Assessment of changes in ecosystem service monetary values in Mozambique

Sérgio Niquisse[a], PedroCabral[b]

[a] Department of GIS and Regional Planning, Universidade Católica de Moçambique, Beira, Sofala, Moçambique

[b] NOVA IMS, Universidade Nova de Lisboa, 1070-312 Lisboa, Portugal

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Sérgio Niquisse, NOVA IMS

Pedro Cabral, NOVA IMS

1. Introduction

Ecosystems provide a wide range of benefits to society known as ecosystem services (ES), which are constituents of well-being (Millenium Assessment, 2003a). However, changes in ecosystems in a global context of increasing demand for agricultural land, forest plantations, and industrial and urban areas are compromising their ability to support mankind (Halpern et al., 2008; Kareiva et al., 2011). By ignoring the benefits provided by nature, mankind puts itself at danger by degrading ES beyond the limits of sustainability (Millenium Assessment, 2003b). One factor having an important impact on the provision of ES is land cover change (Lawler et al., 2014; MEA, 2005) and the effective management of the locations responsible for maintaining ES has been considered essential to prevent their further decline (Cabral et al., 2016; Egoh et al., 2007; Leh et al., 2013; Portela and Rademacher, 2001).

Considerable efforts have been made to draw attention to the importance of preserving natural capital, and also to providing useful information for decision making through economic valuation of ES (Kindu et al., 2016; Sander et al., 2016). To this end, several research works have been carried out at global (Costanza et al., 2014, 1997; de Groot et al., 2012), and/or national and/or regional levels (D'Amato et al., 2016; Joshi and Negi, 2011; Perez-Verdin et al., 2016). Some of these valuation studies also include spatially explicit approaches which provide information on those locations responsible for ES provision (Frélichová et al., 2014; Kremer and Hamstead, 2016; Kubiszewski et al., 2013; La Notte et al., 2012; Liu et al., 2010).

Globally, the ES value in 2011 was estimated at US $125 trillion/yr for 2007 $US (Costanza et al., 2014). According to these authors, between 1997 and 2011 the ES value fell by US $4.3-20.2 trillion/yr as a result of land changes. Losses in ES value at national and regional levels have also been reported (Crespin and Simonetti, 2016; Wang et al., 2015). For Africa there are very few studies about ES valuation as a consequence of land cover change (Dawson and Martin, 2015; Kindu et al., 2016). The main reason for such a scarcity of studies is the absence of data (Leh et al., 2013). The lack of such studies is an important problem because Africa is undergoing significant land changes with important impacts on the provision of ES (Kindu et al., 2016; Power et al., 2010).

Specifically in Mozambique, previous works have analyzed single ES at local or regional levels. (Carissa Wong et al., 2005b) provided a preliminary review of ES threats by region in Mozambique. These authors found that Gaza, Manica, Nampula, Sofala and Tete had all the analyzed ES and well-being constituents being threatened. (Fallis, 2013) reported that the Chibuto district (province of Gaza in south-western Mozambique) largely served as an agro-ecosystem with agricultural, grazing, and fiber collection. More recently, (P. A. L. D. Nunes & Ghermandi, 2015) carried out a study dealing with the understanding and valuation of marine ES for the Northern Mozambique Channel. These authors found that just the Northern Mozambique Channel contributes 5% of national Gross Domestic Product (GDP) in small island states. (Mudaca, Tsuchiya, Yamada, & Onwona-Agyeman, 2015b) show that economic benefits, social inclusion, and forest conservation are the factors influencing household's decisions to participate in the Payments for Ecosystem Services (PES) program in a Community located in Sofala province. (Niquisse et al., 2017) studied the trends of ES and biodiversity biophysical values in Mozambique as a consequence of land cover change. These authors found a moderate increase in climate regulating service between 2005 and 2009, and a decrease in projected water quality (nutrient retention) and biodiversity to the year 2025. Hence studies about ES in Mozambique are rare when compared to other locations, and to our knowledge none of them has provided a monetary valuation at national and/or province levels and/or its changes. The lack of such studies may constitute an important obstacle for maintaining ES provisioning which could be achieved through several available policy instruments in Mozambique when targeting specific or several ES (Table 2.1).

Table 0-1: Policy instruments available in Mozambique related to ES analysed in this study

Biome	Ecosystem service(s)	Policy instrument
Cropland Grass/Rangeland	Food	National Agriculture Investment Plan (República de Moçambique, 2013)
		Action Plan for Poverty Reduction (República de Moçambique, 2011)
Forest	Biodiversity protection	National Strategy for the Sustainable Development of Mozambique (MICOA, 2007)
	Food	National Agriculture Investment Plan (República de Moçambique, 2013)
		Action Plan for Poverty Reduction (República de Moçambique, 2011)
	Raw materials	National strategy for forests (RCM, 2015)
		Strategy for the Mangrove Protection (República de Moçambique, 2015a)
Wetlands	Food	National Agriculture Investment Plan (República de Moçambique, 2013)
		Action Plan for Poverty Reduction (República de Moçambique, 2011)
	Raw material	National Strategy for Forests (RCM, 2015)
		Strategy for the Mangrove Protection (República de Moçambique, 2015a)
		National Strategy for Hydrological Resources Management (República de Moçambique, 2007)

