Assessment of Deforestation and Desertification Induced Impacts on Ecosystem Services in Eritrea

Tsehay Melake Gebremariam[1], Fang Ping[2]

[1]Tongji University, UNEP Institute of Environment for Sustainable Development (IESD): College of Environmental Science and Engineering, Shanghai 200092, P. R. China.

[2]State Key Laboratory of Pollution Control and Resource Reuse, College of Environmental Science and Engineering, Tongji University, Shanghai 200092, P. R. China.

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Abstract

Desertification and Deforestation are serious environmental concerns in the Sahel and East African countries, including Eritrea. The dilapidation and natural forests loss due to deforestation and desertification have an irreversible impact on the services provided by the ecosystem. In recent decades Eritrea also experienced a serious threat of forest ecosystem loss and degradation resulting in the degradation of ecosystem services. Estimating the variation in this ecosystem's economic values due to deforestation and desertification is an important research topic in this area. Therefore, this study quantifies the change in ecosystem service values (ESVs) in response to the shift in Eritrea's forest cover over the past five decades. (1970-2020). The benefit transfer approach method was used to estimate changes in ESVs between 1970, 1980, 2014, and 2020. And to determine the study's consistency, a sensitivity analysis was conducted. The study revealed an overall decline of ecosystem services value (ESV's) from US$ 5.05 billion in 1970 to US$ 4.75 billion, from US$ 3.74 billion and US$ 3.57 billion in 1980, 2014, and 2020, respectively. The overall ecosystem service value in the study period decreased by US$ 1.48 billion due to a decline in Woodland and forest land cover by 1341km^2 and 1785 km^{2,} respectively, resulting from Deforestation and desertification. There were also changes in the values of the 19 individual products and services in the ecosystem. All in all, the findings showed that the decrease in forest and woodland cover in response to natural and human activities results in the degradation of the country's ecosystem services' value.

Keywords: Ecosystem services valuation, forest land, Woodland, Deforestation, desertification.

1. Introduction

human beings derive a variety of ecosystem services for their survival and quality of life[1]. Ecosystem services are the functions through which the natural ecosystem provides to human well-being through the interaction and exchange of its biotic and abiotic components[2, 3]. Ecosystem goods and services can be the direct material benefits derived from the ecosystem like medicinal resources, food, and other raw materials and indirect benefits driven from the ecosystem like water regulation, air purification, climate regulation, and erosion prevention [4, 5]. A well-functioning and robust or resilient ecosystem provide the flow of these direct and indirect benefits [2, 4, 6]. Since the past decades, the nature and value of these earth's life support services have been degraded primarily through their disruption and loss. Ecosystem and biodiversity destruction and depletion impacts the ecosystem's functioning and supply and thereby undermines ecosystems' potential to offer their services to continue to current and future generations [7]. The Millennium Ecosystem Assessment(MEA) analyzed that out of the 24 ecosystem resources, 15 have been depleted worldwide in the last 50 years[6]. The continued and rapid degradation in the ecosystem and its services affect many aspects of human well-being[6, 8, 9], particularly to the individuals who most depend directly on those services, including food, freshwater, fuelwood for their livelihood [10].

Desertification in the arid, semiarid, and sub-humid areas induced from different aspects, mainly climatic variations and

