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Forecasting the Economic Value of Ecosystem Services in Coastal Areas of the Indian Ocean: A Case Study of the Kinondoni District, Tanzania

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Authors' contributions

This work was carried out in collaboration between both authors. This work was carried out in collaboration between all authors from designed the study, literature searches, data collection, performed the statistical analysis, wrote the protocol, and wrote the manuscript. Both authors read and approved the final manuscript.

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ABSTRACT

This study forecasts changes in the economic value of ecosystem services (ESVs) in Kinondoni District, Tanzania, between 2023 and 2033, with a focus on the impacts of land use and land cover (LULC) changes on natural capital. Using a combination of remote sensing, GIS, and ESV estimation methods, the study reveals significant shifts in ecosystem services. Water bodies are expected to dominate the landscape, contributing over 90% of the total ESV, followed by mangrove

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forests. However, the total ESV is projected to decrease by 5.4% to 6.2%, amounting to a loss of between US$ 1.04 million and US$ 1.31 million, mainly due to declines in water and mangroves. The study also anticipates losses in ecosystem functions, particularly in regulating and provisioning services. These losses are primarily attributed to the degradation of water bodies and mangrove forests, which play key roles in maintaining ecosystem balance. The decline in ESVs underscores the risk of deforestation and the challenges of managing public natural resources. The study emphasizes the urgent need to revise and enhance conservation strategies to safeguard the sustainability of coastal ecosystems in Tanzania, ensuring their long-term benefits for both the environment and human populations.

Keywords: Ecosystem services; ecosystem functions; land use/cover change (lulc); coastal areas; kinondoni.

1. INTRODUCTION

The examination of ecosystem services (ES) and its economic significance has achieved worldwide acknowledgment owing to the essential function these services fulfill in preserving human well-being and environmental sustainability. Ecosystem services include the advantages obtained from natural ecosystems, such as purified air, water filtration, and temperature regulation, all of which are vital for human existence and economic well-being [1,2]. With the escalating pressures on ecosystems, especially in coastal regions that are more susceptible to environmental deterioration, the imperative to precisely evaluate and predict the economic value of ecosystem services (ESVs) has intensified. This is especially evident in the Western Indian Ocean region, where swift urbanization, industrial expansion, and population pressures jeopardize the health of coastal ecosystems, including those in the Kinondoni District of Tanzania.

This research is significant due to the global emphasis on ecosystem services as a crucial indicator of sustainable development. This transition was prompted by the seminal 1997 study by Costanza et al., which identified 17 unique categories of ecosystem services and established methods for their economic assessment [1,3]. Since that time, researchers have progressively employed Ecosystem Service Valuations (ESVs) to quantify the advantages offered by ecosystems in monetary terms, thereby facilitating their incorporation into policy and management decisions [4,5]. Nonetheless, despite this advancement, the Western Indian Ocean region particularly coastal zones such as Kinondoni has experienced a paucity of targeted study regarding the effects of land use and land cover changes (LULCC) on the delivery of ecosystem services. This represents a significant deficiency, as these areas are undergoing swift environmental transformations that may profoundly impact local livelihoods and overall ecological stability [6,7].

Kinondoni District, akin to several coastal regions, confronts increasing problems from land use and land cover change (LULCC), predominantly propelled by urban expansion, industrial development, and population growth [8,9]. These alterations result in habitat destruction, a decrease in biodiversity, and heightened pollution, all of which undermine the ecosystem services upon which local communities rely for their sustenance [5,10]. The destruction of coastal mangroves in Kinondoni adversely affects fishery output and eliminates natural defenses against coastal erosion and floods [10]. In this setting, comprehending the future trajectory of ecosystem services under prevailing land use and land cover change patterns is crucial for guiding policy decisions that reconcile economic development with environmental conservation.

The notion of ESVs provides a pragmatic framework for predicting the economic effects of these environmental alterations. Two prevalent methodologies for assessing Ecosystem Service Values (ESVs) are direct ecological evaluations and the equivalent coefficient method, which employs pre-existing ecological data and coefficients to estimate ESVs across broader spatial and temporal scales [3,7]. These approaches have demonstrated notable efficacy in forecasting the spatial-temporal distribution of ESVs in areas undergoing swift land-use transformations, such as Kinondoni [11,12]. Utilizing these tools, researchers may predict the possible economic losses or profits linked to ecological deterioration or conservation initiatives, respectively.

Projecting Ecosystem Service Values (ESVs) is essential for strategic planning, particularly in areas like Kinondoni, where economic pursuits such as tourism, fishing, and agriculture are fundamentally connected to the vitality of local ecosystems [13,14]. In the absence of precise forecasts of potential alterations in these services, policymakers may undervalue the economic repercussions of ecosystem degradation. This may result in unsustainable land-use practices that jeopardize local economy and regional ecological security [5,7]. Moreover, these projections are crucial for formulating solutions to alleviate the detrimental impacts of LULCC, such as soil erosion, biodiversity loss, and heightened susceptibility to natural disasters [10].

