

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

Abstract

This study explores the forecasting of the economic value of ecosystem services (ESV) in the coastal areas of Kinondoni District, Tanzania, over the decade from 2023 to 2033, and examines the impacts of these changes on natural capital. Recognizing the critical link between ecosystem services and human welfare, the study specifically predicts the shifts in ESVs and ecosystem functions resulting from land use and land cover (LULC) changes. Employing a combination of the benefit transfer method, local and global ESV estimations, field surveys, remote sensing, and GIS techniques, the study reveals significant transformations in ESVs across different LULC classes by 2033. Water bodies are projected to dominate the study area, contributing 94.3% (US\$ 17.4 million) and 91% (US\$ 18.2 million) of the total ESV under local and global estimates, respectively, followed by mangrove forests at 4.7% (US\$ 0.9 million) and 8.8% (US\$ 1.8 million). The analysis also forecasts a decrease in total ESVs by 5.4% and 6.2%, equivalent to a loss of US\$ 1.04 million and US\$ 1.31 million under local and global estimates. Furthermore, the study predicts a loss of US\$ 1.04 million and US\$ 1.94 million in ecosystem functions, with the majority of these losses stemming from water bodies (79.1% and 77%) and mangrove forests (21.1% and 23.1%). The projected decline in ecosystem functions is primarily attributed to reductions in regulating services (70.6% and 52.9%) and provisioning services (23.9% and 25.8%) under local and global estimates, respectively. These findings highlight the risk of significant deforestation and the associated challenges of managing public resources, suggesting an urgent need to review and strengthen conservation strategies to ensure the sustainability of Tanzania's coastal areas.

Keywords; Ecosystem services, Ecosystem functions, Land use/cover change (LULCC), Coastal areas, Kinondoni

1. Background information

The intricate relationship between ecosystem services (ES) and human welfare is well-established, as natural ecosystems are fundamental in providing essential resources that fulfill both the needs and desires of human populations (Wang et al., 2021). The global focus on quantifying the value of ecosystem services began with a landmark study in 1997, which identified 17 distinct types of ecosystem services and developed methods for their valuation (Costanza et al., 1997, 1998, 2014). The concept of ecosystem service

values (ESVs) offers a financial framework for quantifying these services, enabling the economic assessment of the benefits provided by natural systems (Anaya-Romero et al., 2016; Gashaw et al., 2018; Msofe et al., 2020; Zella, 2020; Wang et al., 2021). In recent years, ESVs have emerged as a critical area of ecological research, particularly as declining ESVs have been linked to negative impacts on human welfare and livelihoods (Costanza et al., 2014; Alamgir et al., 2016; Zella, 2020; Wang et al., 2021).

The integration of ecosystem services into resource management and policy decisions has been widely advocated by scholars and experts, emphasizing the need for sustainable management of these vital resources (Nelson et al., 2009; De Groot et al., 2010; Koschke et al., 2012; Wang et al., 2021). This increased focus on ESVs in research highlights their importance in addressing pressing environmental and socio-economic challenges (Zheng et al., 2020; Msofe et al., 2020; Zella, 2020; Wang et al., 2021). Globally, land use and land cover change (LULCC) has been identified as a dominant factor influencing ESVs, with current rates of change far surpassing those observed in any previous historical period. This rapid transformation is a major driver of global environmental change, with significant implications for the provision of ecosystem services (Wang et al., 2021; Hou et al., 2021). Key drivers of LULCC include population growth, industrial development, urban expansion, and policy decisions, all of which are exacerbated by climate variability. These factors lead to substantial changes in ecosystem composition and structure, ultimately affecting the quantity and quality of ecosystem services available (Bohn et al., 2018; Kalantari et al., 2019; Hou et al., 2021).

Two primary approaches are commonly used to evaluate ESVs. The first approach relies on primary data, where ecological processes and functions are quantified using ecological models to assess the economic value of specific ecosystem services. However, this method is often limited to evaluating one or a few services, rather than providing a comprehensive assessment of ESVs (Rai et al., 2018; Msofe et al., 2020; Gedefaw et al., 2020; Zella, 2020; Hou et al., 2021; Wang et al., 2021). The second approach, known as the equivalent coefficient method, estimates ESVs based on the equivalent coefficients of various ecosystem services, combined with the unit area of the ecosystem. This approach is particularly effective for evaluating the spatial-temporal distribution of ESVs in the context of LULCC (Costanza et al., 1997, 2014; Hou et al., 2021; Wang et al., 2021).