anthropogenic activities[11, 12], is becoming the main cause for the degradation of Land. As a result, it affects the ecosystem's productivity and its capacity to deliver products and services[8]. The long-term unsustainable use and consumption of land and vegetation resources along with climate change, made desertification expanded globally, mostly in the Sahel regions [13-15]. According to the Millennium Ecosystem Assessment this increase, in dryland desertification accounted for more than 41% of the world's land area, which is home to more than two billion people, threatening the livelihoods of millions of poor people[16]. Forestland cover changes resulting from Deforestation are also another primary concern for the degradation of the ecosystem services globally, especially in the less developed countries like the Sahel and East African countries, including Eritrea. About 850 million hectares of tropical forests worldwide have been destroyed or seriously degraded over the past century, causing severe impacts on the ecosystem and its services[17]. The study from Chakravarty showed a net decrease in forest cover by 8.3 million ha $year^{-1}$ from 1990 to 2000 and 5.2 million ha $year^{-1}$ between 2000 to 2010, resulting from deforestation; the highest deforestation rate occurred in East and Southern Africa, by 0.62% Between 1990 and 2000 and by 0.66% between the years 2000 and 2010[18]. And these threats are predicted to become more significant as a consequence of climate change and ever-growing resource use by humans[7]. Eritrea is part of both the Eastern African Highlands and Horn of Africa global biodiversity hotspots [19]. The nation benefits from a highly diverse range of globally unique and significant terrestrial ecosystems. However, the Country being part of the Sahel and East African countries, has faced the utmost environmental severe challenges caused by desertification and Deforestation [20]. The benefits delivered from the incredibly diverse range of globally distinctive and necessary terrestrial ecosystems have dwindled consequently [21]. The Sahel region is characterized by a decrease in rainfall over the past decades[22]. As a result, it leads to drought, which causes land degradation that causes severe impacts on land productivity. And this becomes the major environmental problem where the rate of desertification and Deforestation reaches the highest stage[20]. According to (Nyssen et al.), the Country forest cover was 30–40% in 1900[23]. Currently, the forest cover of the country declined to approximately 13.7%[24, 25]. The United Nations Food and Agriculture Organization (FAO) also stated that the country has lost 45,000 hectares of forest cover every year from 1990 to 2000. The rate of forest loss was 44,000 hectares per year between 2000 and 2010, and about 89,000 hectares of forest cover disappeared during the two decades of independence, from 1990 to 2010[24]. Though many studies testified the dynamics in forest cover loss in the Country, quantitative analyses of such effect on ecosystem service values are limited. Therefore, this study used the global value coefficient published by de Groot et al.[7] to estimate the shift in the value of ecosystem services in the past five decades in the country. And to check the reliability and robustness of the finding's sensitivity analysis was carried out by 50 percent adjustment of the value coefficients.

2. Materials and Methods

This paper's main purpose is to measure the influence of Deforestation and desertification on the ecosystem services over five decades (1970 to 2020) in Eritrea. Among the following two sections, Section 3.1 defines the background of the area study, Eritrea, and section 2.2 describes the data and methods used to measure the Ecosystem Services (Section 2.1.1)), the change in ESV's among the referenced years (Section 2.1.2) and analyze the accuracy of value coefficients used in ESV estimation for the forest and Woodland LULC of the country (Section 2.1.3).

2.1 Study Area

Eritrea lies in the arid, semiarid, and sub-humid parts of East Africa's Sahel region [24]. (Fig 1) between latitudes $12^0$22' and $18^0$02'N and longitudes $36^0$26'and $43^0$13'E[20, 26, 27]. Eritrea owns over 1,350 kilometers long coastal line that extends from Ras Kasar in the north to Dar Elwa in southeast Eritrea's [28]. It's in border to Sudan on the north and west, Ethiopia on the south, Djibouti on its southeast, and the Red Sea on the north and north-east. The surface area of the country is about 124,324 square kilometers [29], with a mainland and island coastline of more than 3300km[30]. According to the Public Health Statistical(PHS, 2010) population count made in 2010 by the Ministry of Local Government, the population of the country was estimated to be about 3.2 million with an annual growth rate of about 2.91 %[27]. 70-80% of this population depends on primary economic

activities, such as agriculture, pastoralism, fishing, herding, and forestry[24, 31]. Eritrea has an extended shape that includes a very complex topography of mountains, valleys, rivers, escarpments, highlands, and lowlands. The elevation of the country ranges from 120 meters below sea level in the Danakil depression to over 3,000 meters above sea level[31].

The country's weather and climate are strongly affected by its topography and elevation
[30]. The climate ranges from hot and arid near the Red Sea to temperate sub-humid in the eastern highlands [32]. The temperature varies from 16 ^{0}C in the highlands to 30 ^{0}C in the eastern and western lowlands[24]. The average annual rainfall pattern varies from about 100 mm in the Lowlands to about 700 mm in the Southern part of the Central Highlands with certain areas in the Central Highland Zone and Eastern Escarpment (green belt) benefit from bi-modal rainfall, receiving more than 700 mm and 1000mm of rain respectively. While the coastal lowlands are very dry [30]. This variation in the country's weather and climate combine with other factors results in a diversity of the terrestrial ecosystem, which mainly falls under four major categories: woodland ecosystem, forest ecosystem, an ecosystem of bushland/grassland, barren land/semi-desert ecosystem[30].The vegetation cover of the country consists of 0.8% highland forest, 11.3% near, medium and open forest; 63.8% grassland/wooded grassland/ and bushland; 1.6% riverine and mangrove forests[30]. Currently, the country is experiencing different ecological degradation for decades, resulting from desertification and deforestation [24] induced by a combination of human activities and natural calamities [21].

