World Journal of Advanced Research and Reviews, 2020, 08(03), 108–124

World Journal of Advanced Research and Reviews

e-ISSN: 2581-9615, Cross Ref DOI: 10.30574/wjarr

Journal homepage: https://www.wjarr.com

(Research Article)

Economic valuation of ecosystem services of Eastern Corridor of Selous- Niassa ecosystem, Tanzania and Mozambique

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Publication history: Received on 20 November 2020; revised on 01 December 2020; accepted on 05 December 2020

Article DOI: https://doi.org/10.30574/wjarr.2020.8.3.0455

Abstract

This paper explains the less known economic values of ecosystem services of Selous – Niassa ecosystem as a result of spatial and temporal changes of land use and land cover. Objectives of the study were to determine changes of ecosystem services, ecosystem functions, estimate ecosystem services of trees loss/gain and analyse ecosystem services of wood balance resulted from LULCC. The study employs benefit transfer method on local and global estimation of ESV with combination of field survey, remote sensing and GIS techniques Generally, annual changes of ESV for the period 1986 - 2016 estimated as US$ 7 million and US$ 20 million using local and global ESV coefficients respectively. Additionally, for three decades there is local and global annual loss of US$ 322 million and US$ 654 million respectively of ecosystem functions mostly from closed woodlands, open woodlands, grassland and water from 1986 to 2016. Also, there is total annual local and global gain of ecosystem functions of US$ 106 million and US$ 118 million respectively from bushland and cultivated land. The gain of ecosystem functions comes from provisioning services and the degradation of ecosystem functions led by, supporting services, then regulatory services and lastly cultural services. Furthermore, for the period 1986 – 2016 an annual ecosystem services of trees gained by US$ 315 million and US$ 642 million for local and global ESV respectively. Lastly, estimated local and global ESV of wood supply in the study area for the year 2016 is at least 25 times the average demand per year per capita. The study recommends an emergence of reviewing management and conservation strategies to attain sustainability of Selous-Niassa ecosystem.

Keywords: Ecosystem services; Land use and land cover; Ecosystem services of trees and Wood balance

1. Introduction

1.1. Background Information

Ecosystems provide services that are essential for life (Millennium Ecosystem Assessment, 2005; Raudsepp-Hearne *et al*., 2010; and Schmidt *et al*., 2016). These services support ecological processes and functions and provide resources for the survival of all organisms. There are four categories of ecosystem services includes; (i) provisioning services, (ii) supporting services, (iii) regulating services and (iv) cultural services (Ecosystem Assessment, 2005a; Food and Agriculture Organization, 1997 and TEEB, 2015). The values of these services are underestimated or ignored in commercial markets and decision making processes (Kahn, 2005; Pascual, 2010; and Schmidt *et al.*, 2016). This scenario creates risks to natural capital due to probable negligence management (Schmidt *et al.*, 2016). Economic valuation of ecosystem services (ES) is lively debated and finally argued that ES quantification in monetary terms harmonizes conservation strategies and economic objectives, accurately informs decision-makers and finally lessens environmental degradation(Laurans *et al*., 2013; Martin-Lopez *et al*., 2013; and Schmidt *et al*., 2016). Monetary valuation is seen as a powerful tool for decision making worldwide, but preferred to be vital in developing countries (COP, 2010; ten Brink *et al*., 2011; and Schmidt *et al*., 2016). Estimation of ES in monetary values combine a variety of interdisciplinary

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measurements in one unit, they are understandable and easily to communicate, and promise transferability across sites (Downing & Ozuna, 1996; Smith & Pattanayak, 2002; Schmidt *et al*., 2016; and Msofe *et al*., 2020)

ES are valued in prominent assessments of natural capital (Schmidt *et al*., 2016; and Msofe *et al*., 2020), in activities of economic development and poverty reduction (TEEB, 2015; SEEA, 2015 and WAVES, 2015), hazard mitigation programs (Miller, 2013 and Schmidt *et al*., 2016) and business studies (Elliot *et al*., 2014; Hanson *et al*., 2012; and Schmidt *et al*., 2016). The assessments of natural capital can be done through primary valuation methods that follow different economic approaches (travel cost, hedonic, production approaches, conjoint analysis, opportunity cost and replacement cost) and biome (land use proxy-based) method which is the benefit transfer approach (applies the use of the existing information of one area to a new one that has little or no information) (De Groot *et al*., 2012; Farber *et al*., 2006; Richardson *et al*., 2015 and Msofe *et al*., 2020). The benefit transfer approach is popular applied when there is scarcity of primary information and it is also time and cost effective. It provides first-hand information for decision-makers on various aspects of policy actions and strategies for sustainable management of natural capital (Kreuter *et al*., 2001; Kubiszewski *et al*., 2017 and Wang *et al*., 2018). Besides, changes in patterns, scales and intensities of land use and land cover (LULC) types habituate ecosystem services (Tolessa *et al*., 2017 and Wang *et al*., 2017). These variations in LULC types in a given area can be used as a substitute for biomes to estimate values of ecosystem services of the area of interest (Kindu *et al*., 2016; Schmidt *et al*., 2016 and Msofe *et al*., 2020).

Global valuation of the ecosystem services and their changes proposed 17 types of ecosystem services coefficients of 16 biomes and their estimated ecosystem services values (TEEB, 2015). Also, various studies existed that value ecosystem services at the national level, state, or regional level based on proposed value coefficients (Kreuter *et al*., 2001; Hein *et al*., 2006; Troy & Wilson, 2007; Liu and Costanza, 2010; Wang *et al*., 2018; Zhang *et al*., 2019 and Msofe *et al*., 2020). These value coefficients of different biomes employed through a benefit transfer approach together with remote sensing and GIS technologies to estimate the ecosystem services values (ESV) and mapping their distributions (Turner *et al*., 2002; Troy & Wilson, 2007 and Msofe *et al*., 2020). This approach has been practical to estimate ESVs and suggests management options for regions with scarce data (Hein *et al*., 2006; Kindu *et al*., 2016 and Msofe *et al*., 2020). African countries including Tanzania and Mozambique suit the adaptation of this approach due to scarcity of data on values of ecosystem services.

Tanzania and Mozambique are characterized by rich, diverse and distinct terrestrial and marine ecosystems. Modification of habitat due to demographic and socio-economic processes is transforming the environment and often resulting in degrading ecosystems in these countries, causing disruption of the services they provide and biodiversity loss. For instance at the end of the year 2100, Tanzania's population will be nearly half a billion and will rise demand curve for natural resources that sustain the economy and livelihoods in the country, and serve as poverty safety nets in terms of food, water, energy, and shelter security (DENRM, 2010). The future demand of population will be greatest threat to the environment and will exceed ecosystem carrying capacity, unless natural resources are managed more sustainably.