	Water	
Desert	Raw material	National Plan for Fighting Desertification (RCM, 2014)
Lakes / Rivers	Recreation	Strategic Plan for Tourism Development in Mozambique (República de Moçambique, 2004)

In line with the national TEEB (*The Economics of Ecosystems and Biodiversity*) assessments (TEEB, 2010), this study seeks to provide the first monetary assessment of ES for Mozambique. Freely available data was used to assess the ES value for Mozambique and its provinces, between years 2005 and 2009, using a spatially explicit approach. Knowing ES value and its spatial dynamics at national and province levels calls for the importance of considering ES in national well-being accounting and for going beyond GDP as a national welfare measure and policy goal.

2.1. Methods

2.1.1. Study area

Mozambique, officially the Republic of Mozambique, is located in Southeast Africa and comprises a land surface of about 800,000 km^2 (Figure 2.1). Mozambique has a diverse landscape ranging from coastal plains to savanna, and woodlands to mountains. There are numerous rivers flowing from west to east into the Indian Ocean, with the Zambezi and Limpopo being the two largest. Mozambique is divided into 11 provinces and shares borders with six countries. It is separated from Madagascar by the Mozambique Channel to the east. Mozambique had about 27.22 million inhabitants in 2014 (World Bank, 2016). The capital and largest city is Maputo with 1,241,702 inhabitants (INE, 2015). This country became independent from Portugal in 1975, followed by a civil war which ended in 1992. The first democratic elections took place in 1994 and the country has enjoyed political stability since then (Brouwer and Falcão, 2004). Mozambique's GDP was 14,807x10$^{\wedge 6}$ US$ in 2015 (World Bank, 2016). Mozambique ranked 180 out of 188 countries in the most recent Human Development Index (UNDP, 2015).

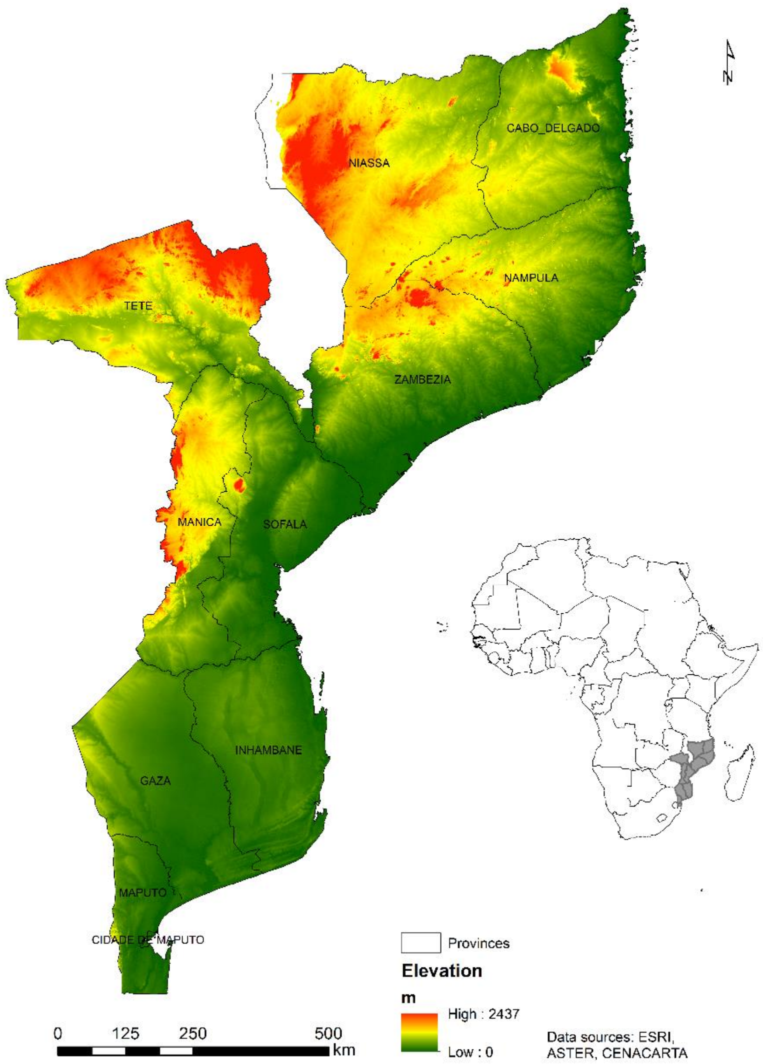

Figure 0-1: Study area

2.1.2. Data collection and processing

Land cover maps of Mozambique for the period of 2004-2006 (hereinafter referred to as 2005) and 2009 from ESA/ESA GlobCover Project (http://due.esrin.esa.int/page_globcover.php) were used in this study. These were the only two available reference years for these datasets, which differentiate 19 classes of land cover (Table A.1, Annex 1). This product was derived from data acquired by the ENVISAT MERIS sensor with 300m of spatial resolution (GlobCover, 2015). The overall accuracy, weighted by the area proportions of the various land cover classes, is 73% (Defourny et al., 2009). Additional data for administrative boundaries were obtained from the National Center of Cartography (http://www.cenacarta.com).