This study seeks to address the information deficit concerning the economic value of ecosystem services in coastal Tanzania, specifically in the Kinondoni District. This project will provide vital insights into the sustainable management of coastal resources by anticipating the economic implications of land-use changes on ecosystem services. The study's conclusions will be especially pertinent to other coastal regions in the Western Indian Ocean, where analogous environmental and socio-economic concerns prevail. Furthermore, the study will establish a scientific foundation for formulating policies that encourage the sustainable utilization of land resources while guaranteeing the enduring provision of vital ecosystem services [5,12].

This study fills a large research gap by concentrating on the prediction of ESVs in coastal Tanzania, a location confronting substantial environmental difficulties due to LULCC. The findings from this research will be crucial for guiding local and regional initiatives to promote sustainable development, conserve ecosystem services, and safeguard the well-being of human populations reliant on these essential natural resources.

2. MATERIALS AND METHODS

2.1 Description of The Study Area

This study examines the coastal wards of Mbweni and Ununio (Fig. 1) in the Kinondoni District of Dar es Salaam, Tanzania, an area recognized for its abundant marine resources and ecological importance. Kinondoni, situated between latitudes 6° 42' 43" S and longitude 39° 07' 54" E along the Indian Ocean and encompassing roughly 531 square kilometers [15], confronts substantial environmental difficulties stemming from growing urbanization, population expansion, and unsustainable economic practices. The coastal ecosystems in this area, integral to the biodiversity-rich Western Indian Ocean region, encompass essential habitats such as coral reefs, mangroves, and seagrass beds that sustain fisheries, tourism, and other crucial economic activities [16]. These ecosystems face escalating threats from habitat destruction, pollution, and resource overexploitation, especially in the Mbweni and Ununio wards [17].

The research underscores the necessity for an economic assessment of the ecosystem services offered by these coastal regions to facilitate sustainable management and policy measures. The research seeks to quantify economic advantages to bolster the argument for conservation initiatives, ensuring a balance between development and environmental sustainability. The results of this study are expected to provide significant insights for the management of coastal resources in Tanzania and other areas experiencing comparable urbanization challenges.

2.2 Data Used and Methods

Fig. 2 shows the flow chart of the methodological approach used in this study for the estimation of the ecosystem service values (ESVs) for the period 2023 - 2033; and predicted ESVs for 2033 and the computation of changes between studies periods [18].

The LULC datasets for the year 2023 in Table 1 were acquired from Kitali [19] and employed methodologies of Zella [18] who utilized Markov Chain Analysis and Cellular Automata Analysis, jointly called CA–Markov, to predict and simulate the future change of LULC in coastal areas of Kinondoni, Tanzania by the year 2033 as shown in Table 1 and Fig. 3. Furthermore, biome equivalents with their corresponding ecosystem service value coefficients (VC) in 1994 US$ $ha^{-1}year^{-1}$ for local and global VC shown in Table 1 were adapted from [1,3,6,18,20].

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 as adapted from Zella [18] and Constaza et al. [1,3].

