Impact of Land Use and Land Cover Changes on Ecosystem Services Value in Mwanza City, Tanzania

Land use is related with land cover. It shouldn't be I suggest to use one or another term

Abstract

trphic chains; food production; biodiversity; rain harvest, soil health.

No, if planned Impact is prior and after...

Ecosystem services are vital services that support life and are the basis for human socio-economic progress. However, changes in land use and land cover (LULC) brought about by urban expansion degrade them. Thus, analysing the impact of land use and land cover (LULC) change on ecosystem service values (ESVs) is crucial for understanding and informing resource policy decisions. This study aims to analyse the impact of land use and land cover changes on ecosystem service values in Mwanza City, Tanzania. To achieve that, the benefits transfer approach was employed to analyse the changes in ESV in response to LULC. We estimated and analysed changes in ESV using satellite image datasets from 1999, 2009, and 2019. The LULC classes that were identified are vegetated land, agricultural land, waterbodies, built-up area, and bareland. The results exhibit that Mwanza City experienced significant LULC changes. While vegetated land, agricultural land, and bareland decreased by 49%, 15%, and 36%, respectively, the built-up area and water bodies increased by 568% and 48%, respectively, during the two decades. The total ESV decreased from 31.35 million US dollars to 26.3 million US dollars between 1999 and 2009 and to 23.96 million US dollars between 2009 and 2019. The waterbodies increased due to the increased volume of water in streams that expanded the floodplains, which resulted from surface runoff attributed to increased paved surfaces as more land was converted into a built-up environment upstream . The built-up area and bareland contributed nothing to ESV. However, the built-up area was the driving force behind the reduction of ESV in other LULC classes, as it was encroaching on them. The study concludes that the decrease in ESV reflects the degradation of ecosystem services due to the change in LULC. Hence, it is recommended that sustainable management of ecosystems be adhered for the proper functioning of the earth's life-support system.

Trend in bare soil?.. This is relevant

Keywords: Benefits transfer method, Ecosystem services, land use/cover, Tanzania, Urbanisation.

1. INTRODUCTION

Healthy ecosystems are vital for producing ecosystem services crucial for human survival [1]. Ecosystems generate oxygen, purify the water and air, and stabilise the climate. Organisms decompose waste, create soil for food production, and recycle nutrients for agriculture. Animals pollinate and fertilise plants, while humans use and trade these species for various purposes, including food, shelter, medicine, and aesthetics [2].

Costanza et al. [3] and Millennium Ecosystem Assessment (MEA) [4], define ecosystem services as the direct and indirect benefits of the ecosystem to people. Costanza et al. [3] grouped ecosystem services into seventeen major categories (Table 1).

Table 1: Ecosystem Services and Functions Adopted from Costanza et al. (1997)

	Ecosystem services	Ecosystem functions
1	Gas regulation	Regulation of atmospheric chemical composition.
2	Disturbance regulation	Capacitance, damping and integrity of ecosystem response to environmental fluctuations.
3	Climate regulation	Regulation of global temperature, precipitation, and other biologically mediated climatic processes at global or local levels
4	Water regulation	Regulation of hydrological flows.
5	Erosion control and sediment retention	Retention of soil within an ecosystem
6	Water supply	Storage and retention of water
7	Soil formation	Soil formation processes.
8	Waste treatment	Recovery of mobile nutrients and removal or breakdown of excess or xenic nutrients and compounds
9	Nutrient cycling	Storage, internal cycling, processing and acquisition of nutrients.
10	Pollination	Movement of floral gametes
11	Food production	That portion of gross primary production extractable as food.
12	Biological control	Trophic-dynamic regulations of populations.
13	Refugia	Habitat for resident and transient populations
14	Raw materials	That portion of gross primary production extractable as raw materials.
15	Genetic resources	Sources of unique biological materials and products
16	Cultural	Providing opportunities for non-commercial uses
17	Recreation	Providing opportunities for recreational activities.

