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Original Research

Evaluation of ecosystem services of Kahe forest reserve, Northern Tanzania

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ABSTRACT:

Changes of land use/cover caused by human pressure on protected landscape can significantly alter the provision of ecosystem services. Estimating the multiple services, particularly those obtained from forestry systems, is seldom attempted. A combined approach of geospatial technology, cross-sectional field investigations, and economic evaluation of natural capital was used to estimate changes in the Ecosystem Services Valuation (ESV) of Kahe Forest Reserve at Northern Tanzania from 1998 to 2018. Benefit transfer method was employed using adapted local and global ecosystem Value Coefficients (VCs) of 2007 US$/ha from TEEB foundation. The study landscape with 749 ha was categorized into five land use classes, which yielded an annual total Ecosystem Services Valuation (ESV) of $ 837, 038.7 or $ 1, 565, 967 in 1998 and $ 713 176.5 or $ 1,630, 883 in 2018 using local and global VCs respectively. Local estimates showed decrement of ESV of 14.8% compared to global estimate of 4.1% increment ESV in a decade. However we observed losses of forest class ESV by 236.1% per annum in a decade due to deforestation. Appreciating the importance of forest in climate change mitigation and provision of ecosystem services, the study strongly recommend that their economic value should be included in management regime and policy implementation for the sustainability of the ecosystem.

Keywords:

Ecosystem services; Ecosystem service valuation; Kahe forest reserve; Land use and conservation policy.

Abbreviations:

ESV: Ecosystem Services Valuation
VCs: Value Coefficients
LUC: Land Use Cover
LULC: Land Use and Land Cover

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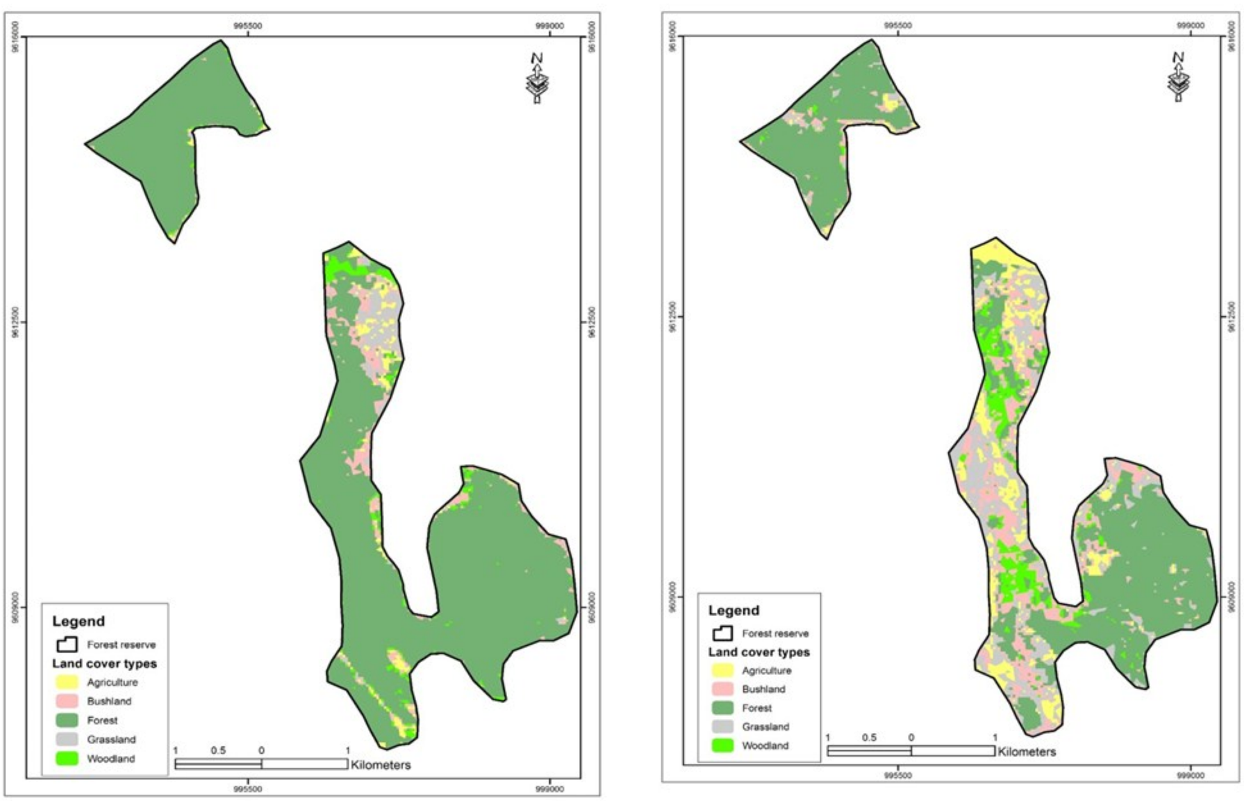
INTRODUCTION