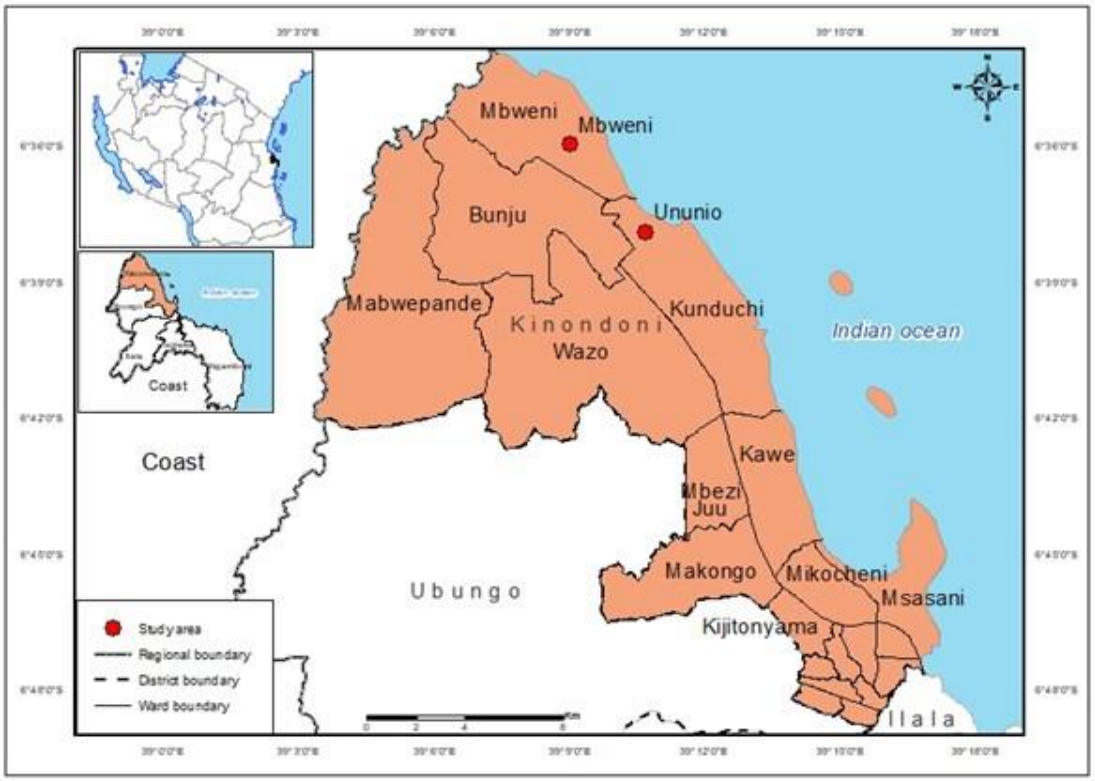

Fig. 1. The Map of the study area

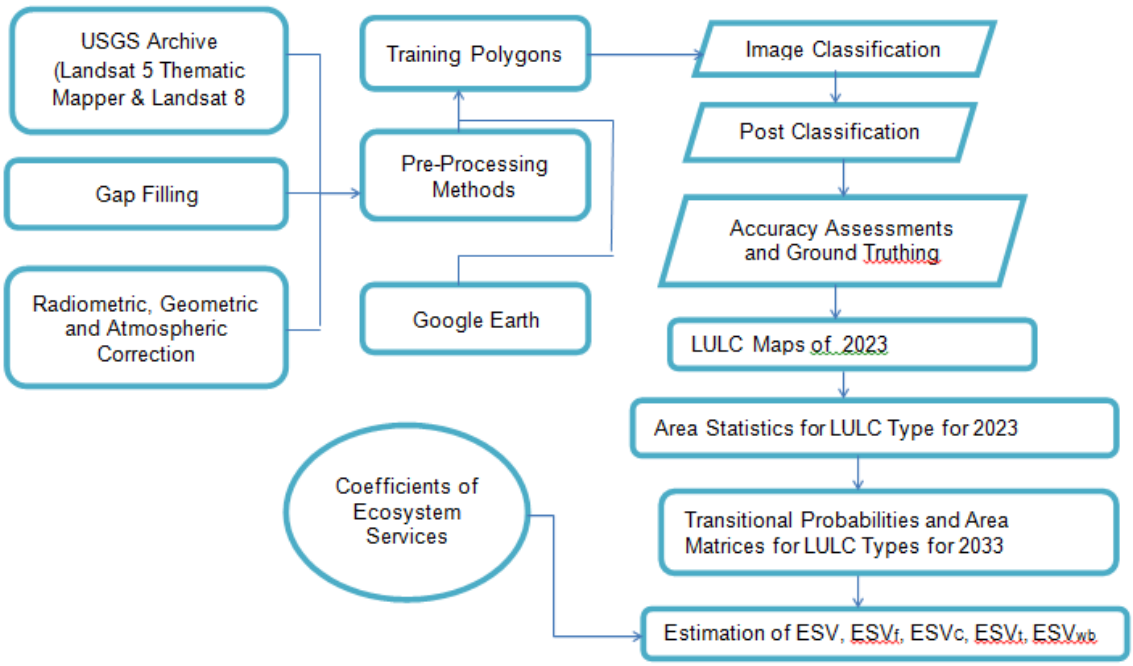

Fig. 2. Flowchart of the methodological approach for this study

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)		Equivalent Biome	Local (VC)1994 US$ $ha^{-1}year^{-1}$	Global (VC) 1994 US$ $ha^{-1}year^{-1}$
	2023	2033		a	b
Mangrove forest	1100.37	877.3	Tropical Forest	987	2008
Shrub land	193.06	194.35	Tropical Forest	987	244
Bare area	113.75	96	Beach sand	0	0
Water	2243.63	2142.05	Fresh water	8103	8498
Built up area	1905.14	2248.96	Urban	0	0
Cultivated land	5.88	3.17	Cropland	226	92

