

# Assessing Land Use/Land Cover Change, Drivers, and Community-Based Interventions for Sustainable Water Availability in the Kidunda River Catchment, Ruvu Basin

Elibariki Joseph Mmassy<sup>1,2\*</sup>, Edmund Mutayoba<sup>1</sup>, Lusajo Mfwango<sup>1</sup>, Simon Chidodo<sup>3</sup>, Nyemo Chilagane<sup>3</sup>

<sup>1</sup>Department of Water Supply and Sanitation Engineering, Water Institute, Dar es Salaam, Tanzania

<sup>2</sup>Wami Ruvu Basin Water Office (WRBWO), Morogoro, Tanzania

<sup>3</sup>Tanzania Research and Conservation Organization, Morogoro, Tanzania

Email: \*elijommassy@gmail.com

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## Abstract

Water availability in sub-Saharan Africa is increasingly threatened by rapid land use and land cover (LULC) changes, particularly within ecologically sensitive areas which are potential areas providing vital hydrological services, and supporting high biodiversity and varieties of ecosystem services. This study assessed spatial and temporal LULC changes, their underlying drivers, and potential community-based interventions in the Kidunda River Catchment, a key upstream area within Tanzania's Wami-Ruvu Basin where the Kidunda Dam is planned to enhance downstream water supply. Using Landsat imagery from 1994, 2005, 2016, and 2024, supervised classification with Random Forest algorithms was applied to detect LULC transitions. Results revealed a significant decline in forest (60.11%) and wetland (68.75%) cover, accompanied by a substantial expansion of cultivated land (226.82%) and built-up areas (196.03%). The most dominant conversion pathways were woodland and wetland to cultivated land, indicating intense anthropogenic pressure. Qualitative data from focus group discussions and key informant interviews identified population growth, agricultural expansion, and weak enforcement as key drivers of change. However, a slight slowdown in LULC transformation observed after 2016 coincided with the gazettement of Nyerere National Park, suggesting that policy interventions can yield positive outcomes. Community-driven solutions such as participatory land use planning, agroforestry, and soil and water conserva-

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tion were highlighted as effective strategies for landscape restoration and water security. The findings underscore the urgent need for integrated catchment management and localized interventions to safeguard the ecological functions of the catchment and ensure the long-term sustainability of the Kidunda Dam and downstream water supplies.

## Keywords

Land Use, Land Cover Change, Remote Sensing, Community Based Intervention

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## 1. Introduction

Water availability is increasingly threatened by rapid land use and land cover (LULC) changes, particularly within ecologically sensitive areas across sub-Saharan Africa (Näschen et al., 2019). In Tanzania, river catchments are experiencing mounting pressure from expanding agricultural activities, unplanned settlements, deforestation, and infrastructure development. These ongoing changes result in reduction in stream flows, accelerate soil erosion, and deteriorate water quality, ultimately undermining the ability of river basins to provide reliable water supply in the face of growing demand (Liu et al., 2022; Mangi et al., 2022; Chilagane et al., 2021; Mutayoba et al., 2018; Kashaigili & Majaliwa, 2013). While large-scale water infrastructure projects are being implemented to enhance supply security and support multiple sectors, such solutions remain vulnerable to upstream land degradation (Coates & Smith, 2012). Without a clear understanding of how LULC is changing, what drives these shifts, and how local communities perceive and respond to them, efforts to secure water resources may be short-lived. This highlights the urgent need to assess landscape dynamics and identify effective, locally grounded strategies to sustain water availability over the long term.

Land use and land cover (LULC) change is one of the most pressing environmental challenges influencing catchment hydrology today. Over recent decades, many catchments have experienced a marked decline in forest and wetland cover, accompanied by the expansion of agricultural land, settlements, and infrastructure (Chidodo et al. 2025; Mangi et al., 2022; Chilagane et al., 2021; Mutayoba et al., 2018). Wami-Ruvu Basin lost 15 % of its forest cover and 0.3 % of wetlands, while agricultural land expanded by 11.6 % and built-up areas by 0.8 % (Ngondo et al., 2022). Modeling of Wami Ruvu basin shows that these land-use/land-cover (LULC) shifts not only alter the physical landscape but also intensify water stress by increasing surface runoff, sediment yield, and evapotranspiration while reducing infiltration and baseflow (Ngondo et al., 2022; Twisa et al., 2020a, 2020b; Mbungu, 2017). Despite their documented negative effects on ecosystems and water resources, LULC changes persist in many landscapes, indicating that the underlying drivers are complex and interconnected. Rapid population growth fuels increased demand for farmland, fuelwood, and housing, often resulting in the loss of forests and wetlands (Msofe et al., 2019; Felix, 2015; Kangalawe & Lyimo, 2010).