Ecosystem provides various resources and processes for the benefit of mankind, termed known as ecosystem services (Temesgen *et al.,* 2018). Ecosystem services are a key producer of human welfare gained from natural capital stocks and human capital services (Constanza *et al*., 1997). Human anthropogenic activities and population growth disturbs ecosystem services due to land use changes (Wang *et al.,* 2015; Temesgen *et al.,* 2018). Land use changes determines an ecosystem's structure and function, which affect the service provision status of ecosystems (Daily, 1997; De Groot *et al.,* 2002; MEA, 2005; Temesgen *et al.,* 2018).

Current reports showed forest ecosystem decline due to forest loss especially in Africa as a result of increased anthropogenic activities and reliance of ecosystems resources for livelihoods (FAO, 2015; Sloan and Sayer, 2015). This reliance affects the natural ecosystem services and functions (Brink *et al.,* 2014; Temesgen *et al.,* 2018; Msofe *et al*., 2020)

Land uses decisions in African countries are based on economic considerations of land value that lead to changes in Land Use/Land Cover (LULC) and ecosystem services deterioration (Constanza *et al.,* 1997; Wang *et al.,* 2015; Temesgen *et al.,* 2018; Msofe *et al*., 2020).

Changes in LULC modify ecosystem services and functions and priotised as a major driving factor for biodiversity loss (Wang *et al.,* 2015; MEA, 2005; De Groot *et al.,* 2012; Msofe *et al*., 2020). Estimating Ecosystem Services Valuation (ESV) of various LULC types is an effective way to assess the environmental costs and benefits of different approaches to policy-based planning (Wang *et al.,* 2015; Mendoza-González *et al.,* 2012; Yirsaw *et al.,* 2016; Temesgen *et al.,* 2018; Msofe *et al*., 2020).



a. Kahe forest reserve in 1998 **b. Kahe forest reserve in 2018**

Figure 1. The map of the study area

Table 1. Estimated area (ha) of LULC change in Kahe forest and overall change (%) between 1998 and 2018

S. No	LULC Type	1998 (ha)	%	2018 (ha)	%	Overall Change (%) 1998–2018
1	Agriculture	26	3	95	10	7
2	Bushland	50	5	136	14	9
3	Forest	833	85	507	51	-34
4	Grassland	41	4	177	18	14
5	Woodland	29	3	64	7	4
6	Total	**979**	**100**	**979**	**100**	

Limited studies have been conducted to valuate ecosystem services rendered by the forest reserves in northern Tanzania. Thus, besides analyzing LULC dynamics, a systematic quantitative understanding of LULC's effect on the Ecosystem Services Valuation (ESV) is missing.

This research aims to: (1) compute changes of ESV from 1998 to 2018 with respect to LULC changes; (2) explore the contribution of individual ecosystem functions and the effects of their dynamics in each LULC type on changes in the corresponding service values; and (3) discuss the relationship between reserve ESV change trends and national land use and conservation policies. In this study, Kahe Forest Reserve is considered a case study site for forest reserves of the northern part of Tanzania and other landscapes with similar ecological characteristics.

MATERIALS AND METHODS

Study Area

Kahe forest reserve (Figure 1 a and b) is located at Moshi rural district in Kilimanjaro region at the Northern tip of Tanzania between latitudes $4^o25'$ and $4^o55'$ South of the equator and longitudes $30^o10'$ and $38^o35'$ East of Greenwich. The area is bordered by Hai district in the North, same district in the South, Moshi urban in the West and Kenya in the East. The area is found between 1000-1200 m above sea level with a mean annual rainfall of 700 mm - 900 mm with average temperature of 30^oC (MDC, 2016; Madame, 2016). The area was purposely selected based on the fact that the dwellers adjacent to Kahe forest reserve are relying on forest energy sources as their main sources of energy which inturn excavates the higher rate of forest degradation (URT, 2003; MDC, 2016). The adjacent villages are Oria, Mwangaria, Mawala, Ngasinyi "A" and Ngasinyi "B".