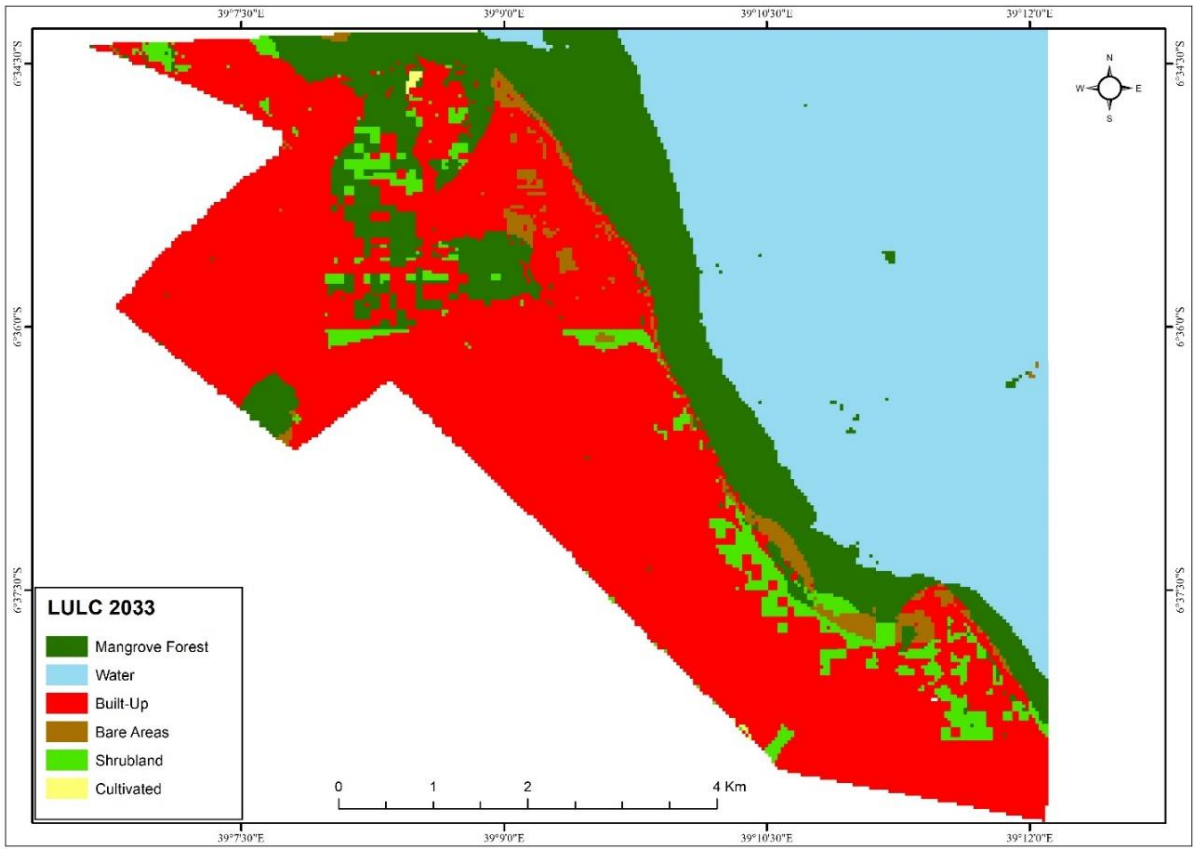

Fig. 3. LULC for the year 2033

2.2.1 Data analysis

To forecast changes of economic value of ecosystem services resulted from LULCC of coastal areas of Kinondoni District for the period 2023 – 2033.

The LULC datasets shown in Table 1 used and the total value of ecosystem services in the study area for years 2023 and 2033 were 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 [1,3,6,18] as follows:

$$\mathrm{ESV} = \sum_{k=0}^{k}(\mathrm{Ak} + \mathrm{VCk}) \ldots\ldots\ldots\ldots\ldots \quad ..(1)$$

where ESV = the total estimated ecosystem service value, A_k = the area (ha) and VC_k = 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 2023 and 2033. The percentage changes in the ESVs between the years were calculated based on the equation below:

$$\text{Percentange ESV} = \frac{(\text{ESVt}_2 - \text{ESVt}_1)}{\text{ESVt}_1} \text{x } 100 \qquad (2)$$

where ESV_{t2} (US$ ha^{-1} year^{-1}) = the estimated ecosystem service value in the most recent year, and ESV_{t1} (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.

To analyse changes of economic values of ecosystem functions based on LULC type of coastal areas of Kinondoni District for the period 2023 – 2033.

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

$$\text{ESVf} = \sum_{k=0}^{k} (\text{Ak} * \text{VC}_{\text{fk}}) \ldots\ldots\ldots\ldots \qquad (3)$$

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.

Table 2. Details of the ecosystem service functions and their modified local value coefficients for each LULC type (adapted from Zella, [18])

Ecosystem Services	Mangrove forest	Shrub land	Water	Cultivated land
Provisioning services:				
Water supply	8	8	2117	
Food production	32	32	41	187.56
Raw material	51.2	51.2		
Genetic resources	41	41		
Medical services				
Sub-total	**132.2**	**132.2**	**2158**	**187.56**
Regulating services:				
Water regulation	6	6	5445	
Waste treatment	136	136	431.5	
Erosion control	245	245		
Climate regulation	223	223		
Biological control				24
Gas regulation	13.68	13.68		
Disturbance regulation	5	5		
Sub-total	**628.68**	**628.68**	**5876.5**	**24**
Supporting services:				
Nutrient cycling	184.4	184.4		
Pollination	7.27	7.27		14
Soil formation	10	10		
Habitat/refugia	17.3	17.3		
Sub-total	**218.97**	**218.97**		**14**
Cultural services:				
Recreation	4.8	4.8	69	
Cultural	2	2		
Sub-total	**6.8**	**6.8**	**69**	
Grand-total	**986.69**	**986.69**	**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. [1])

Ecosystem services	Mangrove forest	Shrub land	Water	Cultivated land
Provisioning services:				
Water supply	8	8	3800	
Food production	32	32	258	54
Raw material	315	315		
Genetic resources	41	41		
Medical services				
Sub-total	**396**	**396**	**4058**	**54**
Regulating services:				
Water regulation	6	6	15	
Waste treatment	87	87	4177	
Erosion control	245	245		
Climate regulation	223	223		
Biological control				24
Gas regulation			133	
Disturbance regulation	5	5	4539	
Sub-total	**566**	**566**	**8864**	**24**
Supporting services:				
Nutrient cycling	922	922		
Pollination				14
Soil formation	10	10		
Habitat/refugia			304	
Sub-total	**932**	**932**	**304**	**14**
Cultural services:				
Recreation	112	112	574	
Cultural	2	2	881	
Sub-total	**114**	**114**	**1455**	**0**
Grand-total	**2008**	**2008**	**14681**	**92**

3. RESULTS

3.1 Future Change in Economic Value of Ecosystem Services Resulted From LULCC of the Study area for the Period 2023 – 2033