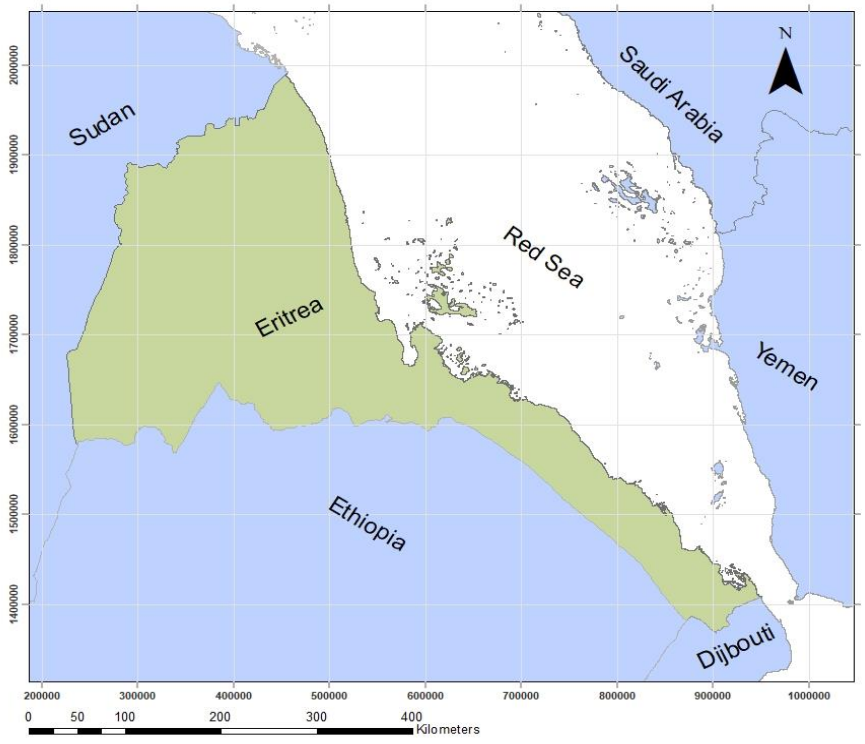

Figure 1. Location map of Eritrea

2.2 Methodology

2.2.1 Estimating the Ecosystem Services Value

To measure the impact of deforestation and desertification on the ecosystem services the land use land cover(LULC) forest land

and woodland have been selected for this study as these LULC categories are the one highly affected by deforestation and desertification [20, 24]. The Estimated cover area of the forest land and Woodland for the years 1970, 1980, and 2014 by (Ghebrezgabher et al.)[24] and the calculated forest and woodland cover for the year 2020 following (Equation 1)[33] (Table 1) were used to calculate the value of ecosystem services for the referenced years. The value transfer method (Equation 2), widely used by many (for example, Ferreira, L. M. R. et al. [34]; Sharma, S. et al. [35]) in an area where local valuation is lacking, was applied to estimating the overall ESV of the study area [36-38]. And to quantify the ESVs from each LULC, the global value coefficient (V.C.) (US$ ha-1a-1) calculated by de Groot et al.[7] was used. The value coefficient of the Tropical and woodland biome recognized by de Groot et al[7] best matches the local forest land and woodland forest therefore, these biomes have been selected as a proxy for the local ecosystem value (Table 2). The coefficients value was modified to December 2020 values using consumer prices index inflation calculator (https://www.bls.gov/data/inflation calculator.htm) to include the effect of time development in the value coefficients (Table 3).

$$A_2 = A_1\text{-}R(t_2\text{-}t_1) \ldots\ldots\ldots (1)$$

Where R is the annual rate of Deforestation (According to (Ghebrezgabher, M. G et al.) [20], the quality of Deforestation is equaled to 53 $km^2\ y^{-1}$), A_1 & A_2 refer to the area of forest land and woodland cover at time t_1 and t_2, respectively.

$$ESV_k = A_k \text{ X } VCk \ldots\ldots\ldots\ldots (2)$$

$$ESV_T = (\sum A_k \text{ X } VC_k) \ldots\ldots\ldots (3)$$

Where ESV_k and ESV_T represent the estimated ESV for LULC category k, and total ESV respectively, A_k is the area (ha), and VC_k is the value coefficient (US$ ha-1 yr.-1) in Table 2.