Limited livelihood alternatives in rural areas lead many households to rely on unsustainable activities such as slash-and-burn farming, charcoal production, and open grazing (Mgalula et al., 2024; Msofe et al., 2019). These pressures are intensified by weak enforcement of environmental and land use regulations, which allow encroachment into protected or ecologically sensitive zones (Andreasen et al., 2022). Infrastructure projects and extractive developments also act as enabling drivers by facilitating access to remote areas. In combination, these forces accelerate landscape degradation and the loss of key ecosystem services.

In response, community-based interventions have been increasingly recognized as practical, low-cost, and contextually appropriate strategies for reversing land degradation and enhancing water security (Singh et al., 2025; Lebu et al., 2024). These approaches prioritize the active involvement of local stakeholders in planning, decision-making, and implementation processes, thereby increasing ownership, sustainability, and alignment with local needs. Participatory land use planning, for instance, enables communities to delineate land for different purposes in ways that reduce conflicts, optimize resource use, and protect critical ecosystems such as forests and wetlands (Kalogiannidis, 2023). Agroforestry practices integrating trees with crops or livestock systems have proven effective in restoring soil fertility, increasing vegetation cover, and regulating microclimates, all of which contribute to improved water infiltration and reduced runoff (Tenge, 2005). Soil and water conservation measures, such as contour bunds, terracing, and check dams, help to stabilize slopes, control erosion, and retain moisture within the landscape. Meanwhile, sustainable grazing management and pasture restoration reduce pressure on fragile ecosystems and enhance the productivity of rangelands. Collectively, these interventions not only rehabilitate degraded lands but also strengthen community resilience to climate and hydrological variability. They offer scalable solutions that align with broader goals of integrated catchment management and sustainable development. However, many existing studies tend to generalize the drivers of land use and land cover change without distinguishing the specific factors behind each type of transition. For example, the drivers that lead to forest being converted to shrubland may differ significantly from those causing forest to be cleared for agriculture. Aggregating all changes under broad categories overlooks these nuanced dynamics and limits the effectiveness of targeted interventions. Understanding the unique drivers associated with each LULC transition is critical for designing context-specific strategies that address the root causes of land degradation and water insecurity.

The Kidunda sub-catchment is a strategically important landscape within the Wami-Ruvu Basin, where ongoing land use and land cover changes threaten sustainable water availability (Ngondo et al., 2022; Mbungu, 2017; Twisa et al., 2020a). It has been selected as the site for a major national infrastructure project the Kidunda Dam intended to enhance water supply reliability for downstream urban centres (Mwanukuzi, 2008). However, despite its significance, there has been no focused assessment of how LULC dynamics within the sub-catchment may affect the dam's performance. Without such understanding, the reservoir

faces risks of accelerated sedimentation, reduced inflow, and potential social conflicts over land and water use. This makes Kidunda an ideal location to investigate spatial-temporal LULC changes, their specific drivers, and the role of community-based interventions in sustaining water resources. Therefore, this study aims to assess LULC changes in the Kidunda Catchment over time, identify the main drivers behind these changes, and explore locally driven strategies to improve and sustain water availability. The findings will support evidence-based decision-making and foster inclusive and sustainable catchment management, particularly in anticipation of hydrological and ecological shifts associated with the proposed Kidunda Dam.