Data sets

Land use/cover data

The study data used land use land cover (LULC) adapted from Kitali (2019) for the year 1998 and 2008

Table 2. Description of LULC types and biome equivalents with their corresponding ecosystem service VC

LULC Type	Description	Equivalent Biome	Local (VC) 2007 US$ $ha^{-1}year^{-1}$ (A)	Global (VC) 2007 US$ $ha^{-1}year^{-1}$ (B)
Agriculture	Farm area with crops and harvested crop/land	Crop land	169.2	0
Bushland	Area dominated with bushes and shrubs	Tropical Forest	897.0	1588
Forest	Area of land covered with low density trees forming open habitat with plenty of sunlight and limited shade	Tropical Forest	897.0	1588
Grassland	Land area dominated by grasses	Grasslands	355.5	2871
Woodland	Area of land covered with low density and scattered trees with crop cultivation activities	Tropical Forest	897.0	1588

Table 3. Monetary values for each ecosystem services per biome in \$ $ha^{-1}year^{-1}$ (US\$ 2007)

S. No	Ecosystem Services	LUC Types/Biome				
		Agriculture	Bushland	Forest	Grass Land	Woodland
1	**Provisioning services**	**125.2**	**187.4**	**187.4**	**183.4**	**187.4**
2	Food	125.2	11.7	11.7	158.1	11.7
3	Water	-	20.9	20.9	-	20.9
4	Raw material	-	130.3	130.3	24.3	130.3
5	Genetic resources	-	24.5	24.5	0.0	24.5
6	Medical services	-	-	-	1.0	-
7	**Regulating services**	**27.0**	**244.5**	**244.5**	**166.6**	**244.5**
8	Water regulation		45.0	45.0		45.0
9	Water treatment	-	-	-	-	-
10	Erosion control	-	104.0	104.0	-	104.0
11	Climate regulation	-	95.0	95.0	143.3	95.0
12	Biological control	27.0	0.5	0.5	-	0.5
13	Air quality regulation	-	-	-	23.3	-
14	**Supporting services**	**17.0**	**459.3**	**459.3**	**0.0**	**459.3**
15	Nutrient cycling	-	-	-	-	-
16	Pollination	17.0	19.0	19.0	-	19.0
17	Soil formation	-	10.0	10.0	-	10.0
18	Habitat/refugia	-	430.3	430.3	-	430.3
19	**Cultural services**	**0.0**	**5.9**	**5.9**	**5.5**	**5.9**
20	Recreation	-	5.9	5.9	5.5	5.9
21	Cultural	-	-	-	-	-
22	**Total economic ESV**	**169.2**	**897.0**	**897.0**	**355.5**	**897.0**

as shown in Table 1. Those results were significant following the procedures explained by followed Bottomley (2000), Temesgen *et al*. (2018), Lillesand *et al*. (2000) and Temesgen *et al*. (2018).

Evaluation of ecosystem services

In some cases, Ecosystem services are limited in satisfying human welfare (MEA, 2005). Thus, economic valuation of these services is vital to attain sustainability (Constanza *et al*., 1997; TEEB Foundation, 2010). One application of Ecosystem Services Valuation (ESV) with regard to economics is natural capital accounting (Liu *et al*., 2010). This process is complex and uncertain in estimating the worth of biodiversity (Daily, 1997; Constanza *et al*., 1997; De Groot, 2012; Constanza *et al*., 2014; Xie *et al*., 2003). There are a variety of methods used to estimate both the market and non-market components of ecosystem services (Johnston *et al*., 2003; Nelson *et al*., 2009). However, benefit transfer seem to be effective and cost effective method applied by various researchers (Costanza *et al*., 1997; De Groot *et al.,* 2012; TEEB Foundation, 2010).