Besides the influence of forestland and Woodland cover change on the value of the 19 individual ES's under each services category was estimated following (equation 4)[39]:

$$ESV_f = (\sum A_K \text{ X } VC_{fk}) \ldots (4)$$

Where ESV_f represents the ecosystem service value of function f, A_k indicates for the cover area (ha), VC_{fk} indicates the value coefficient of function f (U.S. $ha−1 yr. −1), and the LULC category is indicated by k. (Table 3).

Table 1 Forest and Woodland Cover Area (ha) for the Year 1970, 1980, 2014 and 2020

Category	Area (ha)			
	1970	**1980**	**2014**	**2020**
Forestland	296600	264600	140100	118100
Woodland forest	1487900	1446500	1367700	1353800

Table 2 Land Use land Cover with Their Proxy Biomes and Corresponding VC (US$ ha-1 year-1)[7]

Land use land cover	Equivalent biomes	V.C.	Adjusted V.C.
Forestland	Tropical forest	5,263	6772.54
Woodland forest	Woodlands	1588	6120.09

Table 3 Ecosystem Services and Their Monetary Value (2020 $ ha-1a-1)

Ecosystem service	*Woodlands*	*Tropical forest*
Provisioning service	326.37	2352.3
Food	66.92	257.36
water		34.74
raw materials	218.76	108.09
genetic resources		16.73
medicinal resources		1935.38
ornamental resources	41.18	
Regulating services	65.63	3254.37
Air quality regulation		15.44
climate regulation	9.01	2630.27
Moderation of disturbance		84.93
water flow regulation		440.09
waste treatment		7.72
erosion prevention	16.73	19.30
nutrient cycling		3.86
polliation	39.89	38.61
biological control		14.15
Support services	1641.99	50.19
Nursery services	1638.13	20.59
genetic diversity	3.86	29.60
cultural services	9.01	1115.68
Aesthetics information		
Recreation	9.01	1115.68
ESV	6120.09	6772.54

Adjusted values from de Groot et al.[7] to the Consumer Price Index of December 2020

2.2.2 Estimating the Change in ESV's

The relative losses in ESV due to desertification and deforestation of the forest land and woodland cover over the four decades is estimated using ESs change index (CES_k) for specific land use type k. The change in ESV over the succeeding years was calculated using (Equation 5) and the percentage (CES_k) is calculated using (Equation 6).

$$ESV_k \text{ change} = \left(ESV_{(n+1 \text{ year}) k} - ESV_{(n \text{ year}) k} \right)$$

$$CES_k = \left(\frac{ESV_{(n+1 \text{year}) k} - ESV_{(n \text{ year}) k}}{ESV_{(n \text{ year}) k}} \right) X\ 100 \quad (6)$$

"Where "n" represents the reference year and the next reference year is represented by "n+1. Furthermore, in the four decades, the overall ESV change was calculated following (Equation 7) and the percentile change in the overall ESV was calculated using

(Equation 8).

$$\text{ESV change} = \left(\text{ESV}_f - \text{ESV}_i \right) \quad (7)$$

$$\% \text{ ESV change} = \left(\frac{\text{ESV}_f - \text{ESV}_i}{\text{ESV}_i} \right) \text{X } 100 \quad (8)$$

2.2.3 Sensitivity Analysis

Considering the match between the forest and woodland biomes in de Groot et al. [7]. used as proxies for the study area forest land and woodland LULC is not a perfect match in each case, a sensitivity analysis was performed as per Ferreira, L. M. R. et al. [34], Kreuter et al.[40],To determine if varying coefficient values would lead to undesirable uncertainties associated with the transition of unit values. The coefficient values used to measure the ESV of the two chosen LULCs were adjusted by ±50 percent, and the coefficient sensitivity (CS) was calculated with the equation (9) [41] according to the standard economic concept of elasticity[41].

$$CS = \left(\frac{(\text{ESV}_j - \text{ESV}_i) / \text{ESV}_i}{(\text{VC}_{jk} - \text{VC}_{ik}) / \text{VC}_{ik}} \right) \quad (9)$$

Where the original estimated ecosystem service value is ESV i, the modified ecosystem service value is ESV j, the initial and final value coefficient (in US$ ha-1 a-1) is VC_i and VC_j, and the LULC is represented by k. CS indicates the proportion of change in ESV with the proportion of change in VC. Greater than 1 value of CS indicates the estimated total ESV is elastic or very sensitive to the VC, recommended that a more accurate VC is required, whereas less than one value of CS demonstrates that the estimated total ESV is inelastic and robust and the VC is acceptable though it is not very precise [34, 35, 42].