Biomes are "the World´s major communities classified according to the predominant vegetation and characterized by adaptations of organisms to that particular environment" (Campbell, 1996). There are many ways to categorize the biomes according to different criteria, such as climate, habitat, animal and plant adaptation, biodiversity, and human activity (WWF, 2016). To identify the biomes in Mozambique, the land cover classes from GlobCover dataset were assigned to the corresponding biome (Annex 1). GlobCover classes were converted into a simplified land cover scheme (Bai et al., 2014). These classes were then matched to biomes (Costanza et al., 2014). This procedure resulted in seven biomes for Mozambique: Forest, Grass/Rangeland, Wetland, Desert, Urban, Lakes/Rivers, and Cropland (Fig. 2).

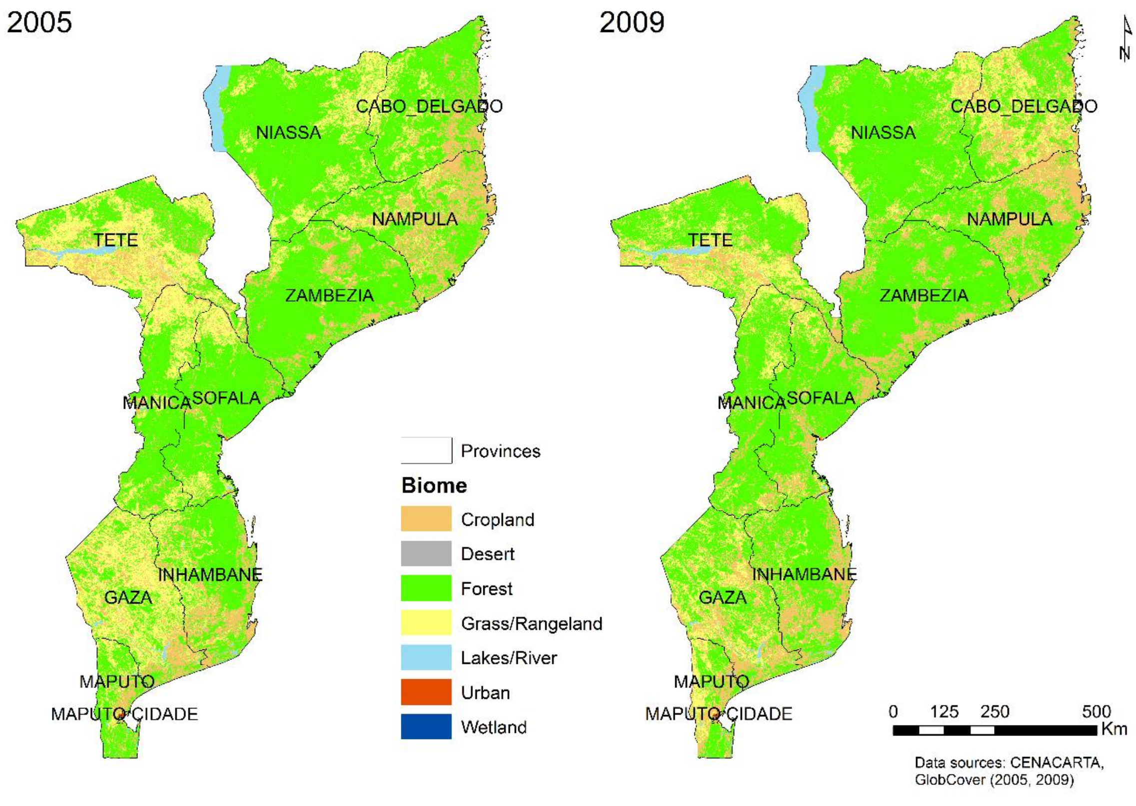

Figure 0-2: Biomes of Mozambique in 2005 and in 2009

2.1.3. Assignment of ecosystem service values to biomes

Several economic valuation methods have been applied to determine the value of ES, such as the simulated market approach (Guy Garrod and Kenneth G, 1999), the surrogate market approach

(Wu et al., 2013) and the benefit transfer method (Chen et al., 2014; Farber et al., 2006). The last has been used to estimate value of ES of global biomes and their changes (Costanza et al., 2014, 1997). In this study a benefit transfer method was used to estimate the ES value of Mozambique. This technique consists of utilizing existing valuation studies or data to estimate the ES value in a similar location (Costanza et al., 1997). It is commonly used when there are insufficient resources and/or time to carry out detailed on-the-ground data collection (Wilson and Hoehn, 2006), as is the case of the present study.