3.1.1 Present and forecasted status of economic values of ecosystem services for Biome in each LULC type of the study area for the period 2023 – 2033

Present and forecasted economic values of ecosystem services using local and global value coefficients for biome in each LULC type for the years 2023 and 2033 are presented in Table 4. Analyzed statistical results show variations in ecosystem services values between two periods under consideration. ESV of the study area dominated by water in the year 2023 for 94.4% and 89.4% followed by mangrove forests for about 5.6% and 10.4% using local and global ESV estimation respectively. Forecasted ESV in the year 2033 indicates water will dominate the study area for about 94.3% and 91% followed by mangrove forest for about 4.7% and 8.8% using local and global ESV estimation respectively. The differences in local and global ESV estimation caused by assigned ESV coefficients which differ in LULC types depends on geographical area and value given by indigenous locality and their socio-culture environment compared to global values.

3.1.2 Forecasted changes of economic values of ecosystem services of LULCC biomes' of the study area for the period 2023 – 2033

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 summarized on Table 5. The increased and decreased amount is represented by negative (-) and positive (+) signs respectively.

Table 4. Ecosystem services values (ESV) year^{-1}distribution between 2023 and 2033

LULC Type	Local ESV (Lakhs US$)				Global ESV (Lakhs US$)			
	2023		2033		2023		2033	
	(ESV)	(%)	(ESV)	(%)	(ESV)	(%)	(ESV)	(%)
Mangrove forest	10.86	5.58	8.66	4.70	22.10	10.36	17.62	8.8
Shrub land	1.91	0.98	1.92	1.04	0.47	0.22	0.47	0.24
Bare area	-	-	-	-	-	-	-	0
Water	18.18	93.43	173.57	94.25	190.66	89.41	182.03	90.96
Built up area	-	-	-	-	-	-	-	0
Cultivated land	0.01	0.01	0.01	-	0.01	-	-	0
Total	194.58	100.00	184.16	100.00	213.24	100.00	200.12	100

Table 5. Changes in local and global ESV of the study area from 2023 to 2033

	Local ESV (Lakhs US$)			Global ESV (Lakhs US$)		
	Change in ESV	% change	ESV annual rate of change	Change in ESV	% change	ESV annual rate of change
Mangrove forest	2.20	21.11	0.22	4.48	34.16	0.45
Shrub land	(0.01)	(0.12)	-	-	(0.02)	-
Bare area	-	-	-	-	-	-
Water	8.23	78.91	0.82	8.63	65.84	0.86
Built up area	-	-	-	-	-	-
Cultivated land	0.01	0.10	-	-	0.02	-
Total	10.43	100.00	1.04	13.11	100.00	1.31

Table 6. Local and global economic values of ecosystem functions from 2023 to 2033

		Local EF (Lakhs US$)			Global EF (Lakhs US$)		
LULC	**Ecosystem services**	**2023**	**2033**	**Relative change**	**2023**	**2033**	**Relative change**
Mangrove forest	Provisioning services	1.46	1.16	0.30	4.36	3.47	0.89
	Regulating services	6.91	5.52	1.39	6.23	4.97	1.26
	Supporting services	2.41	1.92	0.49	10.26	8.18	2.08
	Cultural services	0.08	0.06	0.02	1.25	1.00	0.25
	Sub-total	10.86	8.66	2.20	22.10	17.62	4.48
Shrub land	Provisioning services	0.26	0.26	-	0.77	0.77	-
	Regulating services	1.21	1.22	(0.01)	1.09	1.10	(0.01)
	Supporting services	0.42	0.43	(0.01)	1.80	1.81	(0.01)
	Cultural services	0.01	0.01	-	0.22	0.22	-
	Sub-total	1.90	1.92	(0.02)	3.11	3.90	(0.02)
Water	Provisioning services	48.42	46.23	2.19	91.05	86.92	4.13
	Regulating services	131.85	125.88	5.97	198.88	189.87	9.01
	Supporting services	-	-	-	6.82	6.51	0.31
	Cultural services	1.55	1.48	0.07	32.65	31.17	1.48
	Sub-total	181.81	173.58	8.23	329.40	314.47	14.93
Cultivated land	Provisioning services	0.01	0.01	-	-	-	-
	Regulating services	-	-	-	-	-	-
	Supporting services	-	-	-	-	-	-
	Cultural services	-	-	-	-	-	-
	Sub-total	0.01	0.01	-	-	-	-
Grand Total		194.58	184.17	10.41	354.61	335.99	19.39

The forecasting indicates decrease in economic value of ecosystem services for about 5.4% and 6.2% equivalent to US$ 10.43 lakhs and US$ 13.11 lakhs for local and global ESV estimation respectively from 2023 to 2033. The annual decrease rate of ESV forecasted to be US$ 1.04 lakhs and US$ 1.31 lakhs for local and global ESV estimation respectively from 2023 to 2033.

The decrease in ESV for local ESV estimation will be dominated by water (78.9%) followed by mangrove forests (21.1%) and slight increase of ESV forecasted to be on shrub land (0.1%). Likewise, the global ESV estimation indicates the decrease in ESV dominated by water (65.8%) and mangrove forests (34.2%).

