# Seasonality dynamics for investigating wetland-agriculture nexus and its ecosystems service values in Chibuto, Mozambique

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## Abstract

This study is a subsection of CPWF-30 (Challenge Program on Water and Food) that centers on investigating the wetland, agriculture, and livelihoods interactions. Chibuto, the floodplain of Changane River in Mozambique is a representative downstream site for the Limpopo sub-catchment. It largely serves as an agro-ecosystem with agricultural, grazing, and fiber collection as the prominent set of ecosystem services. Additionally, the freshwater springs in the wetland are valuable for local irrigation and domestic use; largely supporting the subsistence livelihood in the poverty-stricken zone. Given this background, the present analysis is a three-tier framework conceptualized to develop a synoptic overview of spatial, social, and economic elements that governs the system dynamics. The first tier describes the seasonal dynamics and wetland-agriculture interactions based on temporal earth observation data (2001-2007), wherein thematic layers on changing land cover are derived. The second tier investigates the social dynamics serving a dual role: to validate the spatial analysis based on the anecdotal information, and decipher the local people's perception of the ecosystems services. The concluding component is an interactive platform that quantifies the spatial and the social attributes based on the coefficients value by Costanza et al. (1997), to derive value changes in ecosystem services and rank their contribution. Furthermore, the sensitivity analysis validates the veracity of the coefficients value. The preliminary findings present visual representation of the wetland dynamics, ecosystem service value transfer to explain trade-offs, and identify 'integrated stress indicators.' Summarizing, the multiple analyses supply a knowledge base that can help improve wetland management while addressing core issues related to local livelihoods.

## Media grab

Estimating the numerical value of the ecosystem services for the resource systems helps to understand the benefit we have lost and cost we might have to pay in future.

## Introduction

This project is concerned with the use of Limpopo's wetlands for the livelihood support of local communities. The study area resembles a typical landscape in lower Limpopo, where wetlands are associated with river bank overflows and sand dunes drainage. These also constitute the main cropping area and a source of food security to local communities. The communities themselves have a protracted experience of managing these resources for their livelihood. The increasing impact of population pressures upon the natural resource base, however, and an increasing need for the system to provide more resources and more food for an increasing population, strongly suggest a more scientific and well planned management approach. Such a well planned framework would facilitate better livelihoods of the beneficiaries and environmental protection of the system. The present project relies on the local population knowledge combined with spatial inputs to improve existing management options using a cross-disciplinary integrated framework. The area in question experiences different uses of its resources, hence it enables the application of the trade-off analysis for striking the balance in use and management of the resource systems.

Chibuto is a flood plain wetland of the Changane River in Mozambique. It primarily serves as an agroecosystem. It is one of the representative sites of the Limpopo floodplain. Agricultural activities are predominantly a mix of vegetables, banana, maize, and rice (seasonal), whilst cattle grazing and fiber (reeds/grass) collection add another set of ecosystem services. Interestingly, the freshwater spring in the eastern zone of the wetland is of high value for local irrigation and domestic purposes, considering the fact that the adjoining Changane River is brackish and the salinity gradient of the river changes with the hydrological inflow and outflow. Synoptically, the major portion of the Chibuto wetland is cultivated with a few small and isolated patches of native wetland vegetation such as grass and reeds. The wetland bears a pertinent value for the subsistence livelihood of the adjoining village with 50% of the population living below the poverty line

The present analysis is a multitiered analysis conceptualized with the objective of developing a synoptical overview of spatial, social, and economic transitions that impact on the system dynamics. The first tier of the analysis reflects the seasonal dynamics describing the wetland-agriculture interactions on a temporal scale. Multispectral geospatial data are analyzed to derive thematic information on land cover/use change. The socioeconomic component serves a dual role; first to fine tune, verify, and validate the spatial analysis based on the anecdotal information derived from focal group discussion and household survey analysis on wetland resource consumption, and second it views what the local people perceive as threats to the wetlands and their current usage, as well as the pattern of change. The third component is an interactive analysis that economically quantifies the derivatives from the above two. The value coefficients method by Costanza et al. (1997) was used as a framework to derive the valued changes in ecosystem services delivered by each land category.