Accurately forecasting future ESVs is essential for understanding the long-term impacts of human activities on global environmental change and sustainable development. LULCC has a profound effect on the value, benefits, and regional ecological security of ecosystem services, making it crucial to predict these changes with precision (Costanza

et al., 2014; Riao et al., 2020; Mortoja et al., 2020; Hu et al., 2020; Woldeyohanne et al., 2020; Hou et al., 2021; Wang et al., 2021). In coastal areas like those in Kinondoni District, Tanzania, changes in land use can disrupt ecosystem functionality and lead to a host of environmental problems, including pollution, land degradation, biodiversity loss, and soil erosion (Schirpke et al., 2020; Liu et al., 2020; Wu et al., 2020; Zella, 2020; Hou et al., 2021).

The continuous degradation of coastal resources in this region is largely driven by local populations who exploit natural capital without considering the sustainability of ecosystem services (WWF, 2014; Jewitt et al., 2015; Zella et al., 2017; Zella, 2020). Therefore, it is imperative to explore the relationship between ESVs and LULCC to forecast the future impacts of human activities on ecosystem services and natural capital (Wang et al., 2019; Gedefaw et al., 2020; Zella, 2020; Hou et al., 2021). Addressing this research gap is vital for the rational use, protection, and management of land resources in Tanzania's coastal areas. Such efforts are necessary to promote the sustainable development of ecosystem services and to achieve a balance between economic growth and ecological protection. This research is particularly important for informing the development of ecological protection measures in Tanzania's coastal areas and the broader Western Indian Ocean region. The results will provide a scientific foundation for creating strategies that ensure the sustainable management of these vital ecosystems, contributing to the broader goals of environmental conservation and sustainable development in regions facing similar challenges.

2. Materials and methods

2.1 Description of the study area

This study focuses on the coastal wards of Mbwani and Ununio (Figure 1) within the Kinondoni District of Dar es Salaam, Tanzania, an area known for its rich marine resources and ecological significance. Kinondoni, strategically located between latitudes $6^{\circ} 42' 43''$ S and longitude $39^{\circ} 07' 54''$ E along the Indian Ocean, covering approximately 531 square kilometers (URT, 2020) faces significant environmental challenges due to rapid urbanization, population growth, and unsustainable economic activities. The coastal ecosystems in this district, which are part of the biodiversity-rich Western Indian Ocean region, include critical habitats such as coral reefs, mangroves, and seagrass beds that support fisheries, tourism, and other vital economic activities (Richmond et al., 2017). However, these ecosystems are under increasing threat from habitat loss, pollution, and resource overexploitation, particularly in the Mbwani and Ununio wards (Mohammed et al., 2021).

The study highlights the need for an economic valuation of the ecosystem services provided by these coastal areas to promote sustainable management and policy interventions. By quantifying the economic benefits, the research aims to strengthen the case for conservation efforts, ensuring that development is balanced with environmental sustainability. The findings from this study are anticipated to offer valuable insights for managing coastal resources in Tanzania and other regions facing similar urbanization pressures.