Studies in Tanzania and Mozambique identified four human induced critically stressed ecosystem services that need immediate attention namely maintenance of biodiversity; food and fiber provision; water supply, purification and regulation; and fuel provision (International Institute for Sustainable Development for the United Nations Environment Programme, 2005). The main issues related to ecosystem degradation caused by human activities includes land-use change (linked to land conversion to agricultural use, deforestation and land degradation due to unsustainable practices), sedimentation and water pollution (linked to water overconsumption, agricultural run-off and soil erosion), and over harvesting/exploitation of natural resources (for small- and large-scale market and industry).

1.2. Statement of the Problem

Global land use and land cover change (LULCC) already affects the status and integrity of different ecosystems, leading to the loss of the ecosystem services and functions (Msofe *et al*., 2020; Gashaw *et al*., 2018; Tolessa *et al*., 2017; Kindu *et al*., 2016; Zorrillamiras *et al*., 2014; Degroot *et al*., 2012 and TEEB, 2010). The economic valuation of ecosystem services with LULCC assessments is vital for scientific researches because it raises awareness (Msofe *et al*., 2020; Gashaw *et al*., 2018 and Kreuter *et al*., 2001), provides information on the most valuable ecosystem services that need to be conserved (De Groot *et al*., 2012 and Liu *et al*., 2010), improves decision making for the allocation of scarce resources among competing needs and wants (Constanza *et al*., 2014; TEEB, 2010 and Daily, 1997), assists the formulation of policies and strategies that ensure sustainable management of an ecosystems (Tumer and Schaafsma, 2015 and Farber *et al*., 2006), and provides an efficient use of limited funds for conservation and restoration (Schmidt *et al*., 2016). The process of economic valuation of ecosystem services involves the estimation of the marginal value of ecosystem services that determines the costs of losing or the benefit of preserving a given amount or quality of an ecosystem service (Msofe *et al*., 2020; Pearce, 1998 and Schmidt *et al*., 2016). However there have been efforts to estimate values of ecosystem services for areas with scarce data, there are few studies on the ecosystem services valuation in relation to the LULCC dynamics in transfrontier conservation areas (TFCAs), such as Selous – Niassa TFCA.

Selous - Niassa TFCA is an ecosystem connected by the corridor between Selous Game Reserve (Tanzania) and Niassa National Reserve (Mozambique) making an area of 154000 km^2 of natural miombo woodlands ecosystem. The TFCA consists a network of PAs of various categories of protection; an area of 110,000 km^2 of this ecosystem is presently under conservation (Baldus and Hahn, 2009). The corridor connecting these two PAs to form TFCA is unprotected ecosystem. However, areas adjacent to TFCA PAs formulated WMAs (wildlife management areas) so as to involve community in conservation of wildlife outside PAs. Wildlife species use the corridor for migration and others adapted in the corridor due to its suitability for their climatic niche. Also, the corridor provides ecosystem services that are significant for local communities' wellbeing and livelihood (Zella *et al*., 2017). The corridor changes in land-use and production systems (e.g. extensification and intensification of agricultural production, transformation from subsistence use of natural resources to commercial practices) have consequences for ecosystems functioning and biodiversity, as habitats are transformed and fragmented. Degradation of natural forests does not only modify habitat and impact wildlife, but also climate and water catchment regulation capacity. The multiple and excessive use of ecosystem services and extraction of goods is increasing stress for the TFCA corridor of Selous-Niassa ecosystem in Tanzania and Mozambique.

Therefore, this study tries to fill the existing gap of economic values of ecosystem services of the corridors connecting TFCAs based on LULCC using eastern corridor of Selous-Niassa TFCA ecosystem as a case study.

1.3. Objectives

1.3.1. Main objective

The main objective of this study was to estimate economic value of ecosystem services of eastern corridor of Selous-Niassa ecosystem.

1.3.2. Specific objectives

Specifically the study intends to

- determine changes of economic values of ecosystem services resulted from LULCC of eastern corridor of Selous-Niassa ecosystem from 1986 to 2016
- analyse changes of economic values of ecosystem functions based on LULC type of eastern corridor of Selous-Niassa ecosystem from 1986 to 2016
- estimate changes of economic value of ecosystem services of trees loss/gain of eastern Selous-Niassa ecosystem from 1986 to 2016

analyse economic value of ecosystem services of wood balance of corridor dwellers of eastern Selous-Niassa ecosystem.

2. Material and methods

2.1. Materials

2.1.1. Description of the Study Area

The study was carried out in eastern Selous-Niassa TFCA with an area of 1,462,560 hectares called Selous-Niassa wildlife corridor (SNWC) which extends across southern Tanzania into northern Mozambique between 100S to 110 40'S with north-south length of 160 to 180 km (Figure 1). SNWC comprises of two parts, western part (administratively passes in Namtumbo and Tunduru Districts of Ruvuma regions in southern Tanzania) and eastern part (administratively passes in Liwale, Nachingwea, Masasi, and Nanyumbu Districts). This study concentrated in eastern part. In eastern SNWC, migration of elephants, buffalos and zebras has been observed (Pesambili, 2003; Ntongani et al., 2007). Eastern SNWC comprises Msanjesi (2,125 ha) and the Lukwika-Lumesule (44,420 ha) Game Reserves in Masasi and Nanyumbu Districts respectively and areas of Liwale, Nachingwea, Masasi and Tunduru Districts. The study area comprise wildlife management areas (WMAs) bordering Selous, Msanjesi and Lukwika-Lumesule game reserves

(MAGINGO WMA, NDONDA and MCHIMALU proposed WMAs respectively) which are within Liwale, Nachingwea/Masasi and Nanyumbu Districts respectively.