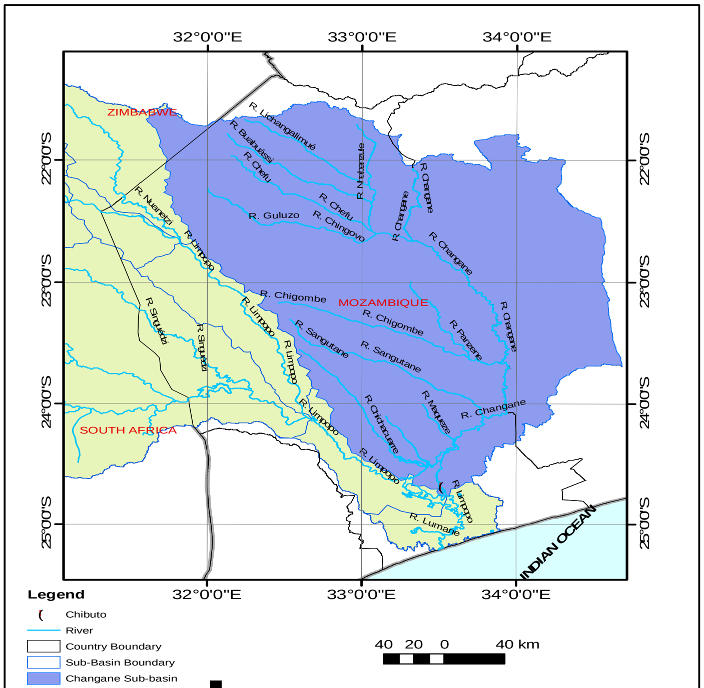


Fig. 1: Study area location

## Methods

### *The study area*

Mozambique is one of the world's poorest countries. Approximately 59.2% of the Mozambican population live below the poverty line (<US$2/day) (INE, 2004), and around 20% of the catchment area is on Mozambican territory. It contributes around 20% of the Limpopo River and finally enters the sea at Xai-Xai province. Changane sub-basin on the northern side of the catchment and immediately adjacent to the Limpopo River, is a low-lying region forming the Changane marsh and floodplains wetlands (INGC, FEWS NET MIND, EMU, 2003). This region serves as an important resource base for crop production and livelihood sustenance for the adjoining communities. The present study focuses on these interactions in the representative wetlands near Chibuto City along the Changane River (Figure 1). The wetlands in the sub-catchment with semi-deep soils offer great potential for agriculture, hence they play an important role in the livelihood of the local people. These ecosystems are productive throughout the whole year. The changing environment of wetlands, however, is driven by the conversion to cultivation, which has potential negative impacts. Prevalence of poverty in the Mozambican portion of the Limpopo Basin is comparatively lower and in Chibuto meeting the basic needs of households in that district is not necessarily easy. It is estimated that approximately 83.7% of people in Gaza Province practice agriculture, solely depending on the surrounding natural resources. In terms of cultivation, the temporary or permanent wetlands and areas adjacent to the river provide wet soil for subsistence agriculture in the cold and dry season from April to September (average rainfall 171-225 mm). The seasonal rainfall in the hot and humid season (October and March) ranges on average between 541 and 600 mm, stimulating the production of pasture to feed the livestock and rainfed crops (INGC, FEWS NET MIND, EMU, 2003). The district of Chibuto has a total population of 197,214 inhabitants (INE, 2008, http://www.ine.gov.mz/censo2007/rp/pop07prov/gaza) and average family size of 4.3 (INE, 1997). Wetland-based agriculture is practiced within community-defined boundaries. Many lakes and wetland zones in the sub-catchment 'wetlands based agriculture' zone serve as a refuge for the communities particularly during the dry season. Against a background of social (unemployment) and natural (irregular rainfall pattern) uncertainties, regulating the conversion of wetlands for agriculture remains uncertain. It is important, however, to ensure that this conversion will not compromise environmental sustainability.

| Data | Year | Resolution |
|---|---|---|
| Wet | | |
| Landsat TM | | 28.5 m |
| Aster | May, 2001 | 15 m |
| Aster | May , 2003 | 15 m |
| Aster | May , 2005 | 15 m |
| | May , 2007 | 15 m |
| Dry | | |
| Aster | Sept, 2005 | 15 m |
| AIOS | Aug, 2007 | 10 m |

Table 1. Tabulation of data used.