Source: Adopted from Costanza et al. (1997)

However, more than ever, humans have changed ecosystems drastically and quickly [5], mostly to accommodate urbanisation and the world's expanding resource needs [6]. Resources such as wood, fresh water, air and water purification, controlling local and regional climates, and mitigating natural dangers are either being depleted or used in an unsustainable manner [5]. Converting landscapes (such as paving) and harvesting biological populations (such as logging), are a threat to the ongoing supply of ecosystem services [7, 4].

The rapid growth of urban areas, which are home to 56% of the world's human population as of 2022 [8], is exerting enormous pressure on ecosystem services within and around cities [7]. Urban land change has disproportionately huge consequences given the area it occupies worldwide [6]. It is projected that by 2030, the built-up area will have added to the world 1.2 million km^2 of urban land [9,10], concentrating pressures on the ecosystems that support those urban regions. However, much of the urban land growth is expected to be in Africa [11].

This trend is relevant for Mwanza city? If so, include in the context

More natural ecosystems on the outskirts of cities are being converted to industrial, residential, or agricultural uses [12). Leading to the loss of agricultural lands, habitat fragmentation, biodiversity loss, and inefficient use of natural resources [10]. The process hampers the ecosystems and the services they provide for human well-being in cities [13, 6]. This is because the changing LULC triggers the demand and supply flow of ecosystem services as well as the economic benefits of commercial, industrial, and residential land uses for urban dwellers [14].

Urbanisation affects the structure, composition, function, and efficiency of ecosystems, thereby affecting the value of ecosystem services [14, 15, 16, 17]. Its effects might be bigger than those caused by natural events, especially if ecosystem surfaces are changed so much that natural processes of succession and recovery are harmed, which makes the system less resilient [12,18,7]. When landscapes are changed for farming, ecosystem services are often swapped, with one service (like increasing crop yields) getting better at the expense of others (like losing the ability to support soil formation) (14, 7; 4).

Thus, addressing the impacts of LULC changes on ecosystems in and around cities is crucial [19, 14]. However, this cannot be done if policymakers and decision-makers are not well informed on the effects of land use and land cover changes on ecosystem services in monetary terms. Because of this, measuring ESVs and their variations has attracted a lot of attention since Costanza et al. [3] published their list of biome ecological service value coefficients (LULC categories) and estimations of global ESVs [20].

Since then, several ecosystem services assessment and valuation methods have been developed, including benefits transfer, replacement cost, contingent valuation, avoided cost, travel cost, and market prices approaches [21, 14]. However, the benefits transfer method has been widely used because it is easy to apply as it "uses a given valuation study to assess a new location of similar characteristics" [21].

The benefits transfer method refers to "the transfer of original ecosystem service value estimates from an existing 'study site' or multiple study sites to an unstudied 'policy site' with similar characteristics that is being evaluated" [22]. Costanza and colleagues estimated the monetary value of 17 ecosystem services from 16 different global landscapes using the benefits transfer method. Later, they conducted case studies of more than 300 places from different parts of the world, which updated the estimations more [21].

The resultant estimates provided the foundation for using them to study other regions with similar characteristics elsewhere. Eventually, researchers have utilised this method to evaluate the impact of land use and land cover changes on ecosystem services, considering land use and land cover changes as a substitute for the supply of ecosystem services [21, 23].

Similarly, ecosystem services in Tanzania, like in any other country in the world, are vital for supporting life systems, including the socio-economic development of the people. For instance, more than 70% of the population in the country is employed in agriculture. The sector contributes approximately 25% of foreign exchange, 30% of the GDP, 65% of industrial raw materials, and 100% of food needs [24]. But also, ecosystems serve as the main source of energy in the country, whereby 90% of households are using either firewood (69%) or charcoal (21%) for cooking [25].