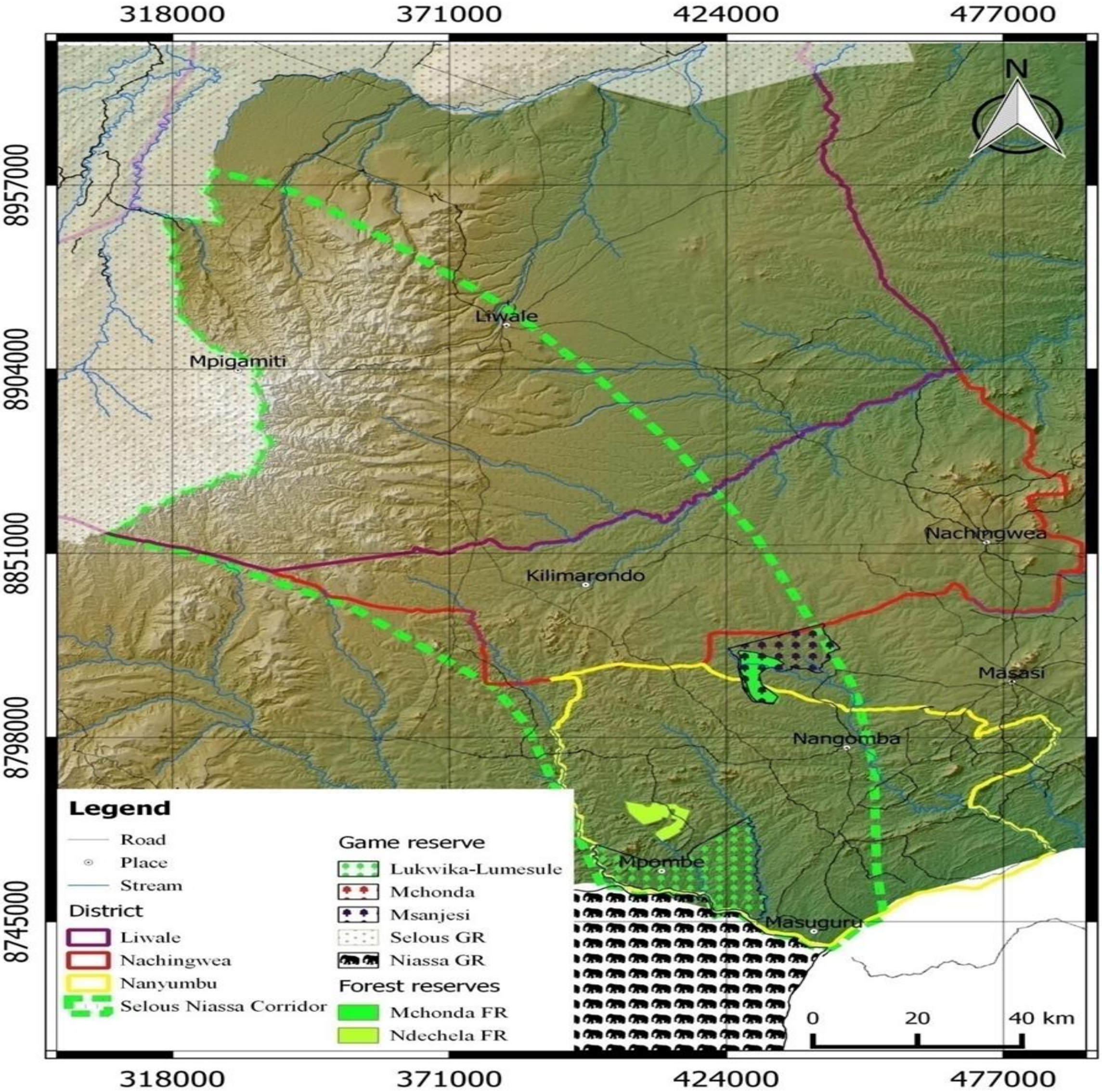

Figure 1 The Map of the study area.

2.2. Data Used and Methods

Figure 2 below shows the flow chart of the methodological approach used in this study for the estimation of the ecosystem service values (ESVs) for 1986, 1997, 2005 and 2016 years and the computation of changes between studies periods.

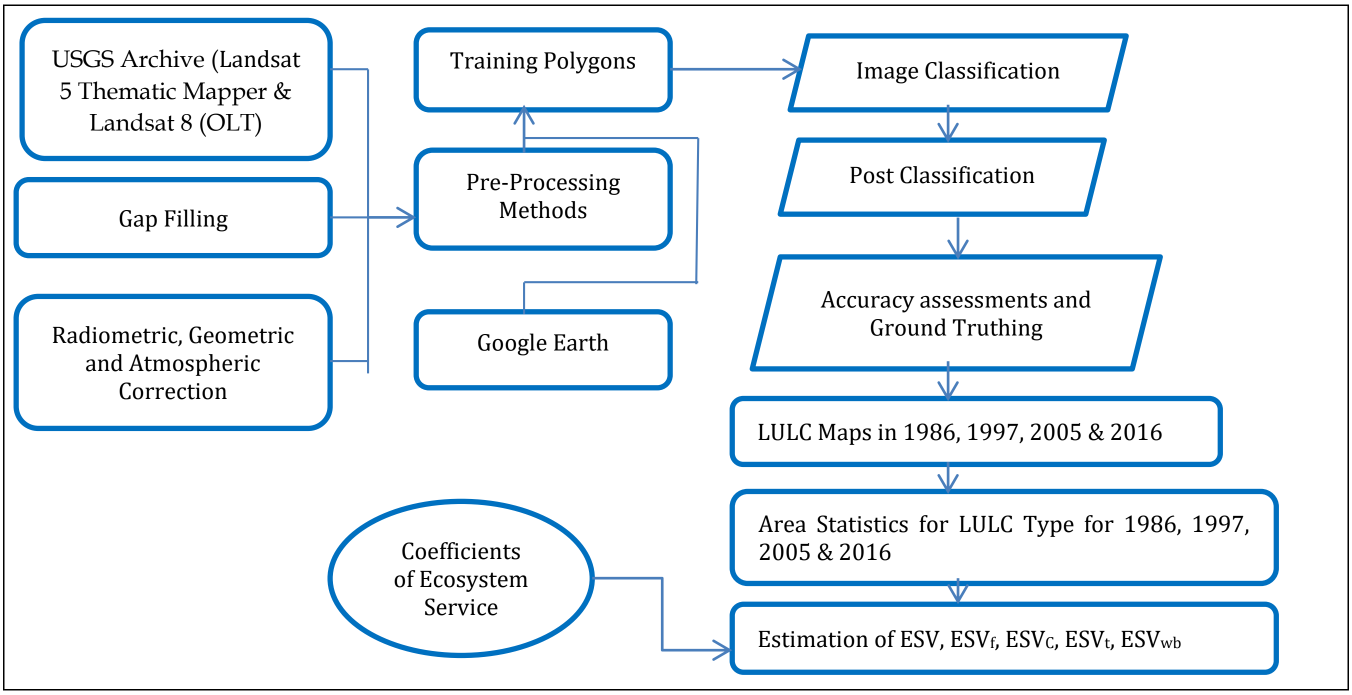

Figure 2 Flowchart of the methodological approach for this study

The LULC datasets were acquired from Zella et al., 2017 and biome equivalents with their corresponding ecosystem service value coefficients (VC) in 1994 US$ ha−1year−1 for local and global VC shown in Table 1 as adapted from Kindu et al., 2016; Constaza et al., 1997 &2014; and Msofe et al., 2020.

Table 1 Land use and land cover (LULC) types and biome equivalents with their corresponding ecosystem service value coefficients (VC)

LULC Type	**Year & Area (ha)**					**Local (VC) 1994 US$ ha^{-1}year^{-1}**	**Global (VC) 1994 US$ ha^{-1}year^{-1}**
	1986	**1997**	**2005**	**2016**	**Equivalent Biome**	**a**	**b**
Closed woodland	227731	244348	103198	89923	Tropical Forest	987	2008
Open woodland	402201	411211	288176	220217	Tropical Forest	987	2008
Bushland	433706	333399	256911	480269	Tropical Forest	987	244
Grassland	394960	437621	515143	394461	Grasslands	293	244
Water	1431	790	906	646	Fresh water	8103	8498
Built up area	2532	3391	7623	8851	Urban	0	0
Cultivated land	0	31799	290602	268193	Cropland	226	92

This study employed the benefit transfer approach to estimate economic values of ecosystem services based on the adapted local and global VC of the ecosystem services for the targeted LULC types. Detailed ecosystem service functions and their global and modified local value coefficients of each LULC type are shown in Tables 2 & 3 below as adapted from Msofe *et al.*, 2020 and Constaza *et al.*, 1997 &2014.