## 2. Material and Methods

### 2.1 Description of the Study Area

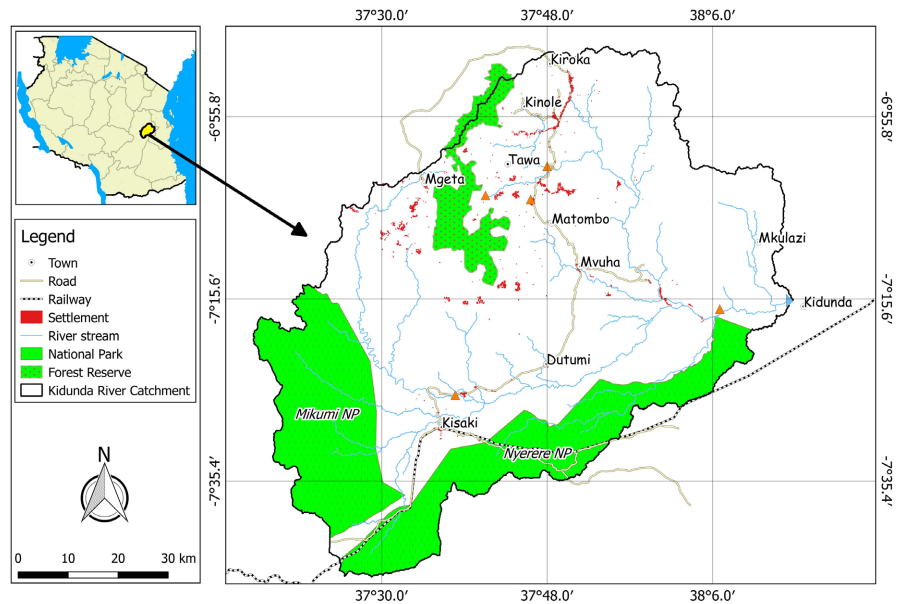
The Kidunda Sub-Catchment (**Figure 1**) is located within the Wami-Ruvu River Basin in eastern Tanzania and forms part of the Ruvu River Catchment. Geographically, it lies in the Morogoro Region, primarily within the Morogoro Rural District, and partially extends into the Nyerere-Selous Ecosystem to the south. The sub-catchment covers a mixture of protected and non-protected landscapes, including forest reserves, wildlife corridors, agricultural lands, and rural settlements. It is drained by a network of seasonal and perennial streams that converge into the Ruvu River, which ultimately supplies water to the rapidly growing city of Dar es Salaam and the surrounding Coast Region. Topographically, the area is characterized by a mix of gently undulating terrain and low-lying floodplains, with elevations ranging between 50 - 2600 meters above sea level. The local climate is tropical sub-humid, with a bimodal rainfall pattern comprising short rains (October-December) and long rains (March-May), with average annual precipitation ranging between 800 mm and 1200 mm. Mean annual temperatures typically range from 20°C to 30°C. Socio-economically, the Kidunda area is home to rural communities that depend heavily on subsistence agriculture, livestock rearing, and the extraction of forest resources. The area is also influenced by national development priorities, particularly the construction of the Kidunda Dam, a strategic water infrastructure project intended to mitigate chronic water shortages in Dar es Salaam. This development has heightened the need for sustainable land and water resource management in the catchment.

### 2.2. Method

#### 2.2.1. Datasets and Data Pre-Processing

This study employed multi-temporal satellite imagery to assess land use and land cover (LULC) changes in the Kidunda Catchment. Landsat 5 Thematic Mapper (TM) imagery from 1994 and 2005, Landsat 8 Operational Land Imager (OLI) for 2016, and Landsat 9 OLI for 2024 were acquired from the United States Geological Survey (USGS) Earth Explorer portal (<https://earthexplorer.usgs.gov/>). All imagery was selected from the dry season period (February & July) to minimize cloud

cover and seasonal variability (Roy & Inamdar., 2019). Image processing and analysis were conducted using QGIS software Version 2.18. High-resolution Google Earth imagery, expert knowledge and ground truthing data were utilized to support visual interpretation and guide the selection of representative training samples. Supervised classification of LULC was carried out using the Random Forest (RF) algorithm (Belgiu & Drăguț, 2016), using the Dzeroski Classification Tool (Karasiak, 2016) in QGIS Version 3.16. During Supervised Classification, maximum of seven distinct land cover classes were identified (Table 1).



**Figure 1.** Kidunda subcatchment.

**Table 1.** Land use land cover classification scheme.

Land cover	Description
Forest	Land covered with naturally regenerated native tree species with canopy cover >40%
Woodland	Area of land covered low density trees forming open habitat with plenty of sunlight and limited shade with canopy cover <40%
Shrubland	Area dominated with sparse vegetation, bushes and shrubs
Wetland	Land area that is saturated with water either permanent or seasonally
Water	Area within body of land, of variable size, filled with water permanent including rives, dam
Cultivated woodland	Area of land covered subjected to crop cultivation activities
Built up land	Man-made infrastructure (roads and buildings) and settlement (cities and villages)