### *Assignment of ecosystem services values*

To estimate the value of ecosystem services, the land-use categories derived form the spatial analysis were compared with the 16 biomes identified in the ecosystem services valuation model of Constanza et al. (1997). A coefficient for each land-use class corresponding to one of the biomes (Table 2) and the total value of ecosystem services was calculated using the given equation (Kreuter et al., 2001):

$$ESV = \sum(A_k \times VC_k)$$

Where ESV is the estimative of ecosystem services value, $A_k$ is the area (ha) and $VC_k$ is the value coefficient (US$/ha year) for the land-use category *k*. The change of ecosystem services values was estimated by the difference of the estimated seasonal values for each land-use category between dry seasons and wet seasons (ranging from 2001-07).

Table 2. The Constanza's et al. (1997) biome equivalent for the six land-use-classes, and the corresponding ecosystem values.

| Land-use class | Equivalent Constanza´s et al. biomes | (US$/ha/year) Land-use coefficient |
|---|---|---|
| Cultivated wetland (maize, rice, other) | Cropland | 92,00 |
| Waterbody/lakes/open water/waterlogged areas | Lakes/rivers | 8.498,00 |
| Seasonally cultivated vegetables | Cropland | 92,00 |
| Reeds/sedges | Swamps/floodplains | 19.680,00 |
| Marshlands with shrubs | Tidal marsh/mangroves | 9.990,00 |
| Fallow, grazing land | Grass/rangeland | 232,00 |

***Socioeconomic analysis***

A focus group discussion held in July 2005 involved 45 stakeholders, including the project team. Seven groups were created; agricultural and commercialization group, cattle producers, reeds and grass collectors, fishers, hunters, local government officials and Corridor Sands Mining Company. These closely corresponded with the spatial pattern of land-use units. The discussion focused on their perceptions, problems, vision on the future, and proposed solution of the existing environmental concerns. Participatory rural appraisal techniques such as community mapping, role playing, etc. was used to collect qualitative data that was later related with changes observed from the spatial analysis and some of the results are presented below to explain the land-use and ecosystem services changes.

**Results and discussion**

***Land-use changes***

The land-use/cover maps for the wet season (2001, 2003, 2005 and 2007) and dry season (2005 and 2007) produced from a variety of earth resource data shows that most of the shrubby marshlands have been slowly and gradually converted for cultivation both in dry and in wet season, although the extent and area varies. For the wet season it was observed that the cultivation zone has increased from 30.1 ha in 2001 to 57.1 ha in 2007 as depicted in Figure 2. Also the conversion of wetland area to seasonal vegetable cultivation shows a similar trend. In the dry season the marshland and reed vegetation show shrinkage. This can probably be attributed to dry soil conditions, whilst the cultivated area has significantly risen between 2005 and 2007. The spatial statistics are graphically represented for the wet and dry season in Figure 3a, c.

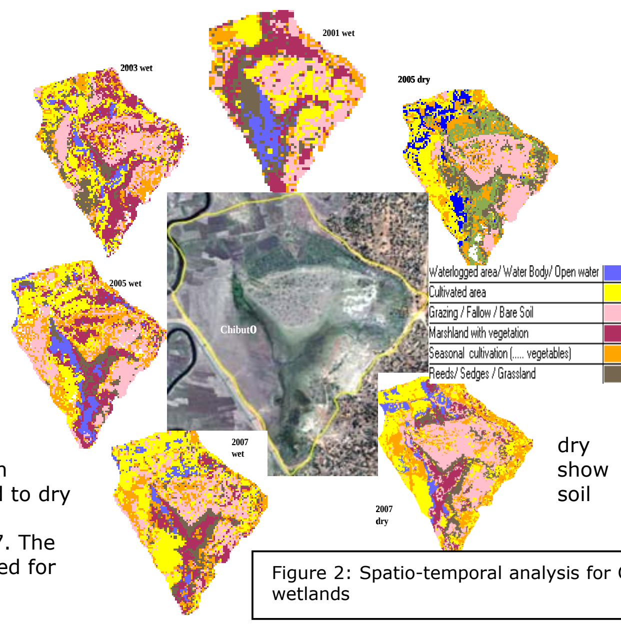


Figure 2: Spatio-temporal analysis for Chibuto wetlands

***Socioeconomic results***

The main outcomes from the socioeconomic analysis have been listed here to support the spatial assessment of changes in land-use pattern. Notably, the stakeholder discussion with farmers highlighted the reduced water availability from the spring, especially during the dry season. This can be explained by the reduction in swamp areas that feed these springs in dry periods. Cattle owners highlighted socioeconomic impacts of the shrinkage in grazing area, which was also confirmed by the spatio-temporal analysis. They also feel that the proportion of cattle population and the extent of shared grazing area are not in equilibrium: for instance, the number of cattle has significantly risen over time. A point of interest raised by the reed collectors was the agriculture intrusion in these zones. These people mentioned that the farmers' encroachment on the reeds area is destroying the reeds, because they burn them to clear the soil for agricultural production. This will gradually lead to widespread negative environmental impacts.