Benefit transfer translates the monetary value determined from one place and time to make inferences about the economic value of ecosystem services at another place and time due to budgets and time constrain for primary data collection (Rosenberger and Stanley,

Table 4. Total economic ESV (\$ $year^{-1}$ in 2007 US\$) estimated for each LUC type using local estimation VC

S. No	LULC Type	1998 (ESV)	%	2018 (ESV)	%	Overall Change 1998-2018 (ESV)	(%)
1	Agriculture	4399.2	0.5	16074	2.3	-11674.8	-9.4
2	Bushland	44850	5.4	121992	17.1	-77142	-62.3
3	Forest	747201	89.3	454779	63.8	292422	236.1
4	Grassland	14575.5	1.7	62923.5	8.8	-48348	-39.0
5	Woodland	26013	3.1	57408	8.0	-31395	-25.3
6	Total	837038.7	100.0	713176.5	100.0	123862.2	100.0

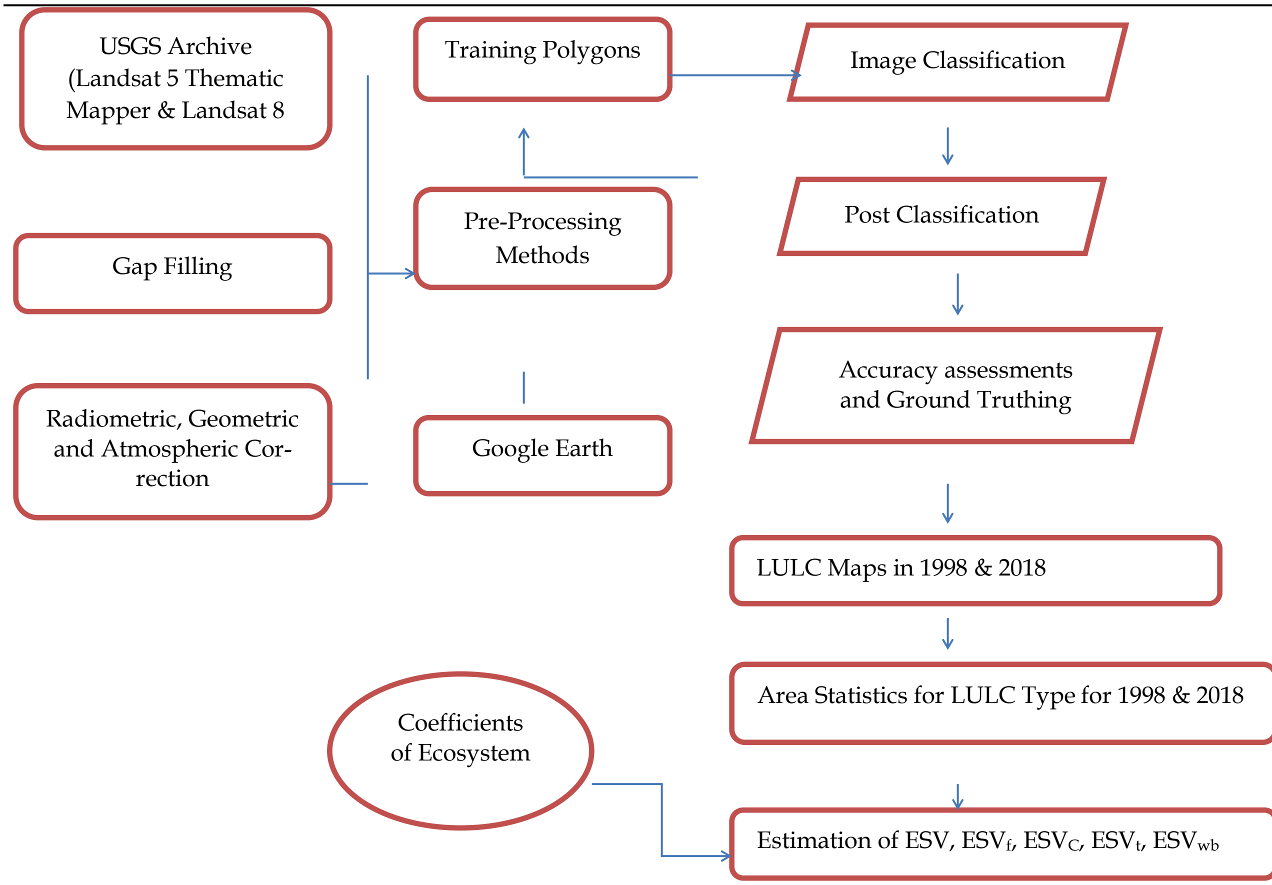


Figure 2. Schematic methodological flow

2006; and Wilson and Hoehn, 2006). Global and local Valuation Coefficients (VC) adapted for Tanzania from Temesgen *et al.* (2018) were summarized in Tables 2 and 3.