### 2.2.2. Change Detection Analysis

Change detection analysis involves finding the type, extent, rate and location of changes in land-use between different time epochs. Various algorithms are available (Singh et al., 2025; Jensen, 1996). The study used post-classification compar-

isons to assess land-use and land-cover changes. The approach identifies changes by comparing independently classified multi-date images pixel by pixel using a change-detection matrix (Kashaigili & Majaliwa, 2013). Post classification comparison conducted using cross classification analysis using Semi-Automatic Classification Plugin in QGIS Version 2.18 (Congedo, 2013, 2016, 2021). The estimation for the rate of change for the different land covers computed based on Kashaigili & Majaliwa (2013). Kappa coefficient statistics used to assess the accuracy of final classified image.

### 2.2.3. Drivers of Change

The study employed mixed methods (Leech et al., 2010) approaches to gather information on the drivers of land use/land cover (LULC) changes. These included a literature review, focus group discussions (FGDs), and key informant interviews conducted at the community level. The FGDs involved representatives from several user and producer groups (stakeholders) utilizing different natural resources and ecosystem services including farmers, livestock keepers, and forest gatherers. Representatives from community-based conservation groups, Local leaders, including village chairpersons, Village Executive Officers (VEOs), and village elders, also participated in the data collection. Physical observations were made during field walks to collect ground-truthing data, validate information, and identify discrepancies between participants' statements and the actual conditions observed on the ground.

## 3. Result

### 3.1. Land Use Land Cover Accuracy

The LULC classifications achieved high levels of accuracy across all study years. The overall classification accuracy improved from 93.59% in 1994 to 98.53% in 2024, with corresponding Kappa coefficients ranging from 0.92 to 0.98 (Table 2). These values indicate a strong agreement between classified and reference data, confirming the reliability of the classification results

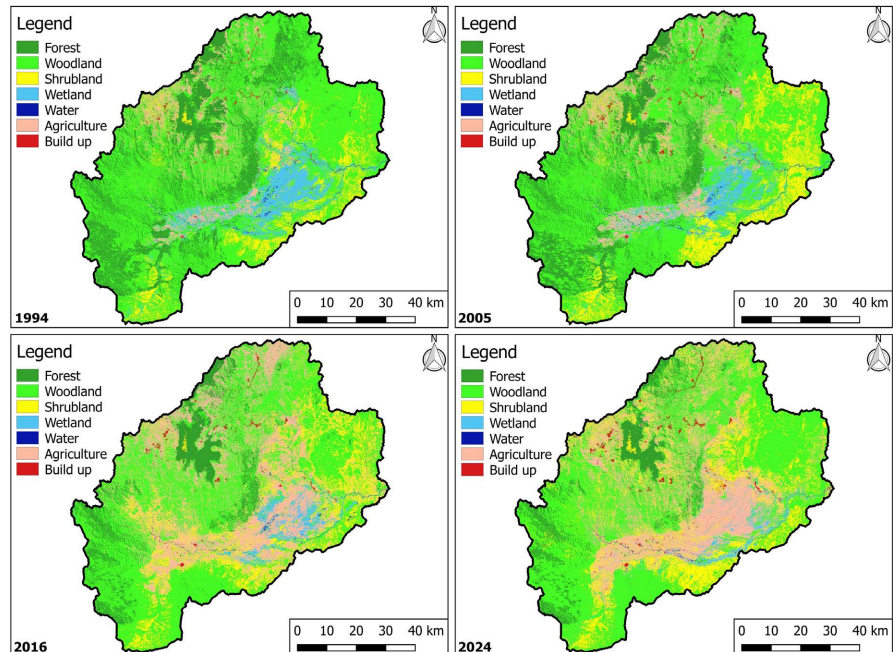
**Table 2.** Classification accuracy.

LULC	1994	2005	2016	2024
Overall accuracy (%)	93.59	89.26	91.75	98.53
Kappa statistic	0.92	0.86	0.90	0.98

### 3.2. Spatial Distribution of LULC Cover Changes

The LULC maps for the years 1994, 2005, 2016, and 2024 (Figure 2) demonstrate a clear spatial pattern of land cover change. Forested areas have receded primarily from upper and mid-catchment zones, while cultivation has spread both along the valley floors and hill slopes. Wetlands have been particularly reduced in the lower floodplain zones adjacent to rivers and seasonal water bodies. The spatial expan-

sion of cultivated land appears to follow watercourses, indicating intensive farming along riparian zones. Built-up areas have emerged closer to existing road networks and near former forested lands, highlighting the role of accessibility in driving settlement growth.