***Changes in ecosystem services***

The economic valuation of ecosystems services for both seasons reflects that the flooded area (reeds/sedges and marsh) contribute more than 80% to wetland service value (Figure 3a, b). The cultivated area is increasing while the rest of the land-use classes are shrinking. The most impacted are the reeds and marshlands areas that provide important ecosystem services (Figure 3c, d). The analysis of annual change for the wet season shows that the conversion of wetland area for cultivation has grown by >2% yearly between 2001 and 2007 (Table 3). Dry season analysis shows similar results. The matrix was used as the base frame for the estimated ecosystem services values and its changing trend over the given time period for both seasons is provided in Annex I. For the wet season, total ecosystem value losses between 2001 and 2007 are estimated at US$350,082. Assuming a linear decrease in ecosystem services, the annual decrease is estimated at US$59,746 for the dry season during the period 2005-2007, ecosystem value decreases are estimated at US$47,195/year.

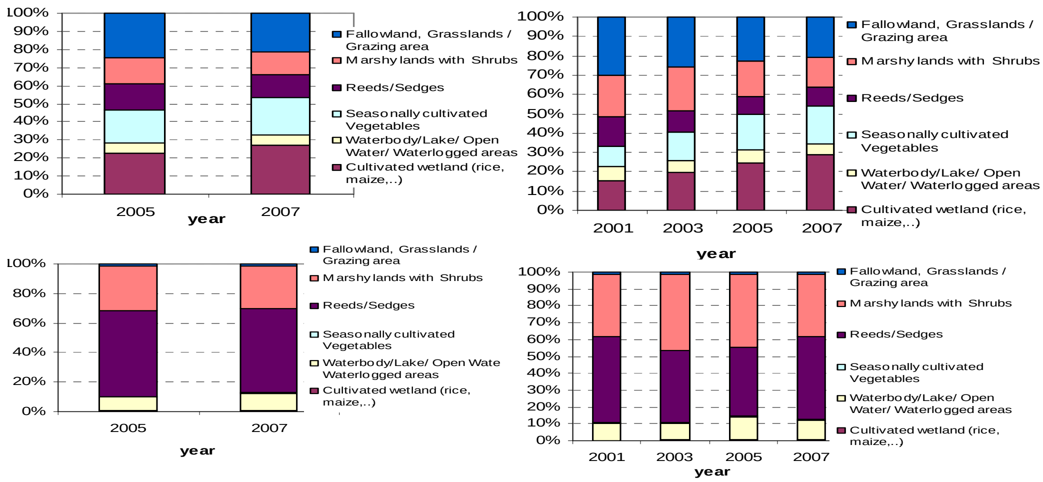


Figure 3. Area (a, c) and value contribution (b, d) contribution of the ecosystem services in Chibuto during wet and dry season.

Table 3. Land-use change from 2001 to 2007 in study area during wet season.

| Land-use classes | 2001-2003 | | | 2003-2005 | | | 2005-2007 | | |
|---|---|---|---|---|---|---|---|---|---|
| | ha | % | %/year | ha | % | %/year | ha | % | %/year |
| Cultivated wetland (rice, maize) | 8.2 | 4.1 | 2.1 | 9.3 | 4.7 | 2.3 | 8.8 | 4.4 | 2.2 |
| Waterbody/lake/open water/waterlogged | -1.9 | -0.9 | -0.5 | 1.9 | 0.9 | 0.5 | -2.8 | -1.4 | -0.7 |
| Seasonally cultivated vegetables | 8.2 | 4.1 | 2.1 | 7.2 | 3.6 | 1.8 | 2.1 | 1.0 | 0.5 |
| Reeds/sedges | -8.5 | -4.3 | -2.1 | -4.0 | -2.0 | -1.0 | 2.6 | 1.3 | 0.7 |
| Marshy lands with shrubs | 2.6 | 1.3 | 0.7 | -8.2 | -4.1 | -2.1 | -7.5 | -3.7 | -1.9 |
| Fallowland, grasslands/grazing area | -8.6 | -4.3 | -2.2 | -6.1 | -3.1 | -1.5 | -3.1 | -1.6 | -0.8 |