Table 2 Details of the ecosystem service functions and their modified local value coefficients for each LULC type (adapted from Msofe *et al*., 2020)

Ecosystem Services	Each LULC Types of Ecosystem Service Values (1994 US$ $ha^{-1}year^{-1}$)					
	Closed woodland	**Open woodland**	**Bushland**	**Grassland**	**Water**	**Cultivated land**
Provisioning services:						
Water supply	8	8	8		2117	
Food production	32	32	32	117.45	41	187.56
Raw material	51.2	51.2	51.2			
Genetic resources	41	41	41			
Medical services						
Sub-total	132.2	132.2	132.2	117.45	2158	187.56
Regulating services:						
Water regulation	6	6	6	3	5445	
Waste treatment	136	136	136	87	431.5	
Erosion control	245	245	245	29		
Climate regulation	223	223	223			
Biological control				23		24
Gas regulation	13.68	13.68	13.68	7		
Disturbance regulation	5	5	5			
Sub-total	628.68	628.68	628.68	149	5876.5	24
Supporting services:						
Nutrient cycling	184.4	184.4	184.4			
Pollination	7.27	7.27	7.27	25		14
Soil formation	10	10	10	1		
Habitat/refugia	17.3	17.3	17.3			
Sub-total	218.97	218.97	218.97	26		14
Cultural services:						
Recreation	4.8	4.8	4.8	0.8	69	
Cultural	2	2	2			
Sub-total	6.8	6.8	6.8	0.8	69	
Grand-total	986.69	986.69	986.69	293.25	8103.5	225.56

Table 3 Details of the ecosystem service functions and their global value coefficients for each LULC type (adapted from Constaza et al., 1997)

Ecosystem Services	Each LULC Types of Ecosystem Service Values (1994 US$ $ha^{-1}year^{-1}$)					
	Closed woodland	**Open woodland**	**Bushland**	**Grassland**	**Water**	**Cultivated land**
Provisioning services:						
Water supply	8	8	8		3800	
Food production	32	32	32	67	258	54
Raw material	315	315	315	106		
Genetic resources	41	41	41			
Medical services						
Sub-total	396	396	396	173	4058	54
Regulating services:						
Water regulation	6	6	6	3	15	
Waste treatment	87	87	87	87	4177	
Erosion control	245	245	245	29		
Climate regulation	223	223	223			
Biological control				23		24
Gas regulation				7	133	
Disturbance regulation	5	5	5		4539	
Sub-total	566	566	566	149	8864	24
Supporting services:						
Nutrient cycling	922	922	922			
Pollination				25		14
Soil formation	10	10	10	1		
Habitat/refugia					304	
Sub-total	932	932	932	26	304	14
Cultural services:						
Recreation	112	112	112	2	574	
Cultural	2	2	2		881	
Sub-total	114	114	114	2	1455	0
Grand-total	2008	2008	2008	350	14681	92

2.3. Data analysis

2.3.1. To determine changes of economic values of ecosystem services resulted from LULCC of eastern corridor of Selous-Niassa ecosystem from 1986 to 2016.

The LULC datasets shown in Table 1 used and the total value of ecosystem services in the study area for 1986, 1997, 2005 and 2016 was calculated by multiplying the area of a given LULC type by the corresponding modified ecosystem service value coefficients that were extracted from weight factors of the ecosystem services per hectare of each biome, see equation (1) adapted from Msofe *et al*., 2020 and Constaza *et al*., 1997 & 2014 as follows:

$$ESV = \sum_{k=0}^{k}(Ak + VCk) \quad \text{……………………………… (1)}$$

Where ESV = the total estimated ecosystem service value, Ak = the area (ha) and VCk = the value coefficient (US$ ha−1 year−1) for LULC type 'k'. The ESVs for all land use and land cover (LULC) types were calculated. Besides, the change in the ESVs was determined by calculating the differences between the estimated values for each LULC category in 1986, 1997, 2005 and 2016. The percentage changes in the ESVs between the years were calculated based on the equation below:

$$\text{Percentange ESV} = \frac{(ESVt_2 - ESVt_1)}{ESVt_1} \text{x } 100 \quad \text{……………………………… (2)}$$

Were ESVt2 (US$ ha−1 year−1) = the estimated ecosystem service value in the most recent year, and ESVt1 (US$ ha−1 year−1) = the estimated ecosystem service value in the previous year. Positive values suggest an increase in the ESVs, whereas negative values imply a decrease in the ESVs.

2.3.2. To analyse changes of economic values of ecosystem functions based on LULC type of eastern corridor of Selous-Niassa ecosystem from 1986 to 2016

Estimated values of the services provided by individual ecosystem functions within the study area using the following equation:

$$ESVf = \sum_{k=0}^{k}(Ak * VC_{fk}) \quad \text{……………………………… (3)}$$

Where ESV_f is the estimated ecosystem service value of function f, Ak is the area (ha) and VC_{fk} is the value coefficient of the function (US$ ha^{-1} $year^{-1}$) for LULC category 'k'. The contributions of the individual ecosystem functions to the overall value of the ecosystem services per year were calculated and summarized in the tables.

2.3.3. To estimate changes of economic value of ecosystem services of trees loss of eastern Selous-Niassa ecosystem from 1986 to 2016

Estimated amount of land (in hectares) that has been converted from closed and open woodlands to other socio-economic activities was used to estimate number of trees loss. The study area belongs to southern zone as classified by URT (2015). The number of trees and volume per hectare of the distribution of forest and woody vegetation resources have been classified by employing methodology used by NAFORMA in URT (2015) as described much by Zella *et al*., 2017 of having average mean volume (m^3/ha) and average number of trees/ha of 49.3 and 1,654 respectively. Then average mean volume (m^3/ha) and average number of trees/ha were assigned modified ecosystem service value coefficients that were extracted from weight factors of the ecosystem services per hectare as adapted from Msofe *et al*., 2020. This was used also to estimate ecosystem service value of individual tree found in the study area.

2.3.4. To analyse economic value of ecosystem services of wood balance of corridor dwellers of eastern Selous-Niassa ecosystem

Human population of corridor dwellers was estimated based on NBS (National Bureau of Statistics), 2012 census and computing average demand for wood compared with supply from the corridor ecosystem as described much by Zella *et al*., 2017. Then obtained information of wood balance were assigned modified ecosystem service value coefficients and get ecosystem services of wood balance of corridor dwellers of eastern corridor of Selous-Niassa ecosystem.

3. Results and discussion

3.1. Changes of Economic Values of Ecosystem Services Resulted From LULCC of Eastern Corridor of Selous-Niassa Ecosystem from 1986 to 2016

3.1.1. Status of Economic Values of Ecosystem Services for Biome in Each LULC Type of Eastern Corridor of Selous-Niassa Ecosystem from 1986 to 2016

Economic values of ecosystem services using local value coefficients for biome in each land use land cover (LULC) type for the year 1986, 1997, 2005 and 2016 are presented in Table 4. Generally, results show variations in ecosystem services values between four periods under consideration. There is a decrease in economic value of ecosystem services of at least 18% equivalent US$ to around 216 million from 1986 to 2016.