The valuation of the ES of each biome identified was carried out using the values obtained in the Ecosystem Services Valuation Database (ESVD) (Van der Ploeg and de Groot, 2010), made available by the Ecosystem Services Partnership (ESP – http://www.es-partnership.org). ES studies available in the ESVD for the existing biomes in Mozambique or in locations at similar latitudes were the ones selected for this study (Table 2.2). All ES value estimates were converted into 2009 US$/ha/yr to match the date of the last GlobCover dataset. The Urban biome was not considered for ES valuation because there was not any study comparable to Mozambican urban areas, including the revised urban coefficient reported in (Costanza et al., 2014) which was considered highly overestimated (Yi et al., 2017). In any event, the total urban area of Mozambique was 17,163ha in 2009, representing only about 0.02% of the total area. Thus, the impact of this biome in total ES value was relatively low. Some of the values in Table 2.2 concern only one ES for each biome (e.g. Cropland, Grass/Rangeland, Desert, and Lakes/River) while others represent multiple ES per biome (Tropical Forest, and Wetland). In this last case, all the values were summed to determine the ES value for these biomes. In the cases in which the values were in different currencies (e.g. Tropical Forest and Grass/Rangeland), the ES coefficients were converted into 2009 US$.

The total value of the ES (ES value) was estimated using (Costanza et al., 1997) (1):

$$\text{ES value} = \sum(A_k \times VC_k) \qquad (1)$$

where A is the area (ha), and VC the value coefficient in ($/ha/year) for each land cover category k. The changes in ES value were obtained by calculating the difference between the estimated values for each year (Kreuter et al., 2001).

Table 0-2: Biomes and correspondent ES value coefficients ($/ha/year)

Biome	ES coefficients ($/ha/yr)	Country	Ecosystem services	Source
Cropland	77.6	Tanzania	Food	(Turpie, 2000)
Tropical Forest	11.95 (sum of all ES values and conversion from RAND to US$ in 2009)	South Africa	Raw materials, Food, Biodiversity protection, Pollination	(Rausser, Small, Rausser, & Small, 2000) (Mike H. Allsopp, Willem J. de Lange, 2003)
Grass/Rangeland	185 (conversion from PULA to US$ in 2009)	Botswana	Food	(Barnes, 2002)
Wetland	98.3 (sum of all ES values)	Malawi	Food, Raw material and Water	(Schuijt, 2002)
Desert	166 (sum of all ES values)	Kenya	Raw material	(Mogaka, 2007a)
Lakes/River	1,205.4 (sum of all ES values)	Kenya	Recreation	(Mogaka, 2007b)

2.2. Results

2.2.1. Changes in biomes' areas between 2005 and 2009

The area of the biomes, as well as gains and losses in each category between 2005 and 2009, are shown in Table 2.3. Forest was the biome that accounted for most of the Mozambican territory (59.57% and 61.13% of total area in, respectively, 2005 and 2009). This biome increased 2.6%

during this time period. The greatest changes were in the Grass/Rangeland (-26.7%) and Cropland biomes (26.6%). These biomes represented, respectively, 16.49%, and 21.5% of total area of Mozambique in 2009. The Grass/Rangeland biome lost 3,732,984ha to the Cropland and 6,016,653ha to the Forest. On the other hand, the Cropland lost 4,513,455ha to the Forest and 1,419,066ha to the Grass/Rangeland. Although the Desert was a small proportion of Mozambique, this biome also increased substantially between 2005 and 2009 (39.9%).

Table 0-3: Changes in biome's surface area (ha) between 2005 and 2009. Cells indicate the amount of area contributed to each biome in 2009 (columns) from the 2005 biome's (rows)

	2009									
2005	Class	Cropland	Forest	Grass/Rangeland	Wetlands	Urban	Desert	Lakes/River	Total ha	%
	Cropland	7,349,436	4,513,455	1,419,066	243	0	1,089	0	13,283,289	16.98
	Forest	5,718,177	37,266,831	3,608,100	666	0	261	0	46,594,035	59.57
	Grass/Rangeland	3,732,984	6,016,653	7,847,829	414	0	2,178	0	17,600,058	22.50
	Wetlands	216	468	81	2,952	0	0	0	3,717	0.00
	Urban	243	126	234	0	17,163	0	0	17,766	0.02
	Desert	144	27	1,836	0	0	2,871	0	4,878	0.01
	Lakes/River	13,842	18,738	24,273	0	0	423	655,209	712,485	0.91
	Total ha	16,815,042	47,816,298	12,901,419	4,275	17,163	6,822	655,209	78,216,228	
	%	21.50	61.13	16.49	0.01	0.02	0.01	0.84		
	∆ % 2005-2009	26.6	2.6	-26.7	15.0	-3.4	39.9	-8.0		

2.2.2. **Changes in ES value between 2005 and 2009**

The estimated total value of ES in 2005 was US$ 5,703.6x10^6. In 2009, this value was US $5,054.4x10^6, representing a decrease of US $649.2x10^6 (-11.4%) (Table 4). The biome with the highest ES value in 2009 was the Grass/Rangeland (US$ 2,386.8 x10^6), i.e. 47.2% of total ES value of the country (Fig. 3). Overall there was an average yearly decrease of -2.3% in Mozambique's ES value. The biomes that considerably increased their ES value were the Desert (39.9%), the Cropland (26.6%) and the Wetlands (15%). In contrast, the Grass/Rangeland (-26.7%) significantly decreased its ES value during the study period. The remaining biomes, i.e. Forest and Lakes/River, had changes in ES value of less than 10% between 2005 and 2009.