**Conclusion**

Based on preliminary results, it was concluded that the major provisioning services of the floodplain are derived from cropping. While considering how these services can be maintained and extended locally, it is important to assess potential impacts on the hydrological functioning of the river and its landscape interactions. Geospatial tools provided the base frame to trace biophysical and livelihood dynamics as discussed in this section. Along with the importance of economic values of ecosystems, goods and services have to be taken into account for informed environmental decision-making that provides a quantitative analysis of the varied wetland services. This has to be based on a cross-disciplinary framework, and calls for greater collaboration between multiple stakeholders involved with the management, conservation, and use of the wetland and its adjoining resources at the landscape level. We recommend that monitoring and measuring changes in resource patterns and evaluation of trade-off between goods/services delivered can contribute a way forward to address some of the uncertainties affecting the sustainable management of such complex systems.

**Acknowledgment**

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Annex I. Estimated ecosystem services values changes in study area in dry and wet season (ESV in US$/year).

| Land-use classes (dry) | 2005 | | | 2007 | | | Overall rank | Trend |
|---|---|---|---|---|---|---|---|---|
| | ESV | % | rank | ESV | % | rank | | |
| Reeds/sedges | 558,764.40 | 58.0 | 1 | 487,839.7 | 57.3 | 1 | 1 | ⇩ |
| Marshy lands with shrubs | 293,568.51 | 30.5 | 2 | 246,244.6 | 28.9 | 2 | 2 | ⇩ |
| Waterbody/lake/open water/waterlogged areas | 92,410.04 | 9.6 | 3 | 99,280.4 | 11.7 | 3 | 3 | ↑ |
| Fallowland, grasslands/grazing area | 11,280.39 | 1.2 | 4 | 9,956.6 | 1.2 | 4 | 4 | - |
| Cultivated wetland (rice, maize) | 4,160.57 | 0.4 | 5 | 4,956.7 | 0.6 | 5 | 5 | ↑ |
| Seasonally cultivated vegetables | 3,379.19 | 0.4 | 6 | 3,797.0 | 0.4 | 6 | 6 | ↑ |
| | 963563.095 | 100 | - | 852074.92 | 100 | - | - | ⇩ |

| Land-use classes (wet) | 2001 | | | 2003 | | | 2005 | | | 2007 | | | Overall rank | Trend |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | ESV | % | rank | ESV | % | rank | ESV | % | rank | ESV | % | rank | | |
| Reeds/sedges | 593,754 | 51.33 | 1 | 426,093.91 | 42.67 | 2 | ####### | 40.67 | 2 | ##### | 49.38 | 1 | 1 | ↑ |
| Marshy lands with shrubs | 427,322 | 36.94 | 2 | 453,218.86 | 45.39 | 1 | ####### | 43.50 | 1 | ##### | 36.80 | 2 | 2 | ⇩ |
| Waterbody/lake/open water/waterlogged areas | 116,913 | 10.11 | 3 | 100,948.83 | 10.11 | 3 | ####### | 13.68 | 3 | ##### | 11.51 | 3 | 3 | ⇩ |
| Fallowland, grasslands/grazing area | 13,884 | 1.20 | 4 | 11,891.71 | 1.19 | 4 | ####### | 1.23 | 4 | ##### | 1.21 | 4 | 4 | ⇩ |
| Cultivated wetland (rice, maize) | 2,840 | 0.25 | 5 | 3,591.96 | 0.36 | 5 | ####### | 0.52 | 5 | ##### | 0.65 | 5 | 5 | ↑ |
| Seasonally cultivated vegetables | 2,001 | 0.17 | 6 | 2,757.14 | 0.28 | 6 | ####### | 0.40 | 6 | ##### | 0.45 | 6 | 6 | ↑ |
| | 1,156,713 | 100 | - | 998,502.41 | 100 | - | ####### | 100 | - | ##### | 100 | - | - | ⇩ |

##signs refer to the estimated values with more than nine natural numbers that have been symbolically represented using hash sign.