cattle
- Goats/sheep
- Donkeys
- Pigs
- Poultry

17. How many carts (or other mean of measure) of manure did you collect in cropping season?
18. Did you exchange or give away manure to your relatives or neighbors? Yes ☐ No ☐
19. If yes, how many carts?
20. What did you receive in exchange?
Cash ☐ How much for one cart?
Labour ☐How many man-days for one cart?
other ☐specify

Other livestock products

21. Did you get other animal product in the copping season? Yes ☐ No ☐
22. If yes, specify,

- Which product?
- From which animal?
- The quantity produced?
- For which use (sale, own consumption, exchange),
- If sold or exchanged specify price or against what?

Source of feed / grazing
23. Do you let your livestock graze in the wetlands? Yes ☐ No ☐
24. If yes, indicate the periods when you let your livestock graze/browse in the wetlands?

	Oct	Nov	Dec	Jan	Feb	March	Apri l	May	June	July	Aug	Sept
Cattle												
Donkeys												
Goats												
Sheep												

25. Indicate on the map which part of the wetland you use for livestock grazing?

26. If no, why?
27. Which other grazing area do you use for your livestock? (locate them on the map)
28. Indicate the periods when you let your livestock graze/browse in this area?

	Oct	Nov	Dec	Jan	Feb	March	April	May	June	July	Aug	Sept
Cattle												
Donkeys												
Goats												
Sheep												

29. Did you cut grasses or bushes to feed your livestock last month? Yes ☐ No ☐
30. If yes specify
    Which plants,
    Where did you collect them? (dryland, wetland, irrigation scheme; if wetland locate on a map)
    For which and how many animals?
    What quantity did you collect?
    How much time did you spent in collection?
    Who in the household did it?
31. Do you cultivate forage to feed your livestock? Yes ☐ No ☐
32. If yes what quantity
33. For which and how many animals is the forage used?
34. What is the mode of distribution? (free grazing, in the kraal…)
35. Do you use crop residue for feeding your livestock? Yes ☐ No ☐
36. If yes specify
    From which crops,
    On which plot? (dryland, wetland, irrigation scheme; locate on a map)
    For which and how many animals?
    What is the mode of distribution? (free grazing, in the kraal…)
    What quantity did you use?
    How much time did you spent in collection?
    Who in the household did it?

Livestock production costs

37. Did you buy any feed for your livestock last cropping season? (Including complement, salt…)

What do you buy?	For which animals?	When?	Quantity	Price	To whom?

38. How much did spend last farming season on veterinary expenses?

	Dry season	Wet season	Total
Cattle			
Donkeys			
Goats			
Sheep			

39. Did you do any work on fences last farming season?

Type of work	Cost of implement	Number of days of family labour	Number of days of hired labour	Cost per day
Build a new fence				
Repair a fence				

40. Did you spend anything else for your livestock in cropping season?
41. How many people take your livestock for grazing for you? ___________________________
42. Who are they? ____
43. Do you hire external labor to take your livestock for grazing? Yes [ ] No [ ]
44. If yes, how many per time ____
45. Do you pay to graze your livestock? Yes [ ] No [ ]
46. If yes how much do you pay?
47. Do your livestock drink from the wetland? Yes [ ] No [ ]
48. If yes, what quantity/how often, for how long?

____

49. What other sources of water do you have for your livestock? (List)
50. Do you take water from the wetland for your livestock? Yes [ ] No [ ]
51. What quantity? ____
52. Locate on the map where you get water for your livestock.
53. What other wetland products do your livestock feed on? (List)
54. How will you describe grazing potential in the wetland area in the past five years?
[ ] Increasing, [ ] Decreasing, [ ] Not changing, [ ] I don't know
55. Why do you graze your livestock's in the wetland?__________________________
56. Is/are these plants available in other places outside the wetland? Yes [ ] No [ ]
57. If yes, where are they located?____
58. Do you also get from this source? ____
59. How accessible is it to you? ____
60. If you do not have access anymore to graze in the wetland, what alternative do you have?
____