3.2 Forecasted Changes of Economic Values of Ecosystem Functions Based on LULC type of the Study Area From 2023 to 2033

The results in Table 6 shows forecasted local and global annual economic value of the ecosystem functions (EF) and their relative changes from 2023 to 2033 in the study area.

The forecasting revealed that, for upcoming one decades there will be a loss of US$ 10.41 lakhs of ecosystem functions using local estimations mostly from water (79.1%) and mangrove forest (21.1%) from 2023 to 2033; while global estimation also shows a loss of total ecosystem functions of US$ 19.39 lakhs from 2023 to 2033 mostly from water (77%) and mangrove forest (23.1%). The results further indicate the loss ecosystem functions will come from regulating services for about 70.6% and 52.9%; and provisioning services for about 23.9% and 25.8% using local and global estimation of ecosystem functions respectively. These results again imply that, there is encroachment of natural capital in coastal areas of Tanzania due to anthropogenic activities and reliance of dwellers to natural resources for their livelihoods.

4. DISCUSSION

4.1 Future Change in Economic Value of Ecosystem Services Resulted From LULCC of the Study area for the Period 2023 – 2033

4.1.1 Present and forecasted status of economic values of ecosystem services for Biome in each LULC type of the study area for the period 2023 – 2033

This study provides a comprehensive examination of the current and anticipated economic values of ecosystem services (ESVs) across various land use and land cover (LULC) types in Kinondoni District, Tanzania, from 2023 to 2033. The study indicates substantial variations in ESVs, primarily influenced by the dynamic characteristics of ecosystems and their susceptibility to land use and land cover changes, a trend previously observed in global research [21,22]. Aquatic ecosystems, especially water bodies, are the primary contributors to ecosystem service values (ESVs), consistent with findings from other areas where water bodies offer vital services such as water purification, habitat provision, and support for local livelihoods [23].

Mangrove forests, recognized as the second most valuable ecosystem, are essential for coastal protection, carbon sequestration, and the support of marine biodiversity [24,25]. These results correspond with international research highlighting the diverse significance of mangroves, particularly in areas susceptible to climate change [26]. Local ESV estimations provide greater value to mangroves because to its direct advantages for local communities, including disaster protection and fishery resources [27,28]. Conversely, worldwide ESV estimates frequently prioritize overarching services such as carbon sequestration, often neglecting the local socio-cultural significance of these ecosystems [29].

The study forecasts minor reductions in ESVs for both aquatic ecosystems and mangrove forests by 2033, influenced by expected land use and land cover changes and environmental stresses. This trend aligns with recent studies indicating that urbanization and climate change pose significant challenges to the integrity of coastal ecosystems [30]. Research indicates that urban development in coastal regions diminishes the scope and efficacy of aquatic and forest ecosystems, resulting in a decrease in ecosystem service values [31]. These findings indicate an immediate necessity for comprehensive land use planning and conservation initiatives to protect these vital ecosystems. Furthermore, the study underscores the intricacies of ecosystem service assessment at various scales. Local ecosystem service value (ESV) assessments indicate elevated values for ecosystems such as mangroves due to their direct contribution to supporting livelihoods, whereas global estimates frequently emphasize services like carbon sequestration that advance global environmental objectives [32,33]. This disparity highlights the necessity of employing a multi-scale methodology for ESV evaluation, as proposed by [34], to ensure the integration of local, regional, and global views in decision-making processes.

When juxtaposing these findings with previous studies, the significance of accounting for local ecological and socio-cultural settings in determining Ecosystem Service Values (ESVs) is evident. Torres et al. [35] and Lu et al. [36] highlight that local groups frequently attribute greater significance to ecosystems essential for their cultural practices and everyday sustenance, a detail that is occasionally neglected in global evaluations. The divergence between local and global valuations is also apparent in the research conducted by Vo et al. [27] and Ojea et al. [37], which promote context-specific ESV evaluations to enhance policy decision-making.

This study underscores the vital importance of aquatic systems and mangrove ecosystems in sustaining ecosystem services that contribute to both local and global ecological stability. The juxtaposition of local and global ESV estimations underscores the intricacies of ecosystem service valuing, especially among swiftly evolving contexts. The research emphasizes the necessity for enhanced valuation techniques and proactive conservation approaches to safeguard the economic advantages of these ecosystems for local communities and the worldwide populace [38]. This methodology corresponds with extensive studies supporting a balance between local livelihood requirements and global conservation objectives [34].

4.1.2 Forecasted changes of economic values of ecosystem services of LULCC biomes' of the study area for the period 2023 – 2033

The projected alterations in the economic values of ecosystem services (ESVs) from 2023 to 2033 in the study area indicate notable and alarming patterns associated with land use and land cover change (LULCC). The study indicates an anticipated overall reduction in ESVs, reflecting the continuous deterioration of natural ecosystems that jeopardizes environmental sustainability and human welfare. This corresponds with global research highlighting the essential connection between the degradation of ecosystem services and the depletion of natural capital [29,39]. Such losses might significantly impact the region's capacity to provide essential ecological services, resulting in extensive repercussions for human welfare. A primary factor contributing to this decline is the diminishment of services offered by aquatic ecosystems and mangrove forests. Water bodies are especially susceptible to degradation from pollution, over-extraction, and the effects of climate change, aligning with other research highlighting the sensitivity of aquatic ecosystems to environmental stressors [40,41].