With an average population growth rate of 3.2% per year, mainly attributed to natural population growth, Tanzania is among the top 8 contributors to global population growth in the world [8] and the fifth in Africa [26]. By 2050, its population is expected to exceed 140 million people [27, 26]. Such growth has some implications for the demand and supply flow of ecosystem services. This is because ecosystem services have to save additional populations in various ways. For example, the country was losing 469,000 ha of forest per year as of 2020, attributed to firewood and charcoal production, agricultural expansion, overgrazing, the development of human settlements, uncontrolled fires, the development of infrastructure and industry, timber extraction, and refugees [28].

However, of particular concern has been the rate at which towns and cities are growing in the country. For instance, in the past three decades, the urban lands of eleven towns and cities in the country grew by 480 km^2 [29]. Such expansion has already resulted to urban sprawl in some cities due to the lack of a clear urban policy in the country [30].

Mwanza City is among the cities in the country that are experiencing fast urban expansion. Mwanza, the second-largest city in the country, was home to 1,245,000 people in 2022 [31]. The population of the city is expected to reach 2.4 million by 2035 [32], assuming the present urban growth rate of 3% per year is maintained [33]. Yet the city is facing the development challenge of unguided urban expansion [34].

For instance, between 1999 and 2009 and between 2009 and 2019, Mwanza City grew by 107% (2179.9 hectares) and 118% (4957.53 hectares), respectively [35]. This expansion changed most of the land use and land cover for urban use [35]. Most land cover and land use turned into physical development for the construction of infrastructure, institutional buildings, commercial, industrial, and residential buildings (34).

However, since the majority of Mwanza City residents remain heavily dependent on local ecosystem services, as is the case in the country, there is a need for managing ecosystems in order to enhance services. Thus, to improve understanding and inform resource policy decisions in the management of

The objective of the study was not declared ecosystems, it is important to quantify and analyse changes in ecosystem service values (ESVs). Therefore, the goals of this study were to (i) quantify LULC changes between the years 1999, 2009 and 2019, and (ii) analyse the economic value of ecosystem service changes (ESVs) associated with LULC dynamics in Mwanza City.

2. MATERIALS AND METHODS

2.1.Description of the study site

Mwanza City is located in northwest Tanzania, on Lake Victoria's southern shores. With a total area of 256.45 km², of which 184.90 km² (72%) is dryland and 71.55 km² (28%) is covered by water, approximately 173 kilometres of the 184.90-kilometre dry land area are urbanised; the remaining parts are made up of farmed plains, valleys, grassy, undulating rocky hill areas, and forests [34]. It is situated between latitudes 2˚15'S and 2˚45'S and between longitudes 32˚45'E and 33˚05'E (Figure 1).

Mwanza City is divided into two administrative districts: the Nyamagana District (Mwanza City Council) and the Ilemela District (Ilemela Municipal Council). On October 1, 2012, the Mwanza City Council was split into the new Mwanza City Council (Nyamagana) and the Ilemela Municipal Council (Ilemela). According to the United Republic of Tanzania (URT) population and housing census of 2022, the Nyamagana District (MCC) had a population of 594,834 and an average household's size of 3.9, while the Ilemela District (IMC) had a population of 509,687 and an average household size of 4.0 [27].

Mwanza City has been experiencing unguided urban expansion [34], which has resulted in land use and land cover changes [35]. According to [34], most land cover and land use turned into physical development for the construction of infrastructure, institutional buildings, commercial, industrial, and residential buildings. Thus, increasing awareness about the loss of ecosystem benefits through quantification in monetary terms is potentially important as it informs environmental managers and planners.