Conversely, limitations of applicability of benefit transfer method in ecological economics include the availability, reliability, and distribution of data on services and values across the ecosystems, and differences in socioeconomic and geographic settings (De Groot *et al*., 2012; Johnston *et al*., 2003; Brouwer, 2000). Navrud and Ready (2007) shows how benefit transfer method applied in a study site using meta-analysis in transferring to a policy site. These procedures used to estimate ESV of Kahe forest reserve as presented in schematic methodological flow (Figure 2).

Data analysis

LULC of Kahe Forest Reserve were assigned ESV as presented in Tables 2 and 3. The value of each type of land use, service function, and total ESV used the following equations:

Table 5. Total economic ESV ($ $year^{-1}$ in 2007 US$) estimated for each LUC type using global estimation VC

S. No	LULC Type	1998 (ESV)	%	2018 (ESV)	%	Overall Change 1998–2018 (ESV)	(%)
1	Agriculture	0	0	0	0	0	0
2	Bushland	79400	5.1	215968	13.2	-136568	210.4
3	Forest	1322804	84.5	805116	49.4	517688	-797.5
4	Grassland	117711	7.5	508167	31.2	-390456	601.5
5	Woodland	46052	2.9	101632	6.2	-55580	85.6
6	Total	1565967	100.0	1630883	100.0	-64916	100.0

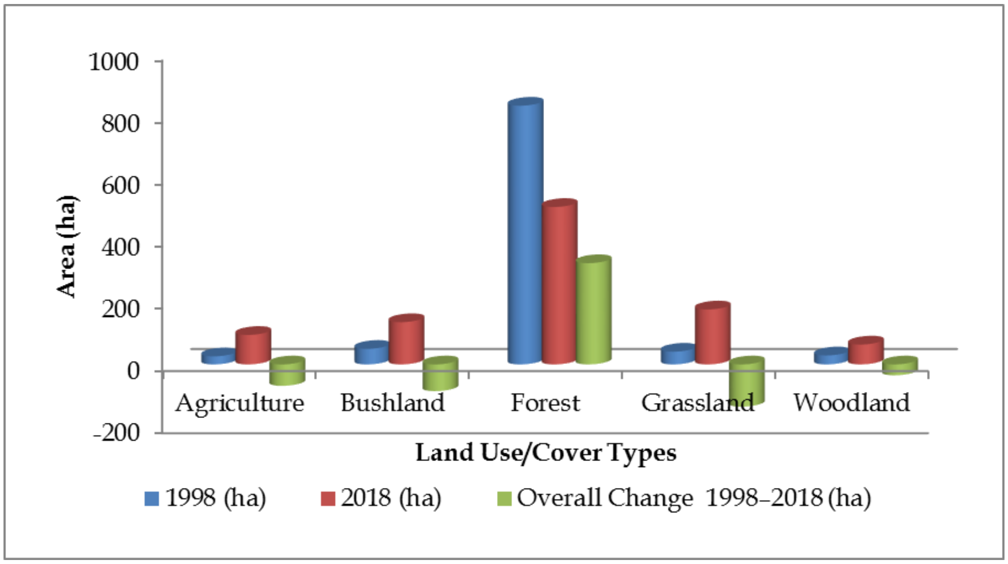


Figure 3. Land use/cover change between 1998 and 2018 of Kahe forest

ESVa = Xa x VCa , (1)

ESV = ∑(Xa x VCa), (2)

ESVb = ∑ (Xa x VCab) , (3)

where ESVa = ESV of LUC type a; Xa = Area (ha) for LUC type a; VCa = Value coefficient (US$ ha^{-1} $year^{-1}$) for land use category a; ESV = Total ESV; ESVb = Value of ecosystem service function b; and VCab is the value coefficient (US$ ha^{-1} $year^{-1}$) for land use category a with ecosystem service function type b respectively.

RESULTS AND DISCUSSION

Land use/cover (LULC) change

Figure 3 depicts the LULC changes of Kahe forest for the period 1998–2018. Forest appears to be the dominant class throughout the study period, eventually increasing by 38% in 2018. The largest spatial reduction was for grassland (14%), with an annual change rate of 1.4%, followed by bushland (9%), agriculture (7%) and lastly woodland (4%).