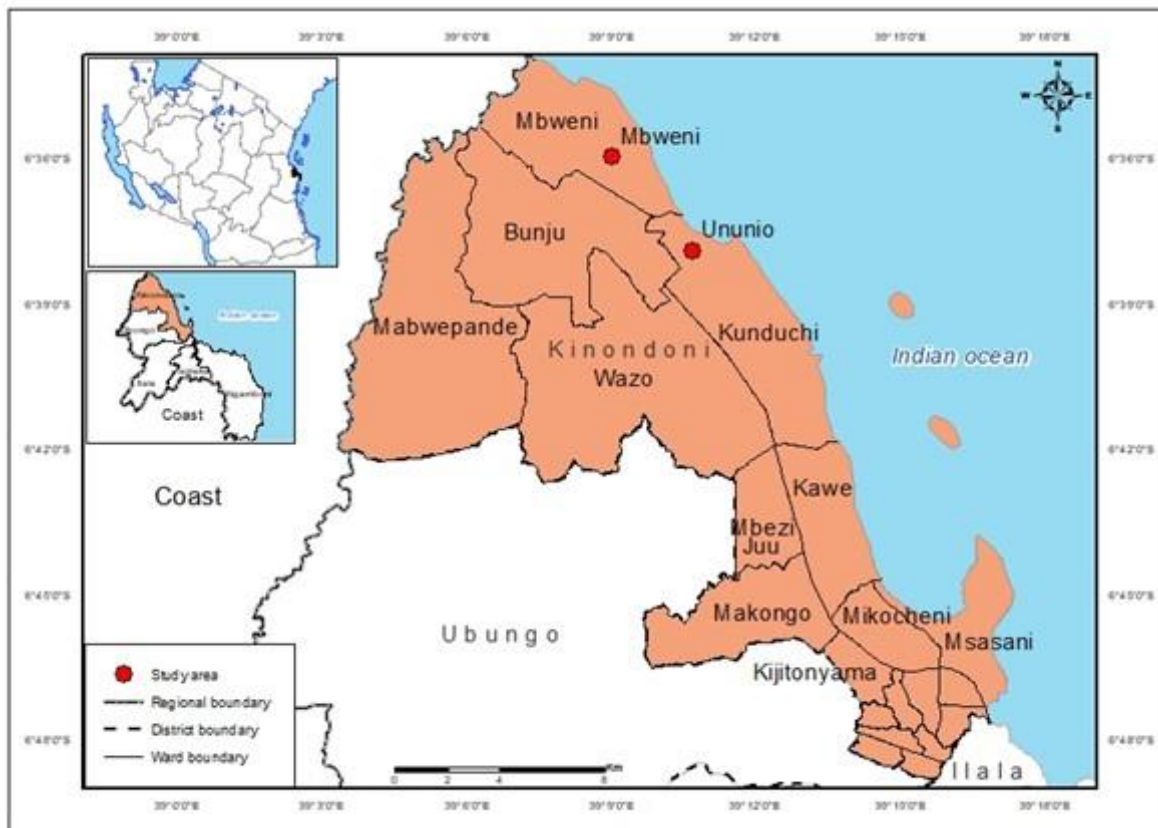
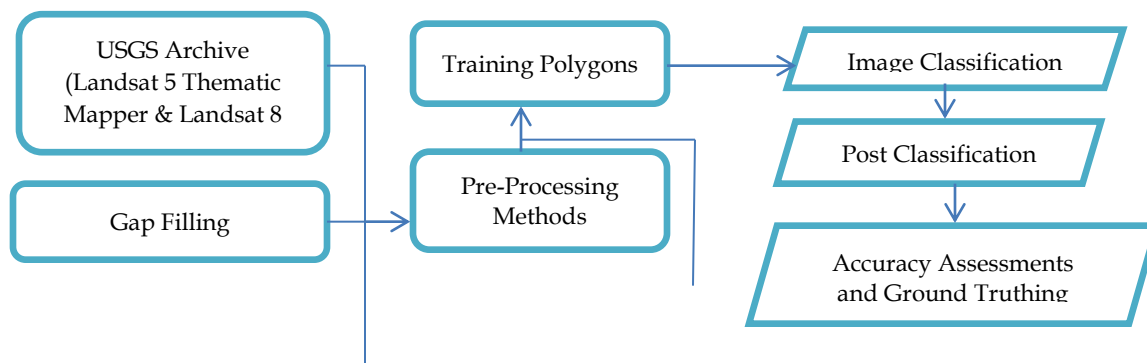