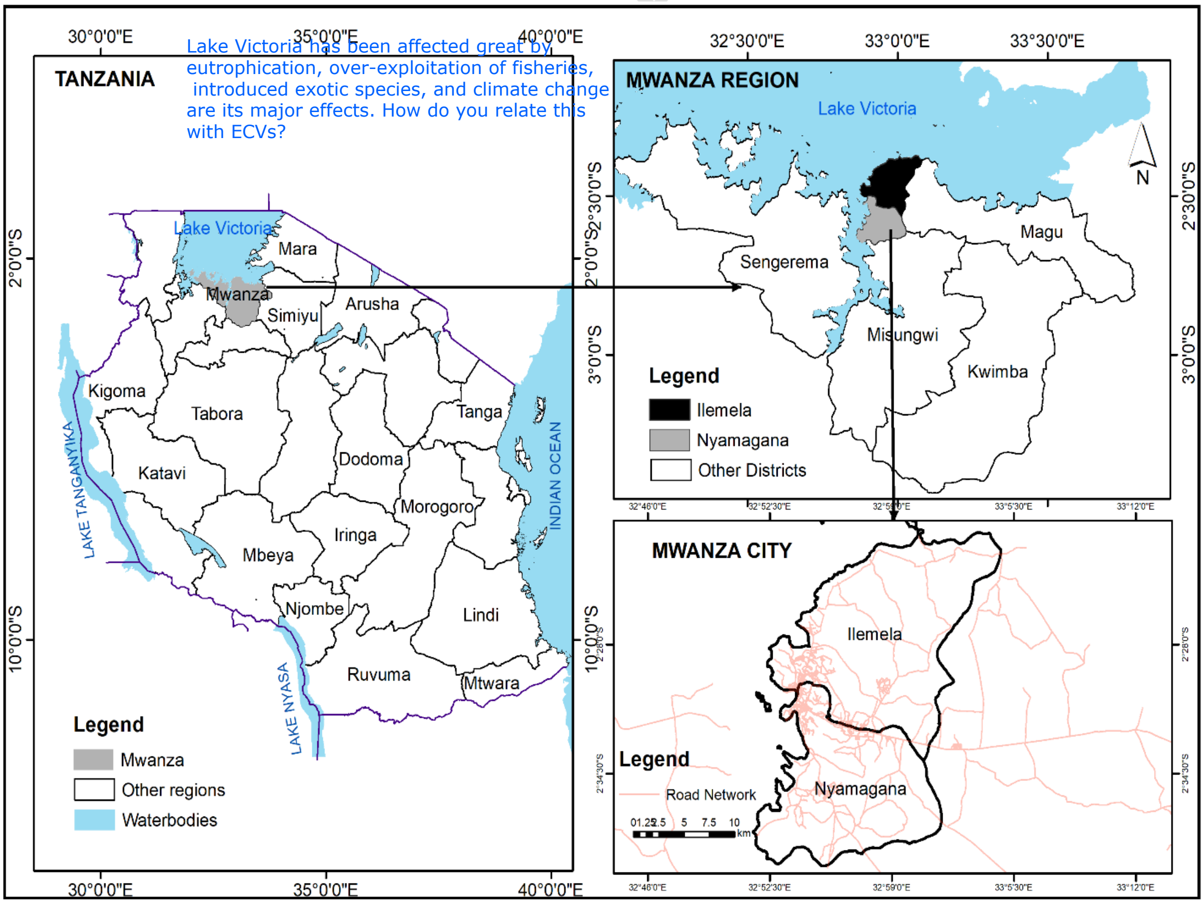

Figure 1: Location of the Study Site

2.2.Pre-Processing and Classification of Images

The land use and cover classes were classified and analysed using Landsat 5 TM and 8 OLI satellite images. The satellite images were obtained through (https://earthexplorer.usgs.gov/) (Table 1). Image data pre-processing and processing were done using QGIS 3.34.1 Prizren. The Semi-Automatic Classification (SCP) plugin tool was used to do this. First, the images were georeferenced and geometrically corrected using the UTM zone 36^0S coordinate system and the Datum ARC 1960. Next, the Maximum Likelihood Classification under supervised classification was used to classify LULC categories. Five LULC categories were created, namely vegetated land, cultivated land, waterbodies, built-up area and bare land (Table 2). Toigraphic correction have to be applied...