The degradation of mangrove forests, albeit on a smaller scale, has significant repercussions, including heightened vulnerability to coastal erosion, loss of biodiversity, and diminished carbon sequestration a trend also shown in worldwide studies [26].Although a marginal rise in the ESV of shrubland biomes is anticipated, perhaps from to natural succession or conservation initiatives, this increment is negligible and inadequate to counterbalance the substantial reductions in more critical ecosystems such as aquatic environments and mangroves [42]. The slight enhancement noted in shrubland services, encompassing habitat provision and soil stabilization, highlights the necessity for extensive interventions aimed at biomes essential for ecological stability.

The study's findings reflect widespread apprehensions over the deterioration of aquatic ecosystems and mangroves, which are vital for ecosystem services including water filtration, carbon sequestration, and biodiversity preservation. Global ESV evaluations indicate analogous trends of deterioration, especially with mangrove ecosystems, which are extensively recognized for their importance in carbon sequestration and biodiversity preservation [29,39]. This underscores the global significance of mangroves and the overarching trend of land use and land cover change adversely impacting essential coastal ecosystems globally. Furthermore, the study's findings underscore an immediate necessity for focused conservation initiatives to prevent the deterioration of ecosystem services. Efforts must concentrate on the protection and restoration of aquatic ecosystems and mangrove forests, which are essential for sustaining ecosystem health and supporting local economies. Potential interventions may encompass wetland restoration, enhanced land use restrictions, and the advocacy of sustainable behaviors to mitigate anthropogenic impacts on these essential ecosystems [23,35].

The anticipated reduction in ESVs during the forthcoming decade highlights the persistent issues confronting natural ecosystems due to LULCC. The essential functions of aquatic ecosystems and mangrove forests in delivering ecosystem services highlight the urgent need for immediate and ongoing conservation initiatives.

As these ecosystems undergo deterioration, their capacity to deliver vital services such as water filtration, flood mitigation, and carbon sequestration will be further undermined, jeopardizing the long-term welfare of the communities dependent on them. These findings underscore the necessity for proactive, extensive initiatives to save and rehabilitate these vital ecosystems, so ensuring their ongoing contribution to both local and global environmental stability.

4.2 Forecasted Changes of Economic values of Ecosystem Functions Based on LULC type of the Study area from 2023 to 2033

The examination of projected alterations in the economic values of ecosystem functions (EFs) from 2023 to 2033 reveals substantial expected losses, illustrating the considerable influence of land use and land cover (LULC) changes on ecosystems' capacity to provide vital services. These functions are essential for environmental stability and human welfare, highlighting the significance of comprehending how land use and land cover changes influence ecosystem capabilities [25,41]. The anticipated reduction in the economic value of ecosystem functions highlights the susceptibility of the region's ecosystems, especially aquatic ecosystems and coastal forests, to both natural and human-induced stressors. The deterioration of aquatic ecosystems and mangrove forests is particularly alarming, as these biomes are crucial for regulating hydrological cycles, sustaining biodiversity, and safeguarding coastlines. Comparable results from additional research underscore the significance of these ecosystems in alleviating environmental threats, including flooding and coastal erosion, while their deterioration heightens susceptibility to these risks [24,30]. Mangrove forests, recognized for their carbon sequestration and coastal protection roles, are anticipated to undergo substantial reductions, underscoring the necessity for targeted conservation initiatives to alleviate the effects of land use and land cover changes.

The study demonstrates that the most substantial losses will transpire in regulating services, encompassing climate management, water purification, and flood control. These services are essential for the resilience of ecosystems, particularly in areas confronting climate change and environmental stressors. The anticipated reduction in these services aligns with recent studies indicating that diminished ecosystem resilience may result in increased frequency and severity of environmental disturbances [43,44]. The study's findings regarding provisioning services, including the extraction of food, water, and raw materials, correspond with global trends of resource over-extraction, wherein local communities depend significantly on natural resources for their livelihoods without implementing sustainable management practices [23,45]. The excessive dependence on these ecosystems for immediate economic gains presents a twin challenge: whereas they offer short-term sustenance, the long-term degradation of provisioning services threatens to intensify poverty and resource depletion. This tendency is reflected in research from other locations, where unsustainable use diminishes natural capital, jeopardizing both ecosystem sustainability and local livelihoods [46,47]. The anticipated deterioration of coastal habitats in Tanzania poses a concerning situation. Human activities, poor land use planning, and economic demands on local people persist in exerting strain on these vital ecosystems. These findings align with extensive global research, which continually demonstrates that inadequate land management practices, exacerbated by economic imperatives, lead to ecological deterioration and heightened socio-economic vulnerability [46].

The projected reduction in regulating and delivering services from 2023 to 2033 indicates an immediate necessity for thorough, sustainable land use strategies in Tanzania's coastal regions. As aquatic ecosystems and mangrove forests continue to deteriorate, the socio-economic and environmental sustainability of these areas will be progressively undermined. It is imperative to implement sustainable management strategies that reconcile local requirements with global environmental concerns to safeguard these crucial ecosystems from further degradation. Integrated management techniques, highlighted in international research, must tackle the fundamental causes of land use and land cover changes to guarantee the enduring sustainability of natural capital and the welfare of reliant populations [23,47].

5. CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

This study sought to assess the prospective alterations in the economic value of ecosystem

services (ESVs) due to land use and land cover change (LULCC) from 2023 to 2033. The investigation concentrated on the current and projected status of Ecosystem Service Values (ESVs) across different biomes for each Land Use/Land Cover (LULC) type, as well as the anticipated alterations in the economic values of ecosystem functions associated with these LULC types. This study's findings highlight the substantial influence of land use and land cover change (LULCC) on the economic valuation of ecosystem services in the coastal areas of Kinondoni District, Tanzania. The analysis indicated that aquatic ecosystems and mangrove forests are the most significant biomes contributing to the overall ecosystem service value in the region, however they are also the most susceptible to degradation. The analysis projected a significant reduction in the economic value of ecosystem services, particularly impacting water bodies and mangroves. This reduction is expected to be more significant in global assessments than in local ones, illustrating the wider consequences of local environmental deterioration on a worldwide level.

The anticipated declines in ecosystem functions, especially in regulatory and provisioning services, underscore the difficulties presented by current and forthcoming land use alterations. Regulating services, essential for sustaining environmental stability, are anticipated to see the most substantial losses, thereby intensifying the region's susceptibility to environmental threats such as flooding, climate change, and biodiversity decline. The expected decrease in supplying services indicates a likely fall in the availability of resources essential for local livelihoods, hence underscoring the necessity of sustainable management techniques.

Consequently, the study presents persuasive evidence of the detrimental impacts of LULCC on the economic value of ecosystem services in the coastal regions of Kinondoni District. The anticipated reductions in ecosystem service values, especially from aquatic environments and mangrove ecosystems, indicate that absent prompt and efficient measures, the region's natural capital will persist in its deterioration, resulting in considerable socio-economic and environmental repercussions.

5.2 Recommendations

Based on the findings of this study, eight key recommendations are proposed to mitigate the forecasted decline in the economic value of ecosystem services in the coastal areas of Kinondoni District, Tanzania:

S/n	Recommendation	Explanation
1.	Implement comprehensive land use planning	A pressing necessity exists for thorough and cohesive land use planning that emphasizes the preservation of essential biomes, including aquatic ecosystems and mangrove forests. Land use plans must be formulated to mitigate the effects of urban growth and other human activities on these sensitive ecosystems. Integrating ecological concepts into land use planning will preserve the integrity of ecosystem functions and services.
2.	Strengthen conservation and restoration efforts	Targeted conservation and restoration efforts must be executed to safeguard and rehabilitate impaired aquatic ecosystems and mangrove forests. Restoration initiatives must prioritize bolstering the resilience of these ecosystems against environmental stressors, including climate change and pollution. This may encompass reforestation, establishment of protected areas, and restoration of natural hydrological systems.
3.	Promote sustainable resource management	Local communities should be encouraged to adopt sustainable management techniques to mitigate the over-exploitation of natural resources. This may encompass community-oriented conservation initiatives, sustainable fishing methodologies, and the advocacy of alternative livelihoods that diminish dependence on ecosystem services vulnerable to degradation. Instructing local communities on the enduring advantages of conservation can promote more sustainable engagements with the environment.
4.	Adopt nature-based solutions	Nature-based solutions, including wetland restoration and green infrastructure implementation, ought to be incorporated into urban development and coastal management programs. These technologies can improve ecological services, including flood regulation and water purification, while delivering socio-economic advantages to local residents.
5.	Enhance monitoring and adaptive management	Ongoing surveillance of ecosystem services and land use/land cover change is crucial for monitoring alterations in ecosystem service values and evaluating the efficacy of conservation and management strategies. Adaptive management strategies must be utilized to address evolving conditions and emerging threats, so assuring the continued relevance and efficacy of conservation initiatives over time.

S/n	Recommendation	Explanation
6.	Incorporate ecosystem services into policy and decision-making	Policymakers ought to include the significance of environmental services into economic and developmental planning procedures. Acknowledging the economic value of ecosystem services might facilitate better informed and sustainable decisions that reconcile developmental need with environmental preservation.
7.	Foster collaboration and stakeholder engagement	Successful conservation and land use planning necessitate cooperation among diverse parties, including governmental bodies, local communities, non-governmental groups, and the corporate sector. Prioritizing stakeholder engagement is essential to guarantee that conservation strategies are inclusive and responsive to the needs and concerns of all interested parties.
8.	Increase investment in research and data collection	Ongoing research is essential to enhance the precision of ESV predictions and to gain a deeper comprehension of the intricate relationships between LULCC and ecosystem services. Investments in data collecting and analytical technologies, including remote sensing and geographic information systems (GIS), will improve the capacity to monitor and forecast alterations in ecosystem services.

Thus, by adopting these recommendations, the coastal areas of Kinondoni District can more effectively safeguard their natural capital, thereby ensuring the ongoing delivery of essential ecosystem services that underpin both environmental integrity and human welfare. The results of this study provide a significant resource for informing future conservation initiatives and land use strategies in the region.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc.) and text-to-image generators have been used during the writing or editing of this manuscript.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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