**Figure 2.** Land use land cover maps for 1994, 2004, 2014 and 2024.

### Spatial and temporal trend in land use and land cover changes

The Kidunda Catchment has undergone significant land use and land cover (LULC) transformations over the past three decades, with notable changes observed across all assessed periods (1994–2005, 2005–2016, and 2016–2024). The most substantial alteration was the drastic decline in forest cover, which decreased by 82,363 hectares, representing a 60.11% loss between 1994 and 2024 (Table 3 & Table 4). The annual rate of forest loss averaged 2,745 hectares per year, indicating sustained deforestation pressure over the years. Woodland also declined markedly, with a net reduction of 53,962 hectares (14.29%), while wetland areas were reduced by 29,591 hectares, equivalent to 68.75%, reflecting severe ecological degradation in low-lying floodplain areas.

In contrast, cultivated land expanded significantly, increasing by 103,922 hectares (226.82%), the most dramatic gain among all LULC classes. Built-up areas also rose sharply by 3,434 hectares, a 196.03% increase, suggesting urbanization or settlement expansion within the catchment. Bushland saw moderate changes, with a net increase of 20,458 hectares (21.98%), which may indicate post-disturbance vegetation regrowth in previously deforested or abandoned agricultural areas. Across the three-time intervals, the period between 2005 and 2016 experienced the most accelerated LULC transitions, particularly for forest (−46.20%), woodland (−12.49%), and wetland (−41.22%) loss. Conversely, cultivated land

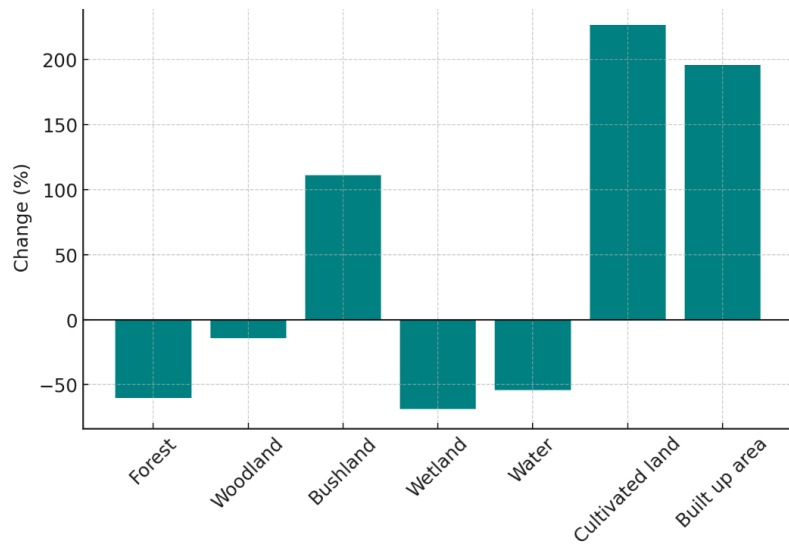
surged by 48.76% during the same period. These changes suggest intensification of anthropogenic activities, likely driven by agricultural expansion and settlement development. However, between 2016 and 2024, the rate of land transformation particularly the conversion of woodland to other land uses showed a slight decline. During Focus Group Discussion, Local community perceive the upgrading of the Selous Game Reserve to Nyerere National Park in 2019 as a turning point to this change, which resulted in enhanced protection measures, stricter enforcement, and increased security. This change likely reduced illegal logging, poaching, and unauthorized encroachment into protected and adjacent buffer areas, thereby contributing to a slowdown in woodland and forest degradation. The overall percentage change and annual rate of change in LULC between 1994-2024 are presented in **Figure 3** & **Figure 4** respectively.