Table 2: Landsat Images

Landsat image	Sensor	Path/row	Acquisition	Resolution	Source
Landsat 8	Operational Land Imager	171/62	4^{th} June 2019	30m	United States Geological Survey
Landsat 5	Thematic Mapper	171/62	22^{nd} June 2009	30m	United States Geological Survey
Landsat 5	Thematic Mapper	171/62	8^{th} June 1999	30m	United States Geological Survey

2.3.Land Use and Land Cover Change Detection

The amount of change in LUCL in hectares was calculated. Equally, the percentage change at a ten-year interval throughout the study period was as well computed (Table 4). The following formula (Eq. 1) was used to determine the percent rate of change:

$$\Delta\% = 100 \times \left(\frac{final - initial}{initial}\right) \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{Equation 1}$$

Where, Δ% is the change percentage, *final* is later year, *initial* is earlier year.

2.4.Valuations of Ecosystem Services

The geographical information systems and remote sensing technologies were applied in the estimation process. The geographical information systems technology was used to estimate and map the distribution, while the remote sensing helped to generate LUCL categories identified in the study area, and then they were used as proxies for measurements. Important web-based technologies for spatial mapping are gradually being used to value ecological services [36, 22]. Thus, this study employed the ESV coefficients of Costanza et al [3] to obtain the ESV for the LULC categories. This is because these coefficients are" the most comprehensive set of approximations available for quantifying the change in the value of services provided by a wide array of ecosystems" [37].

As presented by Costanza et al. [3], the 16 biomes were put into LULC categories, such as (1) cropland (agricultural land), (2) ice or rock (bareland), (3) forest and trees, (4) urban (built-up areas), and (5) lakes and rivers (waterbodies) (Table 3). The study did not use the ESVs that were proposed by de Groot et al. [39] and Costanza et al. [40] because the values overestimated the defined ecosystem functions and are deemed not appropriate for the LULC identified in Mwanza City.

Table 3:LULC Types with Biome Equivalents and the Corresponding ESV (Costanza et al. 1997 (in 2007 US$ ha/year))

Type of land use/cover	Equivalent biome	ESV Coefficient (in 2007 US$/ ha/year)
Vegetated land	Forest and trees	2007
Agricultural land	Cropland	92
Waterbodies	Lakes/river	14785
Built-up area	Urban	0
Bare land	Ice or rock	0

Source: Adopted from Costanza et al. 1997

These data is point coordinates. You are using raster data, so you should derive the monetary value at city scale as the study propose

The benefits transfer method was adopted, whereby the ecosystem service values of each LUCL category was calculated using the corresponding equivalent coefficient value of each ESV (Table 3). The method helps in “adapting the monetary value of ecosystem services determined at one location and time to draw conclusions about the monetary value at a different location and time” [41]. Using the formula (Eq.2) in the estimated ESV of each LULC category in the site, the ESVs for all LULC categories were determined for each period (Tables 5, 6 & 7).

$$ESV = \sum (A_k \times VC_k) \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{Equation 2}$$

Where, ESV = ecosystem service value, A_k=area in hectares (ha), VC_k=value coefficient (US$ ha/year) for land category ‘k’. Summation of the individual ES represent total ecosystem service for a specific year.

But also, the changes of ESV were computed using the difference of the estimated values in each reference year [41] and the values were presented in US$ and percentages, Eq.3 (Table 8).

$$ESV\, percentage\, change\ (\%) = 100 \times \left(\frac{ESV_{end\ year} - ESV_{start\ year}}{ESV_{start\ year}} \right) \ldots\ldots \text{Equation 3}$$

3. RESULTS AND DISCUSSION

3.1 LULC Changes Between the Years 1999, 2009 and 2019

Trend?