3. Results

3.1 Ecosystems Service Value

The total ESV for the LULC forest land and woodland, for Eritrea, was quantified for the respective years 1970, 1980, 2014, and 2020 (Table 4). The country's total ESV from forest land and Woodland were US$ 5.05 billion, the U.S. $ 4.75 billion, U.S. $ 3.74 billion, and the U.S. $3.57 billion for the years 1970, 1980, 2014, and 2020 respectively (Table 4). The contribution of Woodland accounted for about US$ 3.04 billion, US$ 2.96 billion, US$ 2.79 billion, US$ 2.77 billion for the year 1070, 1980, 2014, and 2020 respectively, is higher as compared to the contribution of forest land, which accounted for about US$ 2.01 billion, US$ 1.79 billion, US$ 0.95 billion, US$ 0.80 billion for the years 1970, 1980, 2014 and 2020 respectively **(Table 4),** as the coverage area for Woodland, is greater than the forest land coverage area.

Table 4. Estimated ESV (2020 US$ billion yr^{-1}) for Each Land Uses "k" in the Referenced Year in Eritrea

	ESV_K			
	1970	1980	2014	2020
Forest land	2.01	1.79	0.95	0.80
Woodland	3.04	2.96	2.79	2.77
Total ESV	5.05	4.75	3.74	3.57

3.2 Change in Estimated Ecosystem Service Value

Across the study period, the ecosystem service value provided from the two land use land coves showed a decreasing trend (Table 5) in which the forest land ecosystem service values decreased from US $2.01billion to US $ 0.80 billion, while the woodland ecosystem service value decreased from US $3.04 billion to US $ 2.77 billion in the respective years 1970 to 2020 (Table 4). The overall ecosystem service value was drastically reduced by 13.57 % from 1970 to 1980, 52.22% from 1980- 2014, and 16.72 % from 2014 to 2020 (Table 5). The overall shift in the value of ecosystem service was calculated at 69.19%, with 60.18 percent of losses in the value of ecosystem service from forest land (Table 5) from US$ 2.01 billion to 0.80 billion (Table 4). And from 1970 to 2020, Woodland's ecosystem service value declined by 9.01 percent **(Table 5).**

Table 5. Change in ESV (2020 US$ billion yr^{-1}) and ES Change Index (CES K %) Among the Referenced Years (1970, 1980, 2014, 2020) in Eritrea

	1970-1980		**1980-2014**		**2014-2020**		**1970-2020**	
LULC	ESV_k	CES_k	ESV_k	CES_k	ESV_k	CES_k	ESV_k	CES_k
Forest land	-0.22	-10.79	-0.84	-47.1	-0.15	-15.7	-1.21	-60.18
Woodland	- 0.09	-2.78	-0.16	-5.45	-0.03	-1.02	-0.27	-9.01
Total ESV	-0.31	-13.57	-1	-52.55	-0.18	-16.72	-1.48	-69.19

3.2.1 Estimated Change in Individual Ecosystem Services Value

The result showed a decreasing trend among the referenced years in the estimated value of the 19 individual ecosystem services (Table 6). The first seven individual ecosystem services based on their contributions (from high to low) to the overall value of the ecosystem services were mainly from the ecosystem goods and services Climate regulation, medicinal resource, water flow regulation, food, and raw materials (Table 6. In which the highest ecosystem service value contribution from climate regulation was estimated at US$ 0.794 billion, US$ 0.709 billion, US$ 0.381 billion, US$ 0.323 billion for the years 1970, 1980, 2014, and 2020 respectively. On the other hand, the lowest contribution of ecosystem service to the overall ESV was estimated from nutrient cycling was estimated at US$ 0.001 billion, US$ 0.001 billion, US$ 0.0005 billion, US$ 0.00046 billion for the years 1970, 1980, 2014, and 2020 respectively. The contribution of the 4 ecosystem service categories, i.e., provisioning services, regulating services, supporting services, and cultural services for the year 1970 was about US$ 1.183 billion, US$ 1.062 billion, US$ 2.443 billion, US$ 0.344 billion respectively. When comparing this value with their respective value throughout the study period the results revealed a declining trend (Figure 2). The highest decline in ecosystem service value was for the group of regulating services (reduced by US$ 0.59 billion), followed by provisioning services (reduced by S$ 0.46 billion), supporting services (reduced by US$ 0.229 million), and cultural services (reduced by US$ 0.2billion) (Table 6) (Figure 2).