Evaluation of changes of ecosystem services

Using adapted local VCs and global VCs (Table 2 and Table 3) and the area covered by each LULC class (Table 1), an ESV for each cover category and the total value for each study year (1998 and 2018) were calculated (Table 4 and Table 5). In 1998 and 2018, forest (US$747, 201/year (89.3%) and US$ 454, 779/ year (63.8)) for local VC respectively and (US$ 1, 322, 804/year (84.5%) and US $ 805, 116/year (49.4%)) for global VC respectively dominated the study area compared to other LULC types. The aggregate ESV for this leading land uses indicating that the categories provide the most important ESs in Kahe forest reserve.

ESV provision trend using local estimation from 1998 to 2018 dropped tremendously for forest by 236.1% and gives chances for bushland, grassland and woodland to rise by 62.3%, 39% and 25.3% respective-

Table 6. Values of ecosystem functions (US$) from 1998 to 2018

S. No	LULC Type	1998	2018	Relative Change
1	Agriculture	4399.2	16074	-11674.8
2	Bushland	44850	121992	-77142
3	Forest	747201	454779	292422
4	Grassland	14575.5	62923.5	-48348
5	Woodland	26013	57408	-31395
6	Total	3148170.3	3148170.3	123862.2

ly. However, the global estimation shows eightfold decrease of forest cover and disturb total annual ESV for a decade. These trends show dramatic degradation of forests in the study area due to community reliance of forest resources for livelihood. However, the total annual ESV for local and global VCs showed different trends due to some limitations of the methodology. Since most ESs ware not traded in markets and need to be valued using intricate non-market pricing techniques, more indirect and varied means of valuation must be devised and used frequently. Each valuation methodology has its own strengths and limitations which then restrict its use on the type of ecosystems, the services to be valued, and the information available to valuate (Mendonza-Gonzalez *et al*., 2012; Temesgen *et al.,* 2018).

Likewise, this study still has limitations that arise from the overlap of ecosystem services and service categories, leading to the likely presence of economic double-counting in the final value estimation. This problem persists due to the interdependence of ecological values particularly between supporting services (whose services are not directly used by the people) and the other three service bundles (MEA, 2005; Temesgen *et al.,* 2018). Valuing natural capital comprises uncertainties and variation of techniques employed thus considers minimum service values; while, maximizing ESV becomes difficult due to complexity, dynamics, nonlinear properties of ecosystems and ecosystem infrastructures (Constanza *et al*., 1997; Turner and Pearce, 1993; Turner *et al*., 2003; Rosenberg and Stanley, 2006; Temesgen *et al.,* 2018)

Changes of values of ecosystem functions based on LULC type of Kahe forest reserve from 1998 to 2018

The results in Tables 6 shows estimated annual value of the ecosystem functions and their changes in each year from 1998 to 2018 in Kahe forest reserve. It was revealed that there are changes of economic values of ecosystem functions from the year 1998 to 2018. The relative changes mostly indicated in forest which loose by nearly US$ 0.3 million and overall relative change of US$ 0.12 million for all LULC types. These imply high degradation of Kahe forest reserve which always lead to disintegration of ecosystem services which are vital for livelihoods. These results call for new management strategies of Kahe forest reserve to attain ecosystem sustainability of surrounding communities.

The relationship between land use cover change and ecosystem services

Table 6 and Figure 4 depict the flow of land use cover change impact on the necessary supplies of vari-