Over the course of 20 years, the study reveals that LULC categories changed from one type to another. Figure 2 indicates the classified LULC maps, whereby the built-up areas, in red, have experienced a notable increase between 1999 and 2019. In a similar vein, wetland (blue colour) somewhat increased throughout in the study period. Conversely, throughout the 20 years, there was a large decline in agricultural land (purple colour), bareland (yellow colour), and vegetated land (green colour) (Figure 2).

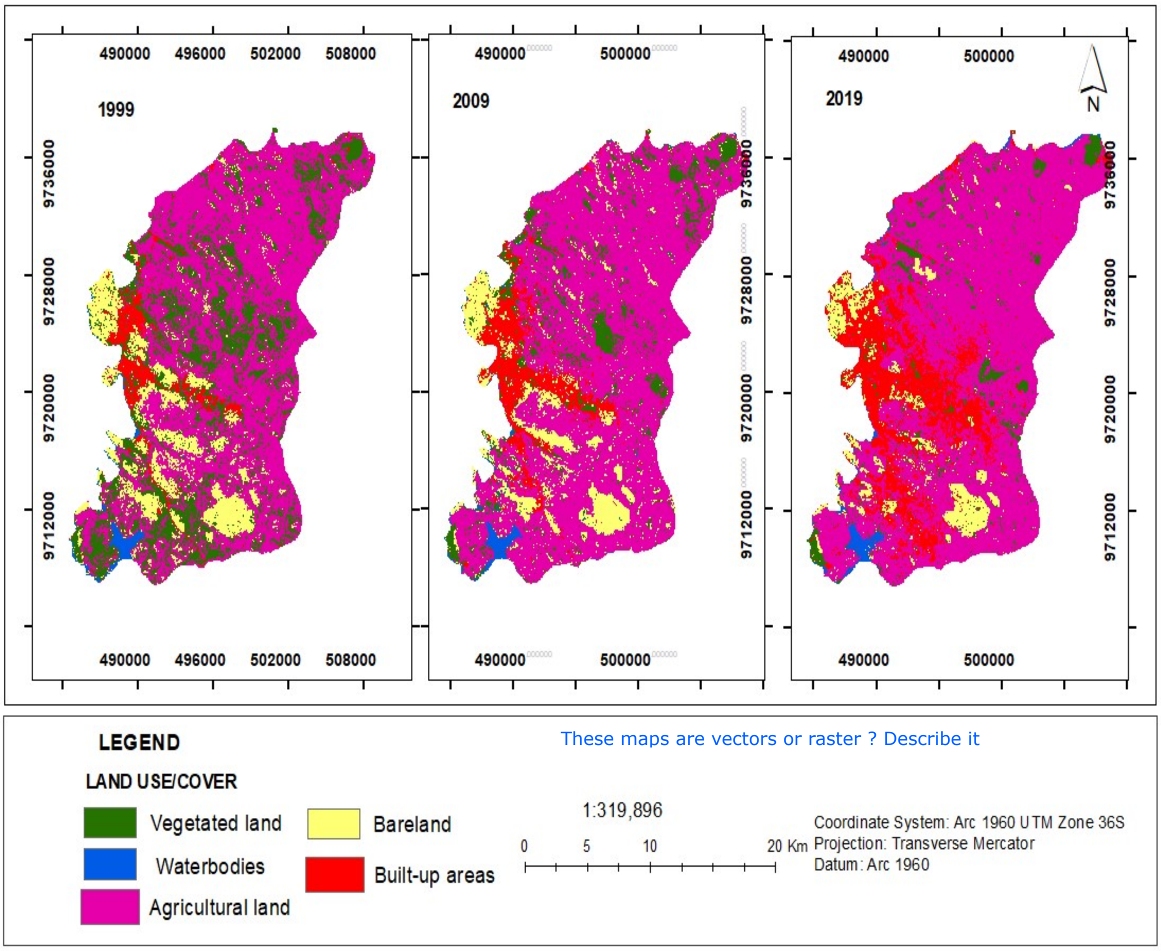

Figure 2: The 1999, 2009 & 2019 Classified LULC Maps

In the period between 1999 and 2019, the findings show that the total built-up area increased by 568% (Table 4). Whereby, 4,368.3 hectares (217%) of built-up area increased between 1999 and 2009, and 7,074.27 hectares (111%) increased between 2009 and 2019 (Table 4). This increase was at the cost of other LULC types. Also, between 1999 and 2019, waterbodies increased by 48% (236.78 hectares). Conversely, between 1999 and 2019, there was a decrease of 5,214.57 hectares (49%), 4,570.51 hectares (15%), and 1,894.27 hectares (36%), in vegetated land, agricultural land, and bareland, respectively (Table 4).

Table 4: LULC Change

LULC classes	1999		1999-2009	2009		2009-2019	2019		2019-1999
	Area (ha)	Area (%)	Rate of change (%)	Area (ha)	Area (%)	Rate of change (%)	Area (ha)	Area (%)	Rate of change (%)
Vegetated land	10555.56	21	-30	7404.6	15	-28	5340.99	10	-49
Agricultural land	30212.28	62	-2.3	29516.85	60	-13	25641.77	53	-15
Waterbodies	499.05	1	19	593.46	1.2	24	735.83	1.5	48
Built-up area	2014.83	5	217	6383.13	13.8	111	13457.4	28.5	568
Bare land	5287.5	11	-12	4671.18	10	-27	3393.23	7	-36
Total	48569.22	100	-	48569.22	1	-	48569.22	100	-

Source: Computed from Satellite Images

The findings imply that within the period of 20 years, Mwanza City experienced the loss of vegetated land, agricultural land, and bareland to built-up areas. The slight increase in waterbodies was due to the increased volume of water in streams resulting from surface runoff attributed to increased paved surfaces as more land was converted into a built-up environment [42]. The increase in the built-up area corresponds to a population increase in the city. The population of Mwanza City increased from 241,923 in 2002 [34] to 706,353 in 2012, with an annual growth rate of 3% [43]. As of 2022, the total population of Mwanza City was estimated to 1,245,000 [31]. This growth heightened the demand for land to construct infrastructure, institutional buildings, commercial, industrial, and residential buildings [34].