Table 6. The Estimated Value of the 19 Individual Ecosystem Services in the Referenced Years (ESV $_f$ (US$2020 billion yr-1) and the Overall Change in the Value of the Individual Ecosystem Services (from 1970 to 2020) in Eritrea

	ESV$_f$				Overall change ESV$_f$
Ecosystem Service	1970	1980	2014	2020	1970-2020
Provisioning service	1.183	1.094	0.776	0.72	-0.46
Food	0.175	0.164	0.127	0.120	-0.054
water	0.011	0.009	0.005	0.004	-0.007
raw materials	0.357	0.344	0.314	0.308	- 0.049
genetic resources	0.005	0.004	0.002	0.002	-0.003
medicinal resources	0.574	0.512	0.271	0.229	-0.35
ornamental resources	0.061	0.059	0.056	0.0557	-0.005
Regulating services	1.062	0.956	0.546	0.473	-0.59
Air quality regulation	0.005	0.004	0.002	0.0018	-0.003
climate regulation	0.794	0.709	0.381	0.323	-0.47
Moderation of disturbance	0.025	0.022	0.012	0.01	-0.015
water flow regulation	0.13	0.116	0.062	0.052	-0.079
waste treatment	0.002	0.002	0.001	0.0009	-0.001
erosion prevention	0.03	0.029	0.026	0.0249	-0.006
nutrient cycling	0.001	0.001	0.0005	0.00046	-0.0007
pollination	0.07	0.068	0.059	0.0586	-0.012
biological control	0.004	0.0037	0.002	0.0017	-0.0025
Support services	2.458	2.388	2.253	2.229	-0.229
Nursery services	2.443	2.375	2.243	2.22	-0.223
genetic diversity	0.015	0.013	0.009	0.008	-0.006
cultural services	0.344	0.308	0.169	0.144	-0.2
Recreation	0.344	0.308	0.169	0.144	-0.2