Table 4 Local Ecosystem Services Values (ESV) year^{-1}distribution between 1986 and 2016**.**

LULC	1986		1997		2005		2016	
	(ESV)	(%)	(ESV)	(%)	(ESV)	(%)	(ESV)	(%)
Closed woodland	224770497	19.1	241171476	21.6	101856426	11.8	88754001	9.2
Open woodland	396972387	33.7	405865257	36.3	284429712	32.9	217354179	22.6
Bushland	428067822	36.4	329064813	29.4	253571157	29.4	474025503	49.3
Grassland	115723280	9.8	128222953	11.5	150936899	17.5	115577073	12.0
Water	11595393	1.0	6401370	0.6	7341318	0.8	5234538	0.5
Built up area	0	0	0	0.0	0	0.0	0	0.0
Cultivated land	0	0	7186574	0.6	65676052	7.6	60611618	6.3
TOTAL	1177129379	100.0	1117912443	100.0	863811564	100.0	961556912	100.0

Table 5 shows economic values of ecosystem services using global value coefficients for biome in each land use land cover (LULC) type for the year 1986, 1997, 2005 and 2016. Results show high variations in ecosystem services values between four periods under consideration compared to local values of ecosystem services indicated in Table 4. Economic values of ecosystem services decreases for about 41% amounted approximately US$ 612 million from 1986 to 2016. The global ESV overpass local ESV for about 20.4 % (US$ 302 million), 26.2% (US$ 396 million), 14.4% (US$ 145 million) for the year 1986, 1997 and 2005 respectively; and underpass for about 11% (US$ 95 million) for the year 2016.

Table 5 Global Ecosystem Services Values (ESV) distribution between 1986 and 2016

LULC	1986	1997	2005	2016				
	(ESV)	(%)	(ESV)	(%)	(ESV)	(%)	(ESV)	(%)
Closed woodland	457283848	30.9	490650784	32.4	207221584	20.5	180565384	20.8
Open woodland	807619608	54.6	825711688	54.5	578657408	57.4	442195736	51.0
Bushland	105824264	7.2	81349356	5.4	62686284	6.2	117185636	13.5
Grassland	96370240	6.5	106779524	7.1	125694892	12.5	96248484	11.1
Water	12160638	0.8	6713420	0.4	7699188	0.8	5489708	0.6
Built up area	0	0.0	0	0.0	0	0.0	0	0.0
Cultivated land	0	0.0	2925508	0.2	26735384	2.7	24673756	2.8
TOTAL	1479258598	100.0	1514130280	100.0	1008694740	100.0	866358704	100.0

The differences in local and global ESV raise uncertainties in decision making and planning for sustainable management of ecosystems. The logic behind is that, conservation benefit of ecosystems should overpass consequences of those ecosystems to local human livelihoods and wellbeing; also to fauna and flora resides inside and outside of that ecosystem. This phenomenon calls for balance in social, economic and environment in the phase of uncertainties whereby natural capital (environment) should be priotised and using global ESV for making such decisions.

3.1.2. Changes of Economic Values of Ecosystem Services of LULCC Biomes' of Eastern Corridor of Selous-Niassa Ecosystem from 1986 to 2016

The extent of changes of economic values of ecosystem services of land use land cover change (LULC) biomes including change in ESV, percentage ESV change and percentage annual rate of change are summarised on Tables 6 & 7. The increased and decreased amount is represented by negative (-) and positive (+) signs respectively.

Table 6 Changes in Local ESV from 1986 to 2016

LULC	1986 – 1997			1997 – 2005			2005 – 2016		
	Change in ESV (US$))	% change	Annual Rate of Change (ESV/year) (US$))	Change in ESV (US$))	% change	Annual Rate of Change (ESV/year) (US$))	Change in ESV (US$))	% change	Annual Rate of Change (ESV/year) (US$))
CWD	-16400979	-27.7	-1490998.1	139315050	54.8	17414381.3	13102425	-13.4	1191129.5
OWD	-8892870	-15.0	-808442.7	121435545	47.8	15179443.1	67075533	-68.6	6097775.7
BS	99002022	167.2	9000183.8	75493656	29.7	9436707.0	-2.2E+08	225.5	-20041214.5
GL	-12499673	-21.1	-1136333.9	-22713946	-8.9	-2839243.3	35359826	-36.2	3214529.6
WTR	5194023	8.8	472183.9	-939948	-0.4	-117493.5	2106780	-2.2	191525.5
BLT	0	0.0	0.0	0	0.0	0.0	0	0.0	0.0
CL	-7186574	-12.1	-653324.9	-58489478	-23.0	-7311184.8	5064434	-5.2	460403.1
TOTAL	59215949	100.0	5383268.1	254100879	100.0	31762609.9	-97744361	100.0	-8885851.0

CWD = Closed woodland, OWD = Open woodland, BS = Bushland, GL = Grassland, WTR = Water, BLT = Built Up area, and CL = Cultivated land

The results in Table 6 shows the decrease of total ESV for the period 1986 – 1997 (US$ 59 million), 1997 – 2005 (US$ 254 million) and increase of total ESV for the period 2005 – 2016 (US$ 97 million); and Table 7 shows the increase of total ESV for the period 1986 – 1997 (US$ 35 million), and decrease for the period 1997 – 2005 (US$ 505 million) and 2005 – 2016 (US$ 142 million). These changes of ESV using local and global valuation coefficients must be integrated into national environmental policies to get decision models. For instance , we expected the total ESV to increase for the period 1986 - 1997 as the area were not easily accessible using roads, so transportation of valuable woods found in the area like *Pterocarpus angolensis* were impossible; but global ESV prove true while local ESV is opposite. Also, in these period of 1986 – 1997 national wide operation "uhai" were conducted to stop illegal harvesting of fauna and flora in the country. For the period 1997 – 2005 both local and global ESV shows the decrease in ESV while for the period 2005 – 2016 local ESV shows increase while global ESV shows decrease. The results affected by the value that given to each biome, for example closed woodland, open woodland and bushland given the same ESV so when Closed and Open woodlands changes to Bushland their ESV remain unchanged results to uncertainties.

Generally, annual changes of ESV for the period 1986 -2016 estimated as US$ 7 million and US$ 20 million using local and global ESV coefficients respectively. The differences between local and global ESV for the period 1986 - 2016 is 64.8% (US$ 397 million) indicates global ESV is vital for macroeconomic policies. There are biomes in LULC types for the period 1986 – 2016 leads for degradation using local ESV includes closed and open woodlands which degraded for 63.1% and 83.3% respectively to bushland (21.3%) and cultivated land (28.1%); using global ESV, closed (45.1%) and open (59.6%) woodlands degraded to bushland (1.9%) and cultivated land (4%).