Table 0-4: Total ecosystem service value (in US$/ha/yr, 2009 price levels) estimated for each biome in Mozambique using regional coefficients, and the overall change between 2005 and 2009

Biome	ESV value (US$*10^6) 2005	ES value % 2005	ES value (US$*10^6) 2009	ES value % 2009	∆ ES value (US$*10^6) 2005-2009	Average Annual Change (US$*10^6)	Annual Change (%)	∆ ES value (%) 2005-2009
Cropland	1,030.8	18.07	1,304.8	25.82	274.1	68.5	6.6	26.6
Forest	556.8	9.76	571.4	11.31	14.6	3.7	0.7	2.6
Grass/Rangeland	3,256.0	57.09	2,386.8	47.22	-869.2	-217.3	-6.7	-26.7
Wetlands	0.4	0.01	0.4	0.01	0.1	0.0	3.8	15.0
Desert	0.8	0.01	1.1	0.02	0.3	0.1	10.0	39.9
Lakes/River	858.8	15.06	789.8	15.63	-69.0	-17.3	-2.0	-8.0
Total	5,703.6	100	5,054.4	100	-649.2	-162.3	-2.8	-11.4

2.2.3. **Changes in ES value by province**

According to Table 2.5, all the provinces decreased their ES value between 2005 and 2009, with Gaza (-16.6%) and Sofala (-15.9%) the ones decreasing the most. Cabo-Delgado was the province that decreased the least (-4.3%). Niassa was the province with the highest ES value in 2009 (US$ 837.5x10^6). However, this province lost -10.6% of its ES value since 2005, i.e. US$ -99.35x10^6. Gaza was the province that contributed most to ES value loss with US$ -101.0x10^6.

Maps of Fig. 3 depict ES value in Mozambique using a 300m spatial resolution cell. These maps were built by associating the ES value in $/ha/yr to each biome.

Table 0-5: Total ecosystem service value (ES value in US$//ha/yr, 2009 price levels) estimated for each province in Mozambique using regional coefficients, and the overall change between 2005 and 2009

Province	**ESV($/ha/yr)*10^6 2005**	**ESV($/ha/yr)*10^6 2009**	**∆ 2005-2009 ($/ha/yr)**	**∆ 2005-2009 (%)**
Cabo-Delgado	546.1	522.6	-23.5	-4.3
Gaza	609.5	508.5	-101.0	-16.6
Inhambane	464.6	402.7	-61.8	-13.3
Manica	481.8	415.6	-66.2	-13.7
Maputo	170.5	156.2	-14.2	-8.3
Nampula	486.9	444.1	-42.9	-8.8
Niassa	936.6	837.4	-99.3	-10.6
Sofala	492.6	414.5	-78.1	-15.9
Tete	830.3	732.6	-97.7	-11.8
Zambeze	683.9	619.5	-64.5	-9.4
Cidade de Maputo	0.7	0.6	-0.1	-11.7
Total	5703.6	5054.3	-649.3	-11.4