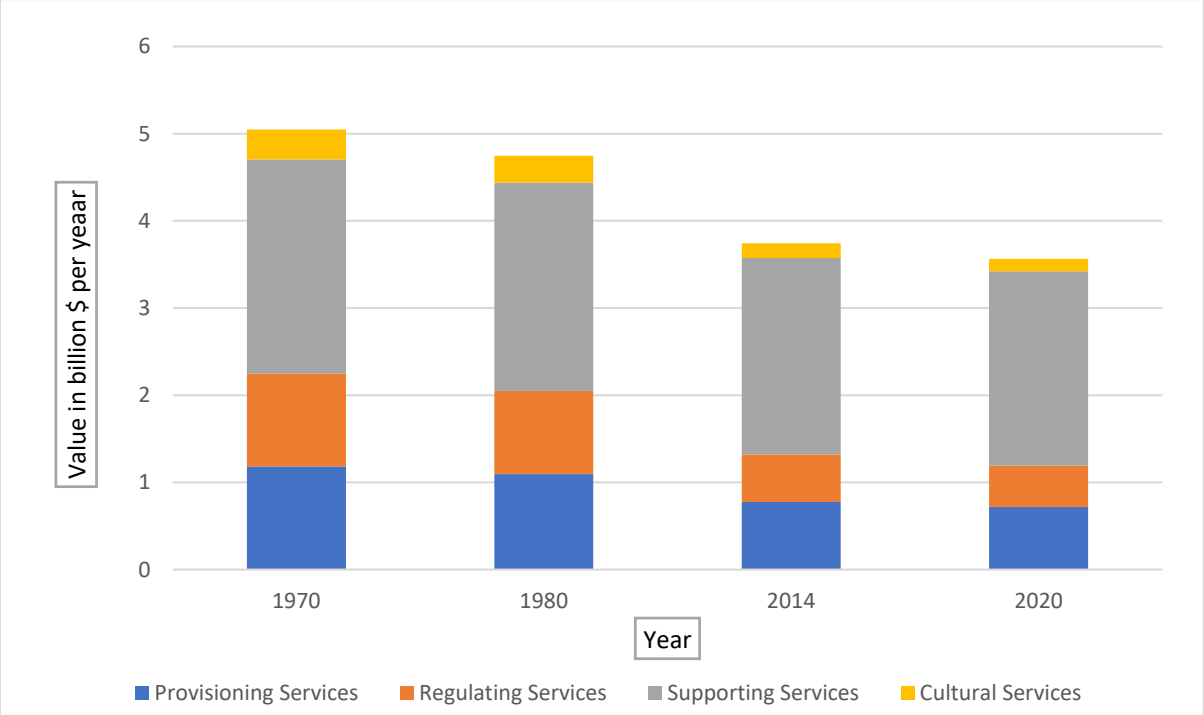

Figure 2 Ecosystem service value contribution from each service category in the referenced years in Eritrea

3.3 Sensitivity analysis of Value Coefficient

Table 7. Estimated ESV Adjusted (2020 US$ billion yr^{-1}) to 50% of Ecosystem Service VC for Each Land Use "k" and the Relative Percentile Change in ESV Adjusted Among the Referenced Years (1970, 1980, 2014, 2020) in Eritrea

	ESV $_{adjusted}$				Change in ESV $_{adjusted}$ (%)			
LULC	1970	1980	2014	2020	1970-1980	1980-2014	2014-2020	1970-2020
Forest land + 50%	6.01	5.64	4.22	3.97	-6.77	-25.27	-5.97	-34.48
Forest land - 50%	4.04	3.85	3.27	3.17	-4.77	-15.13	-3.15	-21.72
Woodland + 50%	6.57	6.22	5.14	4.95	-5.23	-17.42	-3.73	-24.66
Woodland - 50%	3.52	3.27	2.34	2.18	-7.34	-28.25	-6.96	-38.14

Table 8. Coefficient of Sensitivity (CS) After Adjusting the Valuation Coefficients (VC) in Eritrea

	CS			
LULC	1970	1980	2014	2020
Forest land + 50%	0.39	0.38	0.25	0.22
Forest land - 50%	0.39	0.38	0.25	0.22
Woodland + 50%	0.6	0.62	0.75	0.78
Woodland - 50%	0.6	0.62	0.75	0.78

Analysis of sensitivity was performed to verify value coefficients' reliability to use as proxy biomes by adjusting the value coefficients by ±50% to the estimated ESVs. The adjusted value coefficients for the years 1970, 1980, 2014, and 2020 are shown in Table 7. The analyzed sensitivity coefficient showed less than one for both forest land and woodland (Table 8), which shows that the total estimated ESV for the country is relatively inelastic. In other words, they display a relation of low sensitivity to changes of up to 50% in the value coefficients suggested by de Groot et al. [7]. Thus, it is considered that the estimated ESV is reasonably acceptable. The sensitivity coefficient varies from 0.22 to 0.39 for forest land and 0.6 to 0.78 for woodland. The high value of CS for Woodland is due to its relatively larger area cove