Figure 1: The Map of the study area

2.2. Data Used and Methods

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



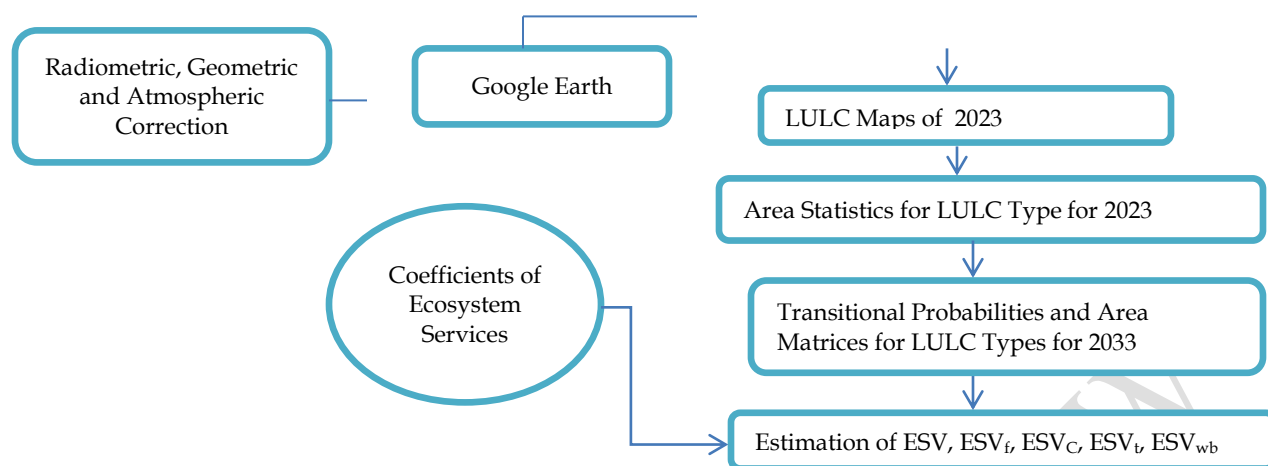


Figure 2: Flowchart of the methodological approach for this study

The LULC datasets for the year 2023 in Table 1 were acquired from Kitali (2024) and employed methodologies of Zella (2021) 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. Furthermore, biome equivalents with their corresponding ecosystem service value coefficients (VC) in 1994 US\$ ha⁻¹year⁻¹ for local and global VC shown in Table 1 were adapted from Kindu *et al.* (2016); Constaza *et al.* (1997 & 2014); Msofe *et al.* (2020); and Zella (2021).

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 | Global (VC) 1994 |
|-----------------|------------------|---------|------------------|--|--|
| | 2023 | 2033 | | US\$ ha ⁻¹ year ⁻¹ | US\$ ha ⁻¹ year ⁻¹ |
| | | | | 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 |

This study employed the benefit transfer approach to estimate economic values of ecosystem services based on the adapted local and global VC of the ecosystem services for the targeted LULC types. Detailed ecosystem service functions and their global and modified local value coefficients of each LULC type are shown in Tables 2 & 3 below as adapted from Zella (2021) and Constaza *et al.* (1997 & 2014).

Table 2: Details of the ecosystem service functions and their modified local value coefficients for each LULC type (adapted from Zella, 2021)

| 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.*, 1997)

| 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 |

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 Zella, 2021; Msofe *et al.*, 2020 and Constaza *et al.*, 1997 & 2014 as follows:

$$ESV = \sum_{k=0}^k (A_k + VC_k) \dots\dots\dots(1)$$

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:

$$\text{Percentage ESV} = \frac{(ESV_{t_2} - ESV_{t_1})}{ESV_{t_1}} \times 100 \dots\dots\dots(2)$$

where ESV_{t_2} (US\$ ha⁻¹ year⁻¹) = the estimated ecosystem service value in the most recent year, and ESV_{t_1} (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:

$$ESV_f = \sum_{k=0}^k (A_k * VC_{fk}) \dots\dots\dots(3)$$

where ESV_f is the estimated ecosystem service value of function f , A_k 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.

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.

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 |

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 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 |

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 Tables 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.

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

| LULC | Ecosystem services | Local EF (Lakhs US\$) | | | Global EF (Lakhs US\$) | | |
|-----------------|-----------------------|-----------------------|--------|-----------------|------------------------|--------|-----------------|
| | | 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 |
| | Provisioning services | 0.01 | 0.01 | - | - | - | - |
| | Regulating services | - | - | - | - | - | - |
| | Supporting services | - | - | - | - | - | - |
| Cultivated land | Cultural services | - | - | - | - | - | - |
| | Sub-total | 0.01 | 0.01 | - | - | - | - |
| Grand Total | | 194.58 | 184.17 | 10.41 | 354.61 | 335.99 | 19.39 |

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. Discussions

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

The study provides a detailed examination of the current and projected economic values of ecosystem services (ESVs) across various land use and land cover (LULC) types within the study area, spanning the period from 2023 to 2033. The analysis reveals significant variations in ESVs between these timeframes, underscoring the dynamic and vulnerable nature of ecosystem services in response to LULC changes. Aquatic ecosystems, particularly water bodies, play a dominant role in the region's ESV, reflecting their critical functions such as water purification, habitat provision for biodiversity, and support for local livelihoods (Wu et al., 2020; Bai et al., 2021).