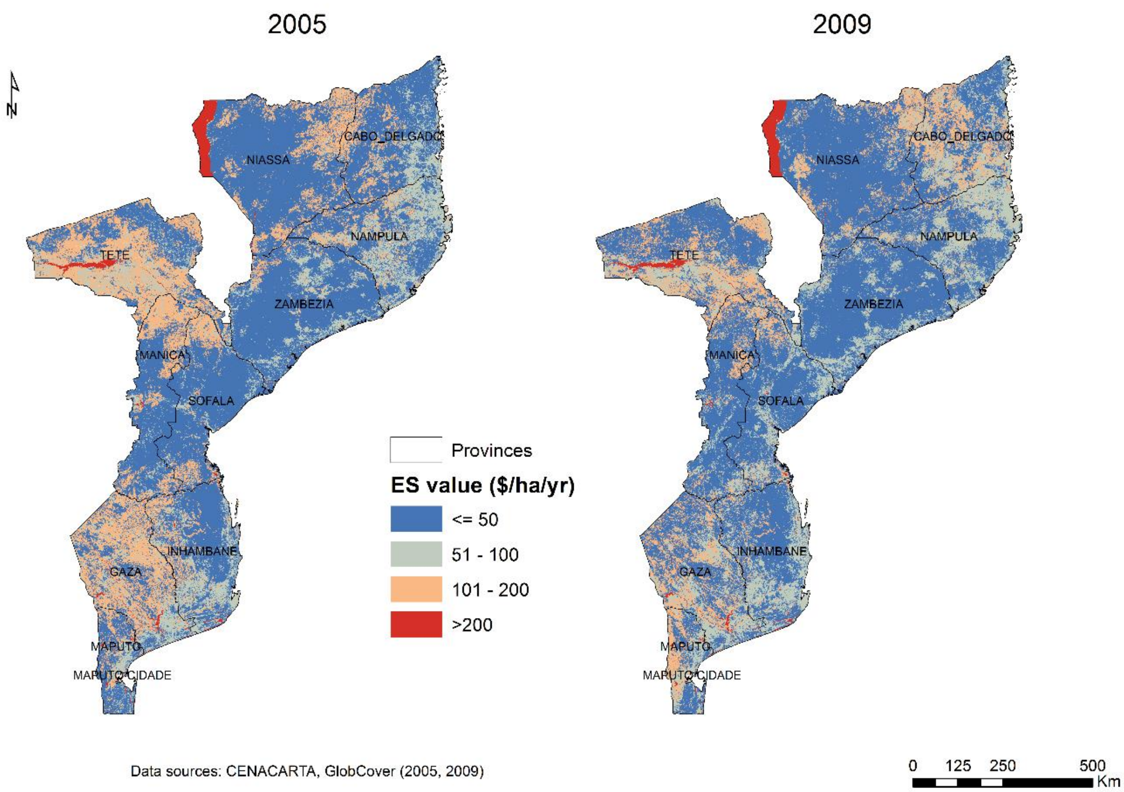

Figure 0-3: ES value in 2005 and 2009 (in US$/ha/yr, 2009 price levels)

In Table 2.6, it is possible to see the changes of ES value (%) per biome at province level between 2005 and 2009. A significant increase in the Cropland biome was noticed in the provinces Niassa (148.2%), and Sofala (166.7%). With the exceptions of Cabo-Delgado (88.9%) and Maputo (34.8%), the Grass/Rangeland biome decreased in all of the provinces, ranging from -53.1% in Zambeze to -27.5% in Niassa. It is worth noting that the increase of Grass/Rangeland in Cabo Delgado and Maputo provinces was coincident with an important increase in the Cropland biome for both provinces (45.9% and 51.9%, respectively). The Forest biome supported the increase of these biomes (-32.9% and -92.9%, respectively). The greatest (and only) decrease in the Wetland biome was verified in Sofala (-2.6%). Tete was the only province that increased the Wetland surface area (30.2%). All other provinces had no changes in this biome. Manica had a very significant increase in the Desert biome (1900%). This biome has increased in almost every provinces except Niassa (-100%), Tete (0%) and Cidade de Maputo (-16.7%). Finally, the

Lakes/Rivers biome has decreased in all the provinces, ranging from -0.7% in Niassa to -22.9% in Cabo Delgado.

Table 0-6: Changes of ES value (%) per biome at province level between 2005 and 2009

Province	Cropland (%)	Forest (%)	Grass/ Rangeland (%)	Wetland (%)	Desert (%)	Lakes/River (%)
Cabo-Delgado	45.9	-32.9	88.9	0.0	55.6	-22.9
Gaza	20.6	51.9	-42.3	0.0	23.9	-9.1
Inhambane	23.0	2.8	-50.4	0.0	44.0	-8.3
Manica	57.6	12.0	-42.8	0.0	1900.0	-9.4
Maputo	51.9	-92.9	34.8	0.0	35.0	-5.4
Nampula	-0.7	9.6	-30.3	0.0	46.4	-14.3
Niassa	148.2	2.8	-27.5	0.0	-100.0	-0.7
Sofala	166.7	-10.0	-45.3	-2.6	78.3	-11.0
Tete	-5.8	45.7	-31.6	30.2	0.0	-2.8
Zambeze	20.7	-0.9	-53.1	0.0	11.2	-9.9
Cidade de Maputo	55.9	-23.3	-32.5	0.0	-16.7	-17.5

Fig. 4 shows the provinces which have changed their ES value above and below the mean using a standard deviation classification scheme. The yellow color denotes the provinces for which the change in ES value was close to the mean between 2005 and 2009 (between -0.5 and 0.5 standard deviations). Light brown (-1.5 to 0.5 standard deviations) and dark brown (<1.5 standard deviations) colors represent the provinces which have changed their ES value below the mean. Turquoise and (0.5 to 1.5 standard deviations) and dark turquoise (>1.5 standard deviations) colors represent the provinces which have changed their ES value above the mean.

