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

Submitted in partial fulfilment of the requirements for the degree of

PhD Environmental Economics

In the
Department of Agricultural Economics,
Extension and Rural Development
Faculty of Natural and Agricultural Sciences
University of Pretoria
South Africa

August 2010

© University of Pretoria
Dedication

To my daughter, Celine, and wife, Phillipa
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.
Acknowledgements

I am very grateful to my supervisor, Professor Rashid Hassan, for his untiring support throughout my PhD programme. I acknowledge his high intellectual guidance and patience throughout the course of this work. His enormous contribution has really shaped this work to what it is.

This study benefited from the financial support of several institutions. The financial support received from the CEEPA-SIDA PhD programme is greatly appreciated. Further acknowledgement goes to the Challenge Program on Water and Food for research funding provided through Project Number 30, which is hosted by the International Water Management Institute (IWMI). The fellowship I was awarded by IWMI through its capacity-building programme is gratefully acknowledged. The author also acknowledges the International Start Secretariat for providing a START/PACOM Doctoral Research fellowship, which funded some stages of this work.

Various persons deserve to be accredited for the support they gave at various stages of this work. In particular, I would like to thank Dr Renneth Mano for his financial assistance during the early stages of my PhD programme without which I could not have proceeded this far. Dr Sylvie Morardet played a significant role in linking me to the project which funded this research. The contributions of Drs Sylvie Morardet, Mutsa Masiyandima and Dinis Juizo in the development of some components of the ecological-economic model are gratefully acknowledged. I also received some useful comments and references from Dr Donovan Kotze, Dr Sara Aniyar and Professor Max Finlayson which I acknowledge.

Many thanks go to Olalekan Adekola, Charles Mametja and local enumerators for helping in the collection of household survey data. I would also like to thank the people of Ga-Mampa for their cooperation and for offering their time and useful insights during the household survey.
I have benefited a lot from the wonderful atmosphere in the Department of Agricultural Economics, Extension and Rural Development. Special thanks go to Dr Eric Mungatana for his friendship, encouragement and, above all, brotherly advice. I treasure the comfort and encouragement received from my fellow PhD students in particular the following: Davison Chikazunga; Charles Nhemachena; Abebe Beyene; Temesgen Deressa; and Sinqobile Chumi.

My father, Benjamin Jogo sadly passed away before he could see the completion of this work. I would like to acknowledge the foundational support he gave me without which I wouldn’t have proceeded this far. May his soul rest in peace.

The support, love and care of my daughter, Celine, and wife, Phillipa, inspired me particularly during the final stages of this thesis. Thank you for your unwavering support and patience during these trying times.

Finally, many others have contributed in various ways to the completion of this thesis, and although not mentioned by name, you are really appreciated.
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.
TABLE OF CONTENTS

Dedication ........................................................................................................................... ii
Declaration .......................................................................................................................... iii
Acknowledgements ............................................................................................................ iv
Abstract .............................................................................................................................. vi
TABLE OF CONTENTS ................................................................................................... ix
LIST OF TABLES ........................................................................................................... xii
LIST OF FIGURES ........................................................................................................... xiii
Acronyms and Abbreviations .......................................................................................... xiv
CHAPTER 1 ....................................................................................................................... 1
INTRODUCTION .............................................................................................................. 1
  1.1 Background and Statement of the Problem .............................................................. 1
  1.2 Objectives of the Study ............................................................................................. 3
  1.3 Hypotheses of the study ............................................................................................ 4
  1.4 Approaches and methods of the study ...................................................................... 4
  1.5 Organisation of the thesis ........................................................................................ 5
CHAPTER 2 ....................................................................................................................... 6
WETLAND ECOSYSTEMS IN SOUTHERN AFRICA AND THEIR IMPORTANCE
FOR HUMAN WELL-BEING ........................................................................................... 6
  2.1 Introduction ............................................................................................................... 6
  2.2 Biophysical and socio-economic characteristics of the study area........................... 6
    2.2.1 Climate and major ecosystems ........................................................................... 6
    2.2.2 Demographic and socio-economic characteristics ........................................... 10
  2.3 Characterisation of wetland ecosystems .................................................................. 11
    2.3.1 Definition of wetlands ...................................................................................... 11
    2.3.2 Types of wetland ecosystems ........................................................................... 12
      2.3.2.1 Marine systems ......................................................................................... 13
      2.3.2.2 Estuarine systems ...................................................................................... 14
      2.3.2.3 Lacustrine systems .................................................................................... 14
      2.3.2.4 Palustrine systems ..................................................................................... 14
      2.3.2.5 Riverine systems ....................................................................................... 15
      2.3.2.6 Endorheic systems .................................................................................... 15
    2.3.3 The distribution of wetlands ............................................................................. 16
  2.4 The importance of wetlands for human well-being ................................................ 19
  2.5 Major threats to wetland ecosystems in southern Africa ........................................ 24
  2.6 Concluding Summary ............................................................................................. 27
CHAPTER 3 ..................................................................................................................... 29
ANALYTICAL FRAMEWORK FOR RURAL HOUSEHOLDS RESOURCE
ALLOCATION DECISIONS AMONG COMPETING LIVELIHOOD ACTIVITIES ......................................................................................... 29
  3.1 Introduction ............................................................................................................... 29
  3.2 Review of selected literature on the determinants of rural household labour
allocation decisions for competing livelihood activities ................................................. 29
  3.3 The Analytical Framework ...................................................................................... 37
  3.4 Concluding Summary ............................................................................................. 43
6.3.4 Natural wetland vegetation module ............................................................... 101
6.3.5 The economic well-being module.................................................................. 104
6.4 The full system of equations showing the linkages between modelled ecological-economic systems ....................................................................................................... 109
6.5 Specification of model parameters and validation................................................ 114
6.6 Simulation of impacts of alternative wetland management and policy regimes .. 120
6.7 Concluding Summary ....................................................................................... 126