Mangrove forests are identified as the second most valuable biome in terms of ESV, highlighting their essential roles in coastal protection, carbon sequestration, and marine biodiversity support (Osland et al., 2021; Friess et al., 2023). The differences between local and global ESV estimates suggest the need for context-specific assessments that account for the unique socio-cultural and ecological conditions of the study area. Local communities often place higher value on ecosystems that are closely integrated into

their daily lives and cultural practices, whereas global estimates may reflect more generalized, less localized values (Martín-López et al., 2021; Ojea et al., 2022).

Looking ahead to 2033, the forecasted ESV suggests a slight shift in the distribution of ecosystem service values. While water bodies are expected to maintain their dominant role, the slight decline in their relative ESV might be driven by anticipated land use changes and environmental factors that could alter the extent and functionality of these ecosystems (Huang et al., 2021; Nguyen et al., 2023). Similarly, the projected minor decrease in the ESV of mangrove forests could result from potential threats such as urbanization or climate change, which could negatively impact the health and coverage of these critical ecosystems (Bunting et al., 2022; Chausson et al., 2023).

The observed differences between local and global ESV estimates for both 2023 and 2033 are largely due to variations in the coefficients assigned to different LULC types. These coefficients are influenced by geographical factors, local community perceptions of ecosystem value, and the broader socio-cultural context (Torres et al., 2021; Lu et al., 2022). For instance, local ESV estimates may be higher for mangroves due to their direct and tangible benefits to local populations, such as resources for fisheries and protection from natural disasters, which are of significant cultural importance (Vo et al., 2021; Lacerda et al., 2022). In contrast, global estimates might undervalue these localized benefits, focusing instead on broader ecosystem functions like carbon sequestration or biodiversity conservation on a global scale (Balvanera et al., 2020; Costanza et al., 2021).

These findings highlight the necessity of adopting a multi-scale approach to ESV assessment that incorporates both local and global perspectives. This approach ensures that the valuation of ecosystem services accurately reflects the diverse benefits provided by different ecosystems, catering to the varying values held by local communities and global stakeholders alike (Gómez-Baggethun et al., 2021; Pascual et al., 2022). Moreover, the forecasted changes in ESV stress the need for proactive land use planning and conservation strategies to preserve the critical ecosystem services offered by water bodies and mangrove forests in the study area.

Thus, the analysis of present and forecasted ESVs within the study area emphasizes the crucial role of water bodies and mangrove forests in maintaining ecosystem services that are vital for both local communities and the broader environment. The differences observed between local and global ESV estimates reveal the complexities inherent in valuing ecosystem services across different contexts and scales. The study highlights the importance of continuing to refine these valuation methods to support informed

decision-making that balances the needs of local populations with the global imperative for environmental conservation.

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

The study's forecasted changes in the economic values of ecosystem services (ESVs) for various land use and land cover change (LULCC) biomes within the study area from 2023 to 2033 reveal significant and concerning trends. The analysis underscores the extent of changes in ESVs and highlights the importance of understanding these dynamics for future ecosystem service provision in the region. The findings point to an overall decline in the economic value of ecosystem services, reflecting the ongoing degradation of natural ecosystems. This degradation poses a significant threat to both environmental sustainability and human well-being, as the loss of critical ecosystem services could have far-reaching impacts on the region's natural capital.

The decline in ESVs is largely driven by the reduction in services provided by water bodies and mangrove forests. Water-related ecosystem services, which are crucial for the region, are particularly vulnerable to pressures such as pollution, over-extraction, and climate change (Bai et al., 2022; Huang et al., 2023). The reduction in mangrove forests, although smaller in proportion, is equally critical, as it increases the region's susceptibility to coastal erosion, biodiversity loss, and reduced carbon sequestration capacity (Friess et al., 2023). While there is a slight forecasted increase in ESV for shrubland, this gain is minimal and insufficient to counterbalance the broader declines in more essential biomes like water bodies and mangroves. Such marginal gains could be attributed to natural succession processes or conservation efforts that enhance certain ecosystem services, such as wildlife habitat or soil stabilization (García-Nieto et al., 2021).

Global ESV estimations reveal a similar pattern, with the decrease in ESV predominantly driven by water bodies and mangrove forests. This global perspective highlights the broader implications of LULCC, suggesting that the local degradation observed is part of a larger, more worrisome trend affecting similar ecosystems worldwide (de Groot et al., 2020; Costanza et al., 2021). The slightly higher percentage of ESV decline attributed to mangroves in the global estimation underscores their global importance, particularly in their roles of carbon storage and biodiversity conservation.