Table 7 Changes in Global ESV from 1986 to 2016

LULC	1986 – 1997			1997 – 2005			2005 – 2016		
	Change in ESV (US$))	**% change**	**Annual Rate of Change (ESV/year) (US$))**	**Change in ESV (US$))**	**% change**	**Annual Rate of Change (ESV/year) (US$))**	**Change in ESV (US$))**	**% change**	**Annual Rate of Change (ESV/year) (US$))**
CWD	-33366936	95.7	-3033357.8	283429200	56.1	35428650	26656200	18.7	2423291
OWD	-18092080	51.9	-1644734.5	247054280	48.9	30881785	136461672	95.9	12405607
BS	24474664	-70.2	2224969.5	18663072	3.7	2332884	-54499108	-38.3	-4954464
GL	-10409284	29.9	-946298.5	-18915368	-3.7	-2364421	29446408	20.7	2676946
WTR	5447218	-15.6	495201.6	-985768	-0.2	-123221	2209480	1.6	200861.8
BLT	0	0.0	0.0	0	0.0	0	0	0.0	0
CL	-2925508	8.4	-265955.3	-23809876	-4.7	-2976235	2061628	1.4	187420.7
TOTAL	-34871926.0	100.0	-3170175.1	505435540	100.0	63179443	142336280	100.0	12939662

CWD = Closed woodland, **OWD** = Open woodland, **BS** = Bushland, **GL** = Grassland, **WTR** = Water, **BLT** = Built Up area, and **CL** = Cultivated land

3.2. Changes of Economic Values of Ecosystem Functions Based on LULC Type of Eastern Corridor of Selous-Niassa Ecosystem from 1986 to 2016

The results in Tables 8 & 9 shows estimated local and global annual economic value of the ecosystem functions and their relative changes from 1986 to 2016 in eastern corridor of Selous-Niassa ecosystem.

It was revealed that, for three decades there is loss of US$ 322030356.1/US$ 653841571 of ecosystem functions mostly from closed woodlands, open woodlands, grassland and water from 1986 to 2016. Also, there is total annual local/global gain of ecosystem functions of US$ 106434997/US$ 118172260 from bushland and cultivated land from 1986 to 2016. The results further indicates that the gain of ecosystem functions comes from provisioning services and the degradation of ecosystem functions led by, supporting services, then regulatory services and lastly cultural services. These results imply that, there is encroachment of natural capital in the study area mostly on closed and open woodlands for valuable wood resources and for changes of land uses due to anthropogenic activities and reliance of dwellers to natural resources for their livelihoods.

3.3. Estimate changes of economic value of ecosystem services of trees loss/gain of eastern corridor of Selous-Niassa ecosystem from 1986 to 2016

The results in Tables 10 shows estimated economic value of the ecosystem services of trees loss from 1986 to 2016 in eastern corridor of Selous-Niassa ecosystem. The results indicate that for the period 1986 – 1997 annual ecosystem services of trees gained by US$ 25293849 and US$ 51459016 for local and global ESV respectively. Furthermore, for the periods 1997 – 2005 and 2005 - 2016 there was a loss of annual ecosystem services of trees of US$ 260749608/US$ 530481472 and US$ 80177958/ US$ 163117872 for local/global ESV respectively. The results implies degradation of ecosystem services for the period 1997 to 2016 due to high utilisation of forest resources especially valuable natural miombo woods found in the study ecosystem. The period 1986 – 1997 shows gain of ecosystem services due to famous countrywide operation “Uhai” occurred during this period, bad infrastructure especially roads, low human population and lack of markets for valuable miombo woods found in the study ecosystem.

Table 8 Local economic values of ecosystem functions (US$) from 1986 to 2016

LULC	Ecosystem services	1986	1997	2005	2016	Relative change
Closed woodland	Provisioning services	30106038.2	32302805.6	13642775.6	11887820.6	18218217.6
	Regulating services	143169925.1	153616700.6	64878518.6	56532791.64	86637133.44
	Supporting services	49866257.07	53504881.56	22597266.1	19690439.31	30175817.76
	Cultural services	1548570.8	1661566.4	701746.4	611476.4	937094.4
	Sub-total	224690791.2	241085954.2	101820307	88722527.95	135968263.2
Open woodland	Provisioning services	53170972.2	54362094.2	38096867.2	29112687.4	24058284.8
	Regulating services	252855724.7	258520131.5	181170487.7	138446023.6	114409701.1
	Supporting services	88069952.97	90042872.67	63101898.72	48220916.49	39849036.48
	Cultural services	2734966.8	2796234.8	1959596.8	1497475.6	1237491.2
	Sub-total	396831616.7	405721333.2	284328850.4	217277103.1	179554513.6
Bushland	Provisioning services	57335933.2	44075347.8	33963634.2	63491561.8	-6155628.6
	Regulating services	272662288.1	209601283.3	161514807.5	301935514.9	-29273226.84
	Supporting services	94968602.82	73004379.03	56255801.67	105164502.9	-10195900.11
	Cultural services	2949200.8	2267113.2	1746994.8	3265829.2	-316628.4
	Sub-total	427916024.9	328948123.4	253481238.2	473857408.9	-45941383.95
Grassland	Provisioning services	46388052	51398586.45	60503545.35	46329444.45	58607.55
	Regulating services	58849040	65205529	76756307	58774689	74351
	Supporting services	10268960	11378146	13393718	10255986	12974
	Cultural services	315968	350096.8	412114.4	315568.8	399.2
	Sub-total	115822020	128332358.3	151065684.8	115675688.3	146331.75
Water	Provisioning services	3088098	1704820	1955148	1394068	1694030
	Regulating services	8409271.5	4642435	5324109	3796219	4613052.5
	Supporting services	0	0	0	0	0
	Cultural services	98739	54510	62514	44574	54165
	Sub-total	11596108.5	6401765	7341771	5234861	6361247.5
Cultivated land	Provisioning services	0	5964220.44	54505311.12	50302279.08	-50302279.08
	Regulating services	0	763176	6974448	6436632	-6436632
	Supporting services	0	445186	4068428	3754702	-3754702
	Cultural services	0	0	0	0	0
	Sub-total	0	7172582.44	65548187.12	60493613.08	-60493613.08
GRAND TOTAL		1176856561	368304285.7	3365827921	3106281056	215595359