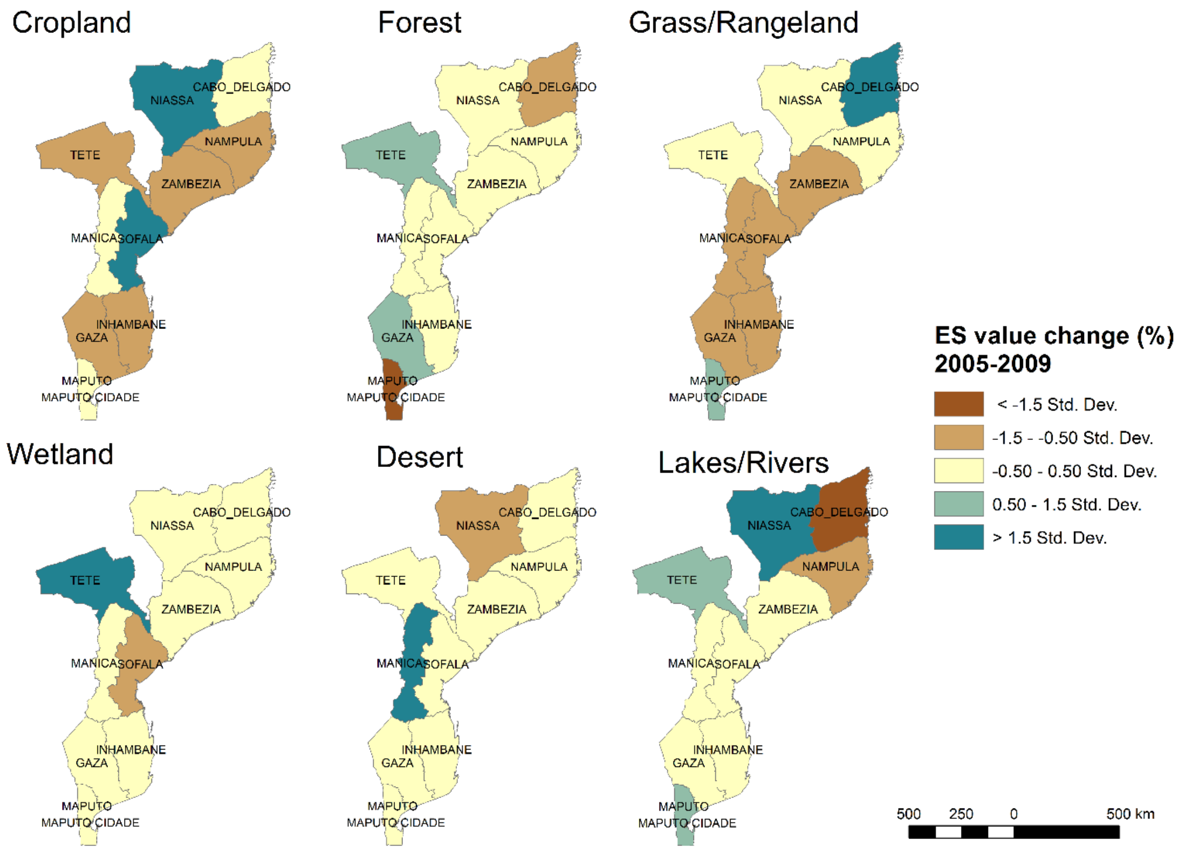

Figure 0-4: Changes of ES value (%) per biome using standard deviations at province level between 2005 and 2009

2.3. Discussion

2.3.1. Changes of ES value in Mozambique as a consequence of land cover change

In this study the services provided by the Cropland and Grass/Rangeland concern only food from agriculture. However, the ES value for Cropland is 77.6 US$/ha/year whereas the Grass/Rangeland is valued at 185 US$/ha/year, which is negatively affecting the total ES value for Mozambique. The Grass/Rangeland biome lost area and value mostly to Forest and Cropland (Table 2.3). It is likely that in the long term, Cropland's ES value will continue growing due to the need for food production to meet the needs of the country's increasing population (World Bank, 2016). This conversion has an important impact on ES provided by Forest and Grass/Rangelands as well, as these are the biomes that supported the growth of Cropland (Table 2.3). The conversion of Grass/Rangeland biome to Forest is a positive factor regarding the provision of several ES, such as flood regulation, which is a serious problem in Mozambique. Floods were very intensive from 2007 to 2009, when several rivers rose dramatically (República de Moçambique, 2008; UNISDRI, 2015).

Forests provide services such as raw materials, food, biodiversity protection and pollination services. However, the time period valued in this study witnessed a near equal conversion of the Forest biome to Cropland. According to (FAO, 2013), the main farming system in Mozambique is rain-fed subsistence farming with low levels of productivity due to the lack of conditions, including technology, market accessibility, storing infrastructure, and agricultural organization (Woodhouse, 2014). Therefore, to increase production, small farms increase agricultural land by converting other biomes into Cropland, mainly Grass/Rangeland because it is much easier for them to prepare the land. The changes in ES value of the other biomes were little, or irrelevant, if considering their proportional area, i.e. less than 1% of total area of Mozambique (Wetlands, Desert, Lakes/River). From this group of biomes the Desert increased its ES value significantly (39.9%). This value was very high in Manica (1900%). Despite the proportional low value of this biome, this should be considered carefully because severe desertification is a serious problem in Mozambique (República de Moçambique, 2015b).

At province level, the total ES value changed negatively in all case. However, changes in biomes were different in both magnitude and location. Manica, Sofala, and Niassa were the provinces with the greatest increase in ES value in Cropland. As mentioned above, the Cropland increased in order to increase the food production as agriculture is considered the key factor for reducing poverty in the country (Cunguara et al., 2013). Cidade de Maputo also had an important increase in Cropland (55.9%). This province hosts the capital and the most populated city of Mozambique: Maputo. However, it is important to note that the increase of Cropland led to the decline of ES value of other biomes, i.e. Grass/Rangeland, Forest and Lakes/Rivers, which provide important ES.