These findings underscore the urgent need for targeted conservation and sustainable management practices aimed at preserving and enhancing the economic value of ecosystem services in the region. The significant losses projected for water bodies and

mangrove forests highlight the critical need to protect these biomes, which are essential for maintaining ecosystem stability and supporting human livelihoods. Effective interventions could include the restoration of degraded wetlands, the enforcement of stricter regulations on land use changes, and the promotion of sustainable practices that reduce pressure on these vital ecosystems (Nguyen et al., 2023; Torres et al., 2023).

Overall, the forecasted decrease in ESVs across the study area from 2023 to 2033 serves as a stark reminder of the ongoing challenges faced by natural ecosystems in the context of land use changes. The significant roles that water bodies and mangrove forests play in the provision of ecosystem services underscore the necessity of immediate and sustained conservation efforts. As these ecosystems continue to face degradation, the long-term provision of the essential services they offer will be increasingly jeopardized, making proactive measures to ensure their preservation crucial for the continued well-being of the communities that depend on them.

4.2 Forecasted changes of economic values of ecosystem functions based on LULC type of the study area from 2023 to 2033

The analysis of forecasted changes in the economic values of ecosystem functions (EFs) in the study area from 2023 to 2033 reveals significant anticipated losses, reflecting the substantial impact that land use and land cover (LULC) changes can have on the capacity of ecosystems to provide essential functions. These functions are critical for maintaining environmental stability and supporting human well-being. The projected decline in the economic value of ecosystem functions underscores the vulnerability of the region's ecosystems, particularly aquatic ecosystems and coastal forests, to the pressures of both natural and anthropogenic factors (Huang et al., 2023; Friess et al., 2023). The stress on water bodies and mangrove forests is of particular concern, as these biomes are crucial for regulating water cycles, providing biodiversity habitats, supporting livelihoods through fisheries, and protecting coastlines. The degradation of these ecosystems is alarming, as it not only threatens their ability to perform these vital functions but also increases the region's susceptibility to environmental hazards. The decline in mangrove forests, which play a key role in carbon sequestration and coastal protection, highlights the urgent need for targeted conservation efforts to mitigate the adverse effects of LULC changes (Osland et al., 2021; Bunting et al., 2022).

The study further indicates that the most significant losses in ecosystem functions will occur in regulating services, which include critical processes such as climate regulation, water purification, and flood control. These services are essential for maintaining the resilience of ecosystems, particularly in the face of climate change and other environmental stressors. The projected decline in these services suggests a diminished

capacity of the region's ecosystems to buffer against adverse environmental impacts, potentially leading to more frequent and severe environmental disruptions (Capon et al., 2021; Balvanera et al., 2022). Provisioning services, which involve the extraction of resources like food, water, and raw materials, are also expected to decline. This trend reflects the over-reliance of local communities on natural resources for their livelihoods, a pattern that is likely to persist unless sustainable management practices are adopted. The reduction in provisioning services not only poses an immediate threat to resource availability but also endangers the long-term sustainability of these ecosystems, potentially exacerbating resource depletion and increasing poverty among dependent populations (Nguyen et al., 2023; Zhen et al., 2022).

These findings strongly suggest that the coastal areas of Tanzania, particularly those within the study area, are facing significant encroachment on their natural capital due to anthropogenic activities. The over-exploitation of natural resources, coupled with inadequate land use planning and management, is leading to the degradation of critical ecosystems. This degradation is likely driven by the economic pressures faced by local communities, who depend heavily on these ecosystems for their livelihoods. This situation intensifies the challenge of balancing development with conservation efforts (Barbier, 2021; Torres et al., 2023).

Thus, the forecasted changes in the economic values of ecosystem functions from 2023 to 2033 present a concerning outlook for the future of coastal ecosystems in Tanzania. The substantial losses in both regulating and provisioning services underscore the urgent need for comprehensive and sustainable land use strategies that prioritize the conservation of water bodies and mangrove forests. Without such interventions, the continued degradation of these ecosystems will likely lead to increased environmental and socio-economic vulnerabilities. Addressing the root causes of LULC changes through integrated management approaches that consider both local needs and global environmental objectives is imperative to safeguarding the future of these vital ecosystems.