Discussion

Several studies indicated that Eritrea is among the most vulnerable countries to desertification associated with anthropogenic activities related to Deforestation of forest land for other land use purposes and natural activities related to climate change, such as irregular rainfall or drought. The loss in Ecosystem production potential is directly connected to desertification as the degradation of the ecosystem and its productivity is an indication of desertification[43]. According to the study conducted by Ghebrezgabher, M. G et al. [43], 35,626 square kilometers of the country's Land became infertile due to substantial desertification land expansion from the year 1070 to 2014. Such an increase in desertification intensifies the degradation of the provision of the country's ecosystem services. A significant reduction was seen in the overall estimated value of ecosystem services (by 69.19%) within the five decades (Table 5), resulting from a decline in forest land and woodland cover from 17845 km^2 to 14719km^2. The decline in forest land cover results in a 10.79 percent, 47.1 percent, and 15.7 percent decrease in ecosystem service value between 1970 to 1980, 1980 to 2014, and 2014 to 2020. While the total loss of ecosystem service value resulting from the decline in woodland cover was estimated to be 9.01%. The sensitivity analysis was applied to check the accuracy of the total estimate ESV predicted and was found to be reliable. However, the gaps of transferring the universal value coefficient to a local value coefficient have been described by many (for example, Richardson, L. et al.[44], Rolfe, J. et al. [36] and Ferreira, L. M. R.et al. [34]) and recognized here as the ecosystem service value developed by de Groot et al. [7] might either underestimated or overestimated the local ecosystem services value. The ESV from both land use types depends on the cover area and the total monetary value of the individual ecosystem services. The adopted value coefficient for the biomass tropical forest and woodland is based on 17 and 9 individual ecosystem goods and services respectively. The limitations here to use those value coefficients is there are some omitted monetary values from the individual ecosystem services. However, those services are delivered from the local forest and woodland. Besides, ecosystem service value coefficients assume spatial homogeneity of services for example the forest land located in the eastern escarpment is denser as compared to the forest land located in the central and southern highlands as well as to the forest land located in the southwestern region of the country but all received the same estimation. Considering the above and other gapes stated by many (Richardson, L.et al., for instance)[44], Rolfe, J. et al. [36] Application of value Coefficient, representing the specific local biophysical characteristics, the ecosystem service value of all individual ecosystem services, and the change in the market value of the services through time would be more accurate in quantifying the change in the value of ecosystem services value, but considering the lack of local data, the existing data sets with caution help to estimate the magnitude of the ecosystem services losses as a result of deforestation and desertification to formulate policies and take the need management measures.

Conclusion

Estimating the cost of tree cover loss resulting from deforestation and desertification is a useful tool to raise awareness and take the appropriate management measures. expressing the value of ecosystem services loss in monetary value provides a reliable estimate of the direct and indirect costs of deforestation and desertification. Therefore, this study estimates the cost of deforestation and desertification on the provisions of ecosystem services in Eritrea by analyzing the change in the ESVs in the past five decades. Considering the absence of local valuation data benefit transfer method was used to quantify the total decrease in ecosystem services value from the year 1970 to 2020. In this study, the forest land and woodland LULC in Eritrea for the years 1970, 1980, 2014 were adopted from Ghebrezgabher, M. G et al.[24], and the forest land and woodland LULC for the year 2020 was calculated using the annual rate of deforestation and desertification. And the value coefficient of the tropical biome and woodland biome has been selected as a proxy for the local ecosystem values.

This study revealed that the overall decrease in forest and woodland cover in the country from 1784500 ha to 1471900, caused a decrease in the value of ecosystem services from US$ 5.05 billion to US$ 3.57 billion with a net loss of US$ 1.48 billion. The highest loss in ESVs was from the forest land decreased by US$ 1.21 billion or by 60.1%. And regarding the woodland, the total decrease in ESVs was estimated US$ 0.27 billion or 9.01%. This decline in the ecosystem service values were mainly associated with the huge losses of forests and woodland cover caused by deforestation resulting from anthropogenic activities like subsistence cultivation, cutting trees for firewood and/or timber, urbanization, and overgrazing, as well as desertification caused by the change in climate, resulting in a prolonged drought. The value of the individual ecosystem functions has also declined

throughout the study period, in which climate regulation, medicinal resources, water flow regulation, provisioning of food and raw material were among the services that showed Significant degradation in their value. Considering the importance of ecosystem services the finding of this study provides use full datasets on the impact of deforestation and desertification on the provisioning of ecosystem services from the study area for future studies and policy formulation.

AUTHOR'S

First Author- Tsehay Melake Gebremariam Master Candidate, Tongji University, UN Environment-Tongji Institute of Environment for Sustainable Development (IESD): College of Environmental Science and Engineering; Email: gtsehaymelake@gmail.com, Phone No +86 13196540850; Address: 1239 Siping Road, Shanghai 200092, China.

Second Author- Fang Ping (Ph.D.) Mentor and Supervisor, Shanghai Institute of Pollution Control and Ecological Security; State Key Laboratory of Pollution Control and Resource Reuse; Key Laboratory of Yangtze River Water Environment, Ministry of Education, Tongji University, Email: fangping2000@tongji.edu.cn; Phone No +86 021- 65983869; Address, Siping Rd 1239, Shanghai, 200092, PR China, 200092, PR China,

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