2.3.2. Limitations and uncertainties

The benefit transfer method has been widely used in ES valuation studies (Bateman et al., 2011; Boyd and Wainger, 2003; Chen et al., 2014; Costanza et al., 2014; Gaodi et al., 2010; Kubiszewski et al., 2013; Liu et al., 2010; Maes et al., 2012; Troy and Wilson, 2006). However, this method has several shortcomings, such as being prone to errors resulting from the lack of correspondence between the estimate of ES value per hectare to all areas having the same land-cover or habitat type

(Plummer, 2009). The ES analyzed in this study are limited to the ones available in the ESVD (Annex 1). However, knowing that each biome may deliver multiple ES necessarily makes our ES value estimates undervalued. For instance, the Tropical Forest delivers relevant services such as erosion protection, water service, gas regulation, etc. However, the study selected in the ESVD to value this biome in Mozambique valued only raw materials, food, biodiversity protection, and pollination services. Also, the ES analyzed per biome were valued all together making it impossible any kind of individualization regarding each specific service. Consequently, an analysis on how much each single service changed between the two dates was not provided. Additionally, assuming constant ES value or lack of measurements, and poorly representative sizes of study sites are also potentially important problems when extrapolating ES values (Eigenbrod et al., 2010; Frélichová et al., 2014).

In this study the biomes and corresponding ES values came from studies applied to different regions, scales, and time, also constituting a source of uncertainty. These studies may also contain biased data due to biophysical and socio-economic conditions different from our study area making them unsuitable for the benefit transfer method application (Wilson and Hoehn, 2006). Finally, the ecological pattern, quality, and processes have strong influences on ES value (Wang et al., 2014; Zang et al., 2017). However, in our study, changes in ES value ignore these factors as only the changes of ecosystem areas are considered.

Land cover data availability was also an important limitation in this study. The most recent data available were from 2005 and 2009, which is quite old considering Mozambique's increasing performance in economic activity (World Bank, 2016). The spatial resolution of the land cover data is coarse and may lead to generalization problems. For instance, small area sizes of wetlands, which have their own typical ES, may be generalized to other land cover types. Additionally, the accuracy value (73%) of GlobCover is below the minimum level of interpretation accuracy in the identification of land use and land cover categories from remote sensing data which should be at least 85% (Anderson et al., 1976). Finally, the conversion of the land cover classes from GlobCover to biomes is also a source of uncertainty due to the transitional characteristics of some of the land cover classes.

Despite all these limitations, and knowing that the evaluation of ES using primary data is costly forcing researchers to work with proxies (Eigenbrod et al., 2010), this studied tried to minimize them. Still, it was not possible to eliminate all of the problems in our assessment considering the available resources. Follow-up studies for more accurate ecosystem service assessment, which will include the use of tools such as InVEST (Tallis et al., 2014), are necessary to reduce the impact of these errors.

2.4. Conclusions

This study contributes to ES science by providing the first monetary evaluation of ES and changes as a result of land cover change in Mozambique between 2005 and 2009. Spatial planning decisions benefit from the incorporation of the effects on ES (Geneletti, 2011). The measurement of the ES value with the benefit transfer method at the province level provided an innovative perspective and a better understanding of the different regional ES value dynamics, which are closely linked to the economic development of the country.

The findings can help policy-makers to optimize Mozambique's land use structure to maximize total ES value. For instance, with this type of information, trade-offs in ES resulting from alternative land use policies can be assessed and used in the definition of land planning policies. The existing policy instruments (Table 2.1) should be jointly coordinated for targeting specific or several ES with the aim of achieving sustainability in the country. With this study, at province level, it is possible to inform policy makers regarding the responsibility of each province in ES provisioning for Mozambique (Table 2.6). The policy makers now have the tools to know how each province is performing regarding ES provisioning (Fig. 4). This will enable them to develop specific efforts for the underperforming provinces. An effort to include sustainability goals based on ES on the existing policy instruments (Table 2.1) is still lacking and it must be pursued by the Mozambican authorities.

It is important to note that not all the services provided by the biomes were assessed, such as climate regulation provided by the Forest biome that could also be linked to specific policy instruments (e.g. the National Strategy for Climate Change Adaptation and Mitigation (República de Moçambique, 2015b)). Thus, this study's results can be considered only as a preliminary ES assessment with the aim of raising awareness of policy makers about the importance of ES.

Although some suitable studies exist in the ESVD to apply the benefit transfer method, there is a lack of updated valuation studies, both biophysical and monetary, for Africa and, particularly, for Mozambique. Thus, there is a strong need to improve the number of ES valuation studies for this important continent and, most specifically, for Eastern African countries that are undergoing significant land changes. Nevertheless, for an initial assessment, the data and methodology can be very useful as a basis for future ES valuation studies in Mozambique aiming at the preservation of ES provisioning.

Mozambique’s total ES value was estimated at 5,054.4x10^6 US$ for the year 2009, representing a variation of -11.4% since 2005. However, considering that the ES value for the year 2009 was about half of the GDP for the year 2009 (10,910x10^6 US $), one might conclude that the ES value of Mozambique is substantial. Additionally, the results of this study can also be used to raise awareness about the importance of preserving ES to improve human-wellbeing in Mozambique, and for going beyond GDP as a national welfare measure and policy goal. Future research should focus on multi-ES that exist in the country, which are not yet studied and/or valued, with the objective of updating the ES value estimates presented in this study.

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