5. Conclusion and Recommendations

5.1 Conclusion

This study aimed to evaluate the future changes in the economic value of ecosystem services (ESVs) resulting from land use and land cover change (LULCC) over the period 2023-2033. The analysis focused on the present and forecasted status of ESVs for various biomes within each LULC type and the predicted changes in the economic values of

ecosystem functions based on these LULC types. The findings of this study underscore the significant impact of LULCC on the economic value of ecosystem services in the coastal areas of Kinondoni District, Tanzania. The analysis revealed that water bodies and mangrove forests are the most critical biomes contributing to the overall ESV in the region, yet these are also the most vulnerable to degradation. The study forecasted a considerable decline in the economic value of ecosystem services, with water bodies and mangroves being the most affected biomes. This decline is anticipated to be more pronounced under global estimations compared to local ones, reflecting the broader implications of local environmental degradation on a global scale.

The projected losses in ecosystem functions, particularly in regulating and provisioning services, highlight the challenges posed by ongoing and future land use changes. Regulating services, which are vital for maintaining environmental stability, are expected to suffer the most significant losses, which could exacerbate the region's vulnerability to environmental hazards such as flooding, climate change, and biodiversity loss. The anticipated reduction in provisioning services also points to a potential decline in the availability of resources that are critical for local livelihoods, further stressing the importance of sustainable management practices.

Therefore, the study provides compelling evidence of the adverse effects of LULCC on the economic value of ecosystem services in Kinondoni District's coastal areas. The forecasted declines in ESVs, particularly from water bodies and mangrove forests, suggest that without immediate and effective interventions, the region's natural capital will continue to degrade, leading to significant socio-economic and environmental consequences.

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 | There is a critical need for comprehensive and integrated land use planning that prioritizes the conservation of key biomes such as water bodies and mangrove forests. Land use plans should be designed to minimize the impact of urban expansion and other anthropogenic activities on these vulnerable ecosystems. Incorporating ecological principles into land use planning will help maintain the integrity of ecosystem functions |

| | | |
|----|--|--|
| | | and services. |
| 2. | Strengthen conservation and restoration efforts | Targeted conservation and restoration initiatives should be implemented to protect and rehabilitate degraded water bodies and mangrove forests. Restoration efforts should focus on enhancing the resilience of these ecosystems to withstand environmental pressures, such as climate change and pollution. This could include reforestation, the creation of protected areas, and the restoration of natural water flows |
| 3. | Promote sustainable resource management | Sustainable management practices should be promoted among local communities to reduce the over-exploitation of natural resources. This could involve community-based conservation programs, sustainable fishing practices, and the promotion of alternative livelihoods that reduce reliance on ecosystem services at risk of degradation. Educating local communities about the long-term benefits of conservation can foster more sustainable interactions with the environment. |
| 4. | Adopt nature-based solutions | Nature-based solutions, such as the restoration of wetlands and the use of green infrastructure, should be integrated into urban development and coastal management strategies. These solutions can enhance ecosystem functions, such as flood regulation and water purification, while providing socio-economic benefits to local communities. |
| 5. | Enhance monitoring and adaptive management | Continuous monitoring of ecosystem services and LULCC is essential to track changes in ESVs and assess the effectiveness of conservation and management interventions. Adaptive management approaches should be employed to respond to changing conditions and emerging threats, ensuring that conservation efforts remain relevant and effective over time. |
| 6. | Incorporate ecosystem services into policy and decision-making | Policymakers should incorporate the value of ecosystem services into economic and development planning processes. Recognizing the economic contributions of ecosystem services can lead to more informed and sustainable decisions that balance development needs with environmental conservation |
| 7. | Foster collaboration and stakeholder engagement | Effective conservation and land use planning require collaboration among various stakeholders, including government agencies, local communities, non-governmental organizations, and the private sector. Stakeholder engagement should be prioritized to ensure that conservation strategies are inclusive and address the needs and concerns of all parties involved. |
| 8. | Increase investment in research and data collection | Continued research is necessary to improve the accuracy of ESV forecasts and to better understand the complex interactions between LULCC and ecosystem services. Investments in data collection and analysis tools, such as remote sensing and geographic information systems (GIS), will enhance the ability to monitor and predict changes in ecosystem services. |

Thus, by implementing these recommendations, the coastal areas of Kinondoni District can better preserve their natural capital, ensuring the continued provision of critical ecosystem services that support both environmental health and human well-being. The findings of this study serve as a valuable resource for guiding future conservation efforts and land use planning in the region.

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