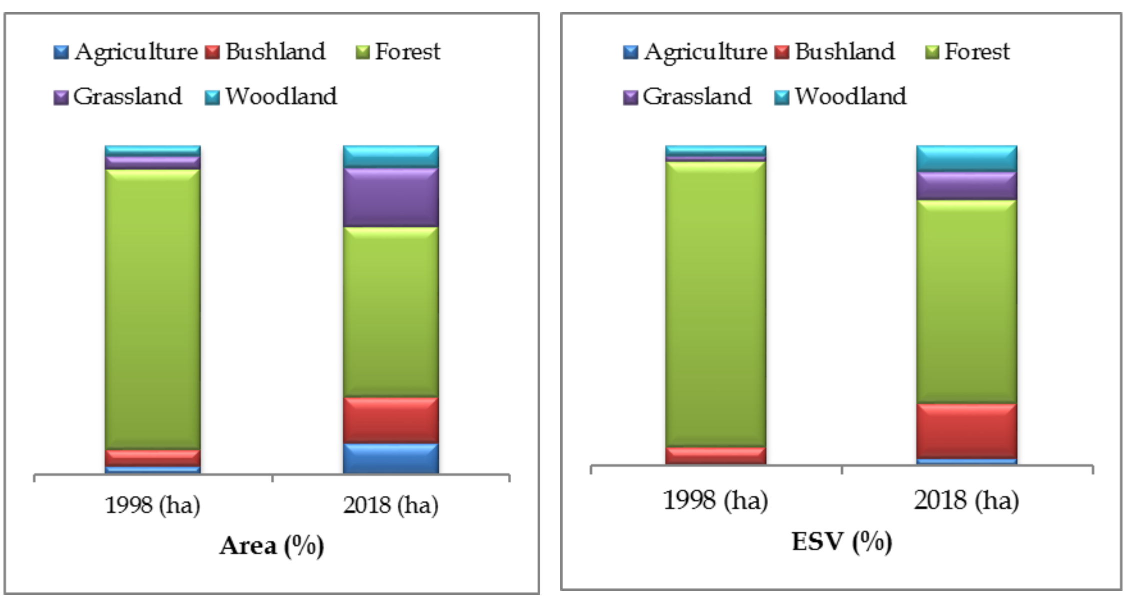


Figure 4. Contributing percentages of area and ESV for each LUC study period

ous ecosystem services. Reduction of forest (Figure 4) led to the threshold expansion of grassland, bushland, agriculture and woodland, which in turn increased the overall economic values of individual service function types and the entire value of ecosystem services. Individual service function types, habitat, raw materials, and climate regulation services show a declining trend, which might attributed to Reserve destruction for charcoaling, wood fueling, timbering and agribusiness.

Land use and conservation policy implications on changes of values of ecosystem service

Decline of forest cover converts its ESV by 35.1% to other LULC and makes an overall change of 4% of ESV in the study area (Table 6). Several contributing factors identified by regional and local leaders include population growth, lack of alternative energy from forest resources, ineffective forest management strategies, insufficient provision of conservation education to adjacent communities, inadequate knowledge of values and significance of ecosystem services to local communities. Inefficiency in the implementation of forest policy (1998), wildlife policy (2007), land policy (1997) and other supporting sectoral policies has led to the disintegration and extinction of Kahe forest reserve if and only if key actors will not intervene to reverse the situation.

CONCLUSION AND RECOMMENDATIONS

Kahe forest reserve with an area of 979 ha has been categorized into five land use cover, yielded a total annual value of ecosystem services of US$ 837, 038.7 and US$ 713, 176.5 in years 1998 and 2018 using local values estimation respectively. Also, the total annual value of ecosystem services of Kahe forest reserve using global value estimation is US$ 1, 565, 967 and US$ 16, 308, 883 in years 1998 and 2018 respectively. The local estimation showed the decrement of 1.5% of total annual value of ecosystem services for a decade compared to the increment of nearly tenthshold using global value estimation. Differences in the estimated values of ecosystem services on adapted local and global VCs were caused by the demerits of methodology. Ecosystem services are uncertainty trade in markets and need to be valued using intricate non-market pricing techniques.

From a decision-making perspective, it is critical to distinguish invaluable ecosystems that (a) deliver high economic value and (b) contribute to the increased cumulative ESV. Both scenarios require appropriate interventions to minimize the negative impacts of ongoing destruction while maintaining the others. Take into account the persisting caveats regarding valuation of ecosystem services in monetary units, these estimates are vital to the economic valuation of ecosystem services; incorporating these services during decision making processes; and improvements of forest reserves management in other similar ecological settings. It is also imperative for appraisal of socio-cultural preferences with regard to ecosystem services to identify the impact of different management options on the societies and the service delivery capacities of ecosystems.

Furthermore, the use of ecosystem services highlights the significance of socially beneficial ecological processes. Works of land use and policy making should aim at balancing society's needs and preferences while sustaining ecosystem services, as natural ecosystems are conserved and utilised properly.

CONFLICT OF INTEREST

The authors have no conflict of interest for publishing this article.

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