Table 9 Global economic values of ecosystem functions (US$) from 1986 to 2016

LULC	Ecosystem services	1986	1997	2005	2016	Relative change
Closed woodland	Provisioning services	90181476	96761808	40866408	35609508	54571968
	Regulating services	128895746	138300968	58410068	50896418	77999328
	Supporting services	212245292	227732336	96180536	83808236	128437056
	Cultural services	25961334	27855672	11764572	10251222	15710112
	Sub-total	457283848	490650784	207221584	180565384	276718464
Open woodland	Provisioning services	159271596	162839556	114117696	87205932	72065664
	Regulating services	227645766	232745426	163107616	124642822	103002944
	Supporting services	374851332	383248652	268580032	205242244	169609088
	Cultural services	45850914	46878054	32852064	25104738	20746176
	Sub-total	807619608	825711688	578657408	442195736	365423872
Bushland	Provisioning services	171747576	132026004	101736756	190186524	-18438948
	Regulating services	245477596	188703834	145411626	271832254	-26354658
	Supporting services	404213992	310727868	239441052	447610708	-43396716
	Cultural services	49442484	38007486	29287854	54750666	-5308182
	Sub-total	870881648	669465192	515877288	964380152	-93498504
Grassland	Provisioning services	68328080	75708433	89119739	68241753	86327
	Regulating services	58849040	65205529	76756307	58774689	74351
	Supporting services	10268960	11378146	13393718	10255986	12974
	Cultural services	789920	875242	1030286	788922	998
	Sub-total	138236000	153167350	180300050	138061350	174650
Water	Provisioning services	5806998	3205820	3676548	2621468	3185530
	Regulating services	12684384	7002560	8030784	5726144	6958240
	Supporting services	435024	240160	275424	196384	238640
	Cultural services	2082105	1149450	1318230	939930	1142175
	Sub-total	21008511	11597990	13300986	9483926	11524585
Cultivated land	Provisioning services	0	1717146	15692508	14482422	-14482422
	Regulating services	0	763176	6974448	6436632	-6436632
	Supporting services	0	445186	4068428	3754702	-3754702
	Cultural services	0	0	0	0	0
	Sub-total	0	2925508	26735384	24673756	-24673756
GRAND TOTAL		2295029615	672453453	6145360494	5671477371	535669311

Table 10 Economic value of ecosystem services of trees loss from 1986 to 2016

Years	Total area converted (ha)	Number of trees loss/gain (in millions)	Local ESV (US$)	Global ESV (US$)
1986 – 1997	- 25627	- 42	-25293849	-51459016
1997 – 2005	+ 264184	+ 437	260749608	530481472
2005 – 2016	+ 81234	+ 134	80177958	163117872
Total	+ 319 791	+ 529	315633717	642140328

3.4. Analyse economic value of ecosystem services of wood balance of corridor dwellers of eastern Selous-Niassa ecosystem

Existing amount of trees from 1986 to 2016 (Table 11) used to estimate local and global ESV of wood balance by using estimated population of the study area in these periods.

Table 11 Economic value of ecosystem services of wood balance from 1986 to 2016

Year	Number of trees (in millions)	Estimated human population	Local ESV (US$) of Wood balance (US$/capita/year)	Global ESV (US$) of Wood balance (US$/capita/year)
1986	1041.9	312, 081	2010.9	4091.0
1997	1084.3	351, 866	1839.0	3741.3
2005	647.3	381, 229	1016.0	2067.0
2016	513	437, 921	699.3	1422.7

The results reveled in Table 9 shows that, local and global ESV of wood supply in the study area for the year 2016 is at least 25 times the average demand per year per capita. This implies that the area is still virgin interms of ESV of wood balance that means the ecosystem is still intact ecologically. However, the trend of ESV of wood supply from 1986 to 2016 shows dramatic disintegration of the study area ESV which implies tragedy of common and is the public property where there is no control policies or rules. The emergence of reviewing management and conservation strategies is of utmost action if we need sustainability of Selous-Niassa ecosystem

4. Conclusion

This study analysed economic values of ecosystem services of eastern Selous – Niassa ecosystem. The findings have revealed that the study area has undergone notable changes in terms of ecosystem services for the period between 1986 and 2016. Local knowledge revealed various factors associated to changes of ecosystem services that includes fire, cultivation, and deforestation. The main factors mentioned as contributing to fire were beekeeping, hunting activities, and local beliefs, while for deforestation include commercial logging and timbering, charcoals production, population growth, expansion of commercial farming and food crops production

The results indicate that land use and land cover change has a significant impact to the management of biodiversity and maintaining ecosystem services of the Selous-Niassa ecosystem. The greater increase of land use conversion alters ecosystem services, wildlife movements, gene flow and stochastic events like fire and climate change. The study concludes that the modification of the land use and cover has resulted in changes of ecosystem functions which influence behavioral changes of some wild animals due to changes of their habitats. The study highlights the effects of land use and land-cover on changes of ecosystem services of trees loss/gain and ecosystem services of wood balance of the corridor dwellers which shows unsustainable supply.

Recommendations

The study provides the following recommendations for sustainable supply of ecosystem services of eastern Selous – Niassa ecosystem:

- The Government through responsible Ministry has to formulate user friendly guidelines for protection of wildlife corridors as stipulated in Tanzania Wildlife Conservation Act No. 5 of 2009;
- The Government through responsible Ministry has to formulate new and enhancing existing wildlife management areas (WMAs), participatory forests managements (PFMs) and joint forests managements (JFMs) so as accrued benefits should be higher than protection costs of the existing resources;
- The Government through responsible Ministry has to formulate land use plans of the corridors so as to protect wildlife routes within the corridors;
- The public have to use alternatives wood resources so as offset the supply deficit of ecosystem services and attain sustainability

Compliance with ethical standards

Acknowledgments

My frank appreciation to the management of The Mwalimu Nyerere Memorial Academy for their technical and financial support during this study. Special thanks are also extended to the management of Tanzania Wildlife Authority (TAWA), Selous Game Reserve, Lukwika-Lumesule and Msanjesi Game Reserves, Liwale WMA (MAGINGO), Nachingwea and Masasi proposed WMA (NDONDA), Nanyumbu proposed WMA (MCHIMALU), District councils of Liwale, Nachingwea, Masasi and Nanyumbu in Tanzania especially Wildlife and Forest Staff for their kindly acceptance and positive cooperation they provided during data acquisition.

Disclosure of conflict of interest

The author has no any conflict of interest for publishing this article

References

[1] COP. Report of the tenth meeting of the conference of the parties to the convention on biological diversity. Nagoya. Contract No. 27. 2010.

[2] Costanza R, Darge R, de Groot R, Farber S, Grasso M, Hannon B, Limburg K, Naeem S, Oneill RV, Paruelo J et al. The value of the world's ecosystem services and natural capital. Nature. 1997; 387: 253–260.

[3] Costanza R, Groot RD, Sutton P, Ploeg SVD, Anderson SJ, Kubiszewski I, Farber S, Turner RK. Changes in the global value of ecosystem services. Glob. Environ. Chang. 2014; 26: 152–158.

[4] De Groot R, Brander L, van der Ploeg S, Costanza R, Bernard F, Braat L, Christie M, Crossman N, Ghermandi A, Hein L et al. Global estimates of the value of ecosystems and their services in monetary units. Ecosyst. Serv. 2012; 1: 50–61.

[5] Downing M, Ozuna T. Testing the reliability of the benefit function transfer approach. JEnvironEcon- Manage. 1996; 30(3): N316–22.

[6] Ecosystem Assessment, M. Ecosystems and Human Well-being: General Synthesis; In Island Press: Washington, DC, USA. 2005.

[7] Elliot S, Duncan S, Malone N. New Nature of Business: How Business Pioneers Support Biodiversity and Ecosystem Services. 2014.