On the other hand, within the same time period, the bareland decreased significantly. It changed to other LUCL types, specifically through the removal of rocks to get building sites and quarrying rocks and sand for construction activities [44]. Mwanza City is geographically a rocky landscape, hence being dubbed "the rocky city." Thus, any physical landscape changes are easily noticeable.

3.2 The Impact of LULC Changes on Ecosysem Sevices Values

The study established that, in 1999, vegetated land (21.19 million US$), agricultural land (2.78 million US$), and waterbodies (7.38 million US$) had the greatest contribution to ecosystem services as they had both higher ecosystem service values per hectare and total areas compared to the following years (Table 5). With the exception of the waterbodies which were increasing with an increase in time. In total, they contributed 31.35 million US dollars to ecosystem services (Table 5).

Table 5: Estimated ESV for 1999

1999 ESV (million us $)				
LULC class	LU (ha)	ES Coefficient (US $ ha-1/ year)	Estimated ESV	
Vegetated land	10555.56	2007	21,185,008.92	21.19
Agricultural land	30212.28	92	2,779,529.76	2.78
Waterbodies	499.05	14785	7,378,454.25	7.38
Built-up area	2014.83	0	0	0
Bare land	5287.5	0	0	0
Total				31.35

However, the changes in vegetated land and agricultural land that took place between 1999 and 2009 significantly reduced their contribution to ecosystem services. Their ecosystem service value was 17.58 million US dollars in total (Table 6). This was because much of those LULC types changed to built-up areas, which was not contributing anything to ecosystem services. On the contrary, the waterbodies contributed more to the ecosystem services as the ecosystem service value grew to 8.77 million US dollars (Table 6) from 7.38 million US dollars in 1999 (Table 5). This was attributed to the increase in the total area. The increase in area may be due to the increased volume of water in streams that expanded the floodplains, which resulted from surface runoff attributed to increased paved surfaces as more land was converted into a built-up environment upstream[42].