SUMMARY, CONCLUSIONS AND IMPLICATIONS FOR POLICY AND RESEARCH .................................................................................................................... 128

7.1 Introduction ....................................................................................................... 128
7.2 Summary of key findings and policy implications ............................................. 128
7.3 Limitations of the study and areas for further research .................................... 131

REFERENCES ........................................................................................................... 133

APPENDICES ............................................................................................................. 146
Appendix A1: First order conditions for the household optimisation model .......... 146
Appendix A2: Logical rules for hydrological dynamics in the modelled wetland .... 148
Appendix A3: Wetlands-based livelihoods agronomic and socio-economic household questionnaire ........................................................................................................ 149
Appendix A4: Household questionnaire used for economic valuation of provisioning services of the Ga-Mampa wetland................................................................. 175
LIST OF TABLES

Table 2.1: Area under the Limpopo river basin by riparian country .............................. 7
Table 2.2: The main ecosystems of southern Africa ..................................................... 9
Table 2.3: Selected population statistics for the Limpopo basin ................................. 10
Table 2.4: Examples of major wetland types in southern Africa and the main services
they provide ................................................................................................................... 16
Table 2.5: Estimates of global wetland areas by Ramsar region .................................. 17
Table 2.6: Estimates of wetland area (in km$^2$) in Limpopo basin countries .......... 19
Table 2.7: Ecosystem services provided by or derived from wetlands ...................... 21
Table 2.8: Net financial values per user household of selected services for selected
wetland systems in southern Africa ........................................................................... 24
Table 2.9: Major threats to wetlands in southern Africa ranked according to extent of
occurrence ..................................................................................................................... 27
Table 4.1: Vegetation characteristics of the Ga-Mampa wetland ................................. 49
Table 4.2: Sample distribution of interviewed households ........................................... 52
Table 4.3: Number of households using wetlands for different uses and estimated values
per household ............................................................................................................... 54
Table 4.4 Definition of variables used in the econometric analysis ............................... 61
Table 4.5: Descriptive statistics of variables used in the econometric analysis ............. 66
Table 4.6: Seemingly unrelated regression results for labour use in productive activities
and supply of grain and wetland products ................................................................... 71
Table 6.1 Parameters used in the CROPWAT model for maize grain ......................... 98
Table 6.2: Definition of endogenous model variables .................................................... 113
Table 6.3: State variables (stocks) in the model ............................................................ 114
Table 6.4: Parameter values and sources ..................................................................... 115
Table 6.5: Changes in value of selected indicator variables, expressed as percentages of
baseline values .......................................................................................................... 122
LIST OF FIGURES

Figure 2.1: Map showing (a) African river basins and (b) the Limpopo river basin riparian countries................................................................. 7
Figure 2.2: Wetland distribution and location of Ramsar sites across major river basins in Sub-Saharan Africa......................................................... 18
Figure 2.3: Linkages between wetland services and human well-being...................... 22
Figure 4.1: Maps showing the location of the Limpopo province and the Ga-Mampa area ....................................................................................... 45
Figure 4.2: Contribution percentage of flow (i.e. monthly average) from the Mohlapitsi catchment to the Olifants River ......................................................... 47
Figure 4.3: Conceptual picture of the main hydrological fluxes in the Ga-Mampa wetland. ................................................................. 48
Figure 4.4: Trend in wetland area in the Ga-Mampa wetland ........................................ 55
Figure 5.1: The Total Economic Value framework..................................................... 77
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 ........................................ 86
Figure 6.1: Conceptual framework showing the interactions between components of the system .................................................................................... 90
Figure 6.2: Schematic representation of the main hydrological fluxes of the wetland.... 92
Figure 6.3: Comparison of model predicted and actual wetland area converted to agriculture. ................................................................. 119
Figure 6.4: Comparison of model predicted versus actual social grant rate .............. 120
<table>
<thead>
<tr>
<th>Acronym</th>
<th>Abbreviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>CBA</td>
<td>Cost-Benefit Analysis</td>
</tr>
<tr>
<td>CPI</td>
<td>Consumer Price Index</td>
</tr>
<tr>
<td>EPA</td>
<td>Environmental Protection Agency</td>
</tr>
<tr>
<td>FAO</td>
<td>Food and Agriculture Organization</td>
</tr>
<tr>
<td>GDP</td>
<td>Gross Domestic Product</td>
</tr>
<tr>
<td>GLWD</td>
<td>Great Lakes and Wetlands Database</td>
</tr>
<tr>
<td>MCA</td>
<td>Multi-criteria Analysis</td>
</tr>
<tr>
<td>MEA</td>
<td>Millennium Ecosystem Assessment</td>
</tr>
<tr>
<td>NTFP</td>
<td>Non-Timber Forest Products</td>
</tr>
<tr>
<td>PCA</td>
<td>Principal Component Analysis</td>
</tr>
<tr>
<td>SAR</td>
<td>South Africa Rand</td>
</tr>
<tr>
<td>SUR</td>
<td>Seemingly Unrelated Regressions</td>
</tr>
<tr>
<td>UNDP</td>
<td>United Nations Development Programme</td>
</tr>
<tr>
<td>USD</td>
<td>United States Dollars</td>
</tr>
<tr>
<td>USFWS</td>
<td>United States Fish and Wildlife Service</td>
</tr>
</tbody>
</table>