[8] Farber S, Costanza RDL, Erickson J, Gross K, Grove M, Hopkinson CS, Kahn J, Pincetl S, Troy A, Warren P. Linking ecology and economics for ecosystem management. Bioscience. 2006; 56: 121–133.

[9] Food and Agriculture Organization. Agriculture and Climate Change: FAO Role; In Viale delle Terme di Caracall; FAO: Rome, Italy. 1997.

[10] Gashaw T, Tulu T, Argaw M, Worqlul AW, Tolessa T Kindu, M. Estimating the impacts of land use/land cover changes on Ecosystem Service Values: The case of the Andassa watershed in the Upper Blue Nile basin of Ethiopia. Ecosyst. Serv. 2018; 31: 219–228.

[11] Hanson C, Ranganathan J, Iceland C, Finisdore J. The Corporate Ecosystem Services Review: Guidelines for Identifying Business Risks & Opportunities Arising from Ecosystem Change. Washington, DC: World Resources Institute. 2012.

[12] Hein L, Van Koppen K, Groot RS, Van Ierland E. Spatial scales, stakeholders and the valuation of ecosystem services. Ecol. Econ. 2016; 57: 209–228.

[13] Kahn JR. Economic Approach to environmental and natural resources 3rd ed. Nashville, TN: South- Western Publishers. 2005.

[14] Kindu M, Schneider T, Teketay D, Knoke T. Changes of ecosystem service values in response to land use/land cover dynamics in Munessa-Shashemene landscape of the Ethiopian highlands. Sci. Total Environ. 2016; 547: 137–147.

[15] Kreuter UP, Harris HG, Matlock MD, Lacey RE. Change in ecosystem service values in the San Antonio area, Texas. Ecol. Econ. 2001; 39: 333–346.

[16] Kubiszewski I, Costanza R, Anderson S, Sutton P. The future value of ecosystem services: Global scenarios and national implications. Ecosyst. Serv. 2017; 26: 289–301.

[17] Laurans Y, Rankovic A, Bille R, Pirard R, Mermet L. Use of ecosystem services economic valuation for decision making: Questioning a literature blindspot. J Environ Manage. 2013; 119: 208–19.

[18] Liu S, Costanza R. Ecosystem services valuation in China. Ecol. Econ. 2017; 69: 1387–1388.

[19] Liu S, Costanza R, Farber S, Troy A. Valuing ecosystem services: Theory, practice, and the need for a transdisciplinary synthesis. Ann. N. Y. Acad. Sci. 2010; 1185: 54–78.

[20] Martin-Lopez B, Gomez-Baggethun E, Garcia-Llorente M, Montes C. Trade-offs across value-domains in ecosystem services assessment. Ecological Indicators. 2013; 37: 220–8.

[21] Millennium Ecosystem Assessment. Ecosystems and Human Well-being: Synthesis. Washington, DC.: Island Press. 2005.

[22] Miller DL. Federal Emergency Management Agency of the USA Mitigation Policy -FP-108-024-01, Consideration of Environmental Benefits in the Evaluation of Acquisition Projects under the Hazard Mitigation Assistance (HMA) Programs. 2013; 7.

[23] Msofe NK, Sheng L, Li Z, Lyimo J. Impact of Land Use/Cover Change on Ecosystem Service Values in the Kilombero Valley Floodplain, South eastern Tanzania. Forests. 2020; 11(109): 2-17.

[24] Pascual U, Muradian R, Brander L, Gómez-Baggethun E, Martín-López B, Verma M. The economics of valuing ecosystem services and biodiversity. In: Kumar P, editor. The Economics of Ecosystems and Biodiversity Ecological and Economic Foundations. London and Washington: Earthscan. 2010.

[25] Raudsepp-Hearne C, Peterson GD, Tengo M, Bennett EM, Holland T, Benessaiah K, et al. Untangling the Environmentalist's Paradox: Why Is Human Well-being Increasing as Ecosystem Services Degrade? BioScience. 2010; 60(8): 576–89.

[26] Richardson L, Loomis J, Kroeger T, Casey F. The role of benefit transfer in ecosystem service valuation. Ecol. Econ. 2015; 115: 51–58.

[27] Schmidt S, Manceur AM, Seppelt R. Uncertainty of Monetary Valued Ecosystem Services– Value Transfer Functions for Global Mapping. PLoS ONE. 2016; 11(3): e0148524.

[28] SEEA. System of Environmental-Economic Accounting Website 2015 [Accessed July 2020].

[29] Smith KV, Pattanayak SK. Is Meta-Analysis a Noah's Ark for Non-Market Valuation? Environmental and Resource Economics. 2002; 22: 271–96.

[30] TEEB Foundations. The Economics of Ecosystems and Biodiversity: Ecological and Economic Foundations; Earthscan: London, UK. 2010.

[31] TEEB. The Economics of Biodiversity and Ecosystem Services Website 2015 [Accessed November 2015].

[32] ten Brink P, Hansjürgens B, Kettunen M, Lehmann M, Neßhöver C, Schröter-Schlaack C, et al. The Economics of Ecosystems and Biodiversity in National and International Policy Making. ten Brink P, editor. London and Washington: Earthscan. 2011.

[33] Tolessa T, Senbeta F, Kidane M. The impact of land use/land cover change on ecosystem services in the central highlands of Ethiopia. Ecosyst. Serv. 2017; 23: 47–54.

[34] Troy A, Wilson MA. Mapping ecosystem services: Practical challenges and opportunities in linking GIS and value transfer. Ecol. Econ. 2007; 60: 435–449.

[35] Turner RK, Paavola J, Cooper P, Farber S, Jessamy V, Georgiou S. Valuing nature: Lessons learned and future research directions. Ecol. Econ. 2002; 46: 493–510.

[36] Wang X, Dong X, Liu H, Wei H, Fan W, Lu N, Xu Z, Ren J, Xing K. Linking land use change, ecosystem services and human well-being: A case study of the Manas River Basin of Xinjiang, China. Ecosyst. Serv. 2017; 27: 113–123.

[37] Wang Y, Dai E, Yin L, Ma L. Land use/land cover change and the effects on ecosystem services in the Hengduan Mountain region, China. Ecosyst. Serv. 2018; 34: 55–67.

[38] WAVES Wealth Accounting and the Valuation of Ecosystem Services Website 2015 [Accessed July 2020].

[39] Zella AY, Saria J, Lawi Y. Analysis of Spatial and Temporal Changes in Land Uses and its Implications to the Conservation of Eastern Selous-Niassa Transfrontier Conservation Areas (TFCA). Journal of Environmental Science and Public Health. 2017; 1(3): 84-91.

[40] Zhang F, Yushanjiang A, Jing Y. Assessing and predicting changes of the ecosystem service values based on land use/cover change in Ebinur LakeWetland National Nature Reserve, Xinjiang, China. Sci. Total Environ. 2019; 656: 1133–1144.

[41] Zorrillamiras P, Palomo I, Gómezbaggethun E, Martínlópez B, Lomas PL, Montes C. Effects of land use change on wetland ecosystem services: A case study in the Doñana marshes (SW Spain). Landsc. Urban Plan. 2014; 122: 160–174.