Table 6: Estimated ESV for 2009

2009 ESV (million US $)				
LULC class	LU (ha)	ES Coefficient (US $ ha-1/ year)	Estimated ESV	
Vegetated land	7404.6	2007	14,861,032.2	14.86
Agricultural land	29516.85	92	2,715,550.2	2.72
Waterbodies	593.46	14785	8,774,306.1	8.77
Built-up area	6383.13	0	0	0
Bare land	4671.18	0	0	0
Total				26.3

Similarly, the study indicates that in 2019, vegetated land and agricultural land had the lowest contribution to ecosystem service values. While the water bodies had the highest contribution to ecosystem service values. Table 7 shows that vegetated land and agricultural land had ecosystem service values of 10.72 million US dollars and 2.36 million US dollars, respectively. Compared to the past two decades, this amount was equivalent to losing ecosystem service values of 10.47 million US dollars (49%) and 0.42 million US dollars (15%) of vegetated land and agricultural land, respectively (Table 8).

Table 7: Estimated ESV for 2019

			2019 ESV (million us $)	
LULC class	LU (ha)	ES Coefficient (US $ ha-1/ year)	Estimated ESV	
Vegetated land	5340.99	2007	10,719,366.93	10.72
Agricultural land	25641.77	92	2,359,042.84	2.36
Waterbodies	735.83	14785	10,879,246.55	10.88
Built-up area	13457.4	0	0	0
Bare land	3393.23	0	0	0
Total				23.96

Conversely, the contribution of waterbodies to ecosystem service value continued to rise as the acquisition of land from other LULC types continued. Table 8 indicates that between 1999 and 2019, waterbodies increased by 47% (3.5 million US dollars). Also, the total decrease in ecosystem service value over the two decades was 14.61 million US dollars (24%) (Table 8). This was attributed to a decrease in the area of vegetated land and agricultural land.

Table 8: Changes in ESVs from 1999 to 2009, 2009 to 2019, and 1999 to 2019 Time Periods

LULC categories	**Ecosystem service values changes (million US $) between study periods**					
	1999-2009		2009-2019		1999-2019	
	Million US$	Change %	Million US$	Change %	Million US$	Change %
Vegetated land	-6.33	-30	-4.14	-28	-10.47	-49
Agricultural land	-0.06	-2	-0.36	-13	-0.42	-15
Waterbodies	1.39	19	2.11	24	3.5	47
Built-up area	0	0	0	0	0	0
Bare land	0	0	0	0	0	0
Total	-10.55		-4.06		-14.61	
% Overall change	-16		-9		-24	

Conclusion is not suported by the results. The study has characterized the land use only but none evaluation on EVSs has been delinetaed.

4. CONCLUSION

This study analysed the impact of land use and land cover changes on ecosystem service values in Mwanza City, Tanzania. The results have shown that LULC changed significantly over the two decades. However, while significant losses are noticed with the vegetated land (49%), there are gains in areal size with the built-up area (568%) during the study period. Subsequently, these LULC dynamics influenced the change in value of the ESV. While the vegetated land lost an ESV of 10.47 million US dollars, the waterbodies gained a total ESV of 3.5 million US dollars during the same time period. This study concludes that the LUCL dynamics affected the value of ecosystem services over the two decades. It is recommended that findings on ESV changes and LULC dynamics provide important evidence for policymakers, suggesting decision-making and management strategies. This can be done by Mwanza City authorities through the design of sustainable ecosystem service management strategies with a great emphasis on sustainable land use management.

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