**Table 3.** Land use land cover coverage.

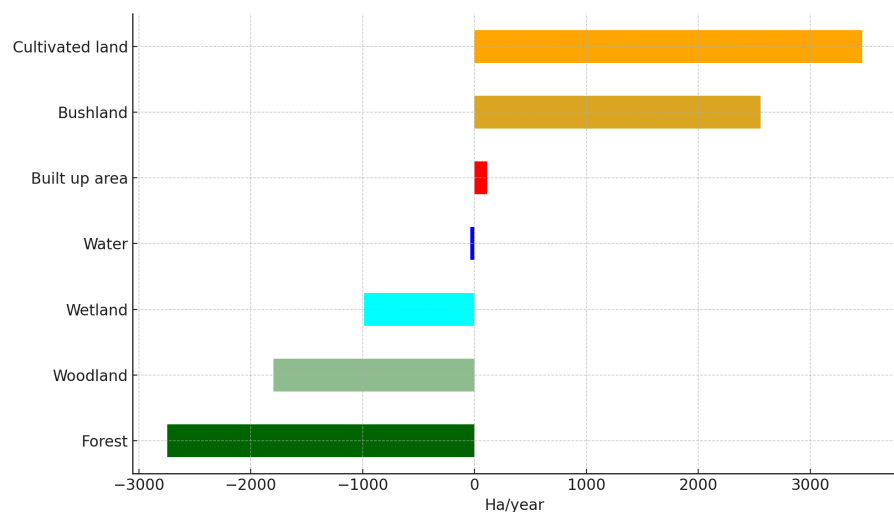
LULC	1994		2005		2016		2024	
	(Ha)	(%)	(Ha)	(%)	(Ha)	(%)	(Ha)	(%)
Forest	137,011	20.72	117,511	17.77	63,217	9.56	54,648	8.27
Woodland	377,537	57.10	366,833	55.49	321,032	48.56	323,575	48.94
Bushland	53,829	8.14	80,076	12.11	93,089	14.08	113,547	17.17
Wetland	43,043	6.51	30,508	4.61	17,931	2.71	13,452	2.03
Water	2143	0.32	1814	0.27	1543	0.23	985	0.15
Cultivated land	45,817	6.93	61,633	9.32	161,528	24.43	149,739	22.65
Built up area	1752	0.26	2754	0.42	2791	0.42	5185	0.78
Total	661,131	100	661,131	100	661,131	100	661,131	100

**Table 4.** Land use land cover changes.

1994-2005			2005-2016			2016-2024			1994-2024		
Area change (Ha)	Percentage change (%)	Annual Rate of Change (Ha/year)	Area change (Ha)	Percentage change (%)	Annual Rate of Change (Ha/year)	Area change (Ha)	Percentage change (%)	Annual Rate of Change (Ha/year)	Area change (Ha)	Percentage change (%)	Annual Rate of Change (Ha/year)
-19499	-14.23	-1773	-54294	-46.20	-4936	-8569	-13.55	-1071	-82363	-60.11	-2745
-10704	-2.84	-973	-45801	-12.49	-4164	2543	0.79	318	-53962	-14.29	-1799
26,247	48.76	2386	13,013	16.25	1183	20,458	21.98	2557	59,718	110.94	1991
-12535	-29.12	-1140	-12577	-41.22	-1143	-4479	-24.98	-560	-29591	-68.75	-986
-329	-15.34	-30	-271	-14.95	-25	-559	-36.20	-70	-1158	-54.06	-39
15,817	34.52	1438	99,894	162.08	9081	-11789	-7.30	-1474	103,922	226.82	3464
1003	57.26	91	37	1.34	3	2394	85.76	299	3434	196.03	114



**Figure 3.** Percentage change in LULC between 1994-2024.



**Figure 4.** Annual rate of change in LULC between 1994-2024.

### Land use cover conversion pathways

The annual rate of change analysis (Table 4) further reinforces the dominance of cultivation as a primary land cover transformation. Cultivated land expanded at an average rate of 3,464 hectares per year, followed by built-up areas at 114 hectares per year. Forest and wetland areas, however, declined at annual rates of 2,745 and 986 hectares, respectively, which underscoring their vulnerability to conversion and degradation. The change detection matrix (Table 5) provides further insight into specific transitions between LULC classes. The most extensive land cover conversion occurred from woodland to cultivated land (74,092 hectares), followed by wetland to cultivated land (27,146 hectares) and forest to cultivated land (16,912 hectares). These transitions reflect not only deforestation and wetland degradation but also intensification of agricultural land use. These dynamic changes imply increased ecological stress on watershed functions. Rapid

vegetation loss, particularly of forests and wetlands, reduces the catchment's ability to regulate hydrological processes such as infiltration, baseflow maintenance, and sediment retention.

**Table 5.** The land use/cover change detection matrix between 1994-2024.

1994		2024						
LULC	Frst	Wood	Bush	Wet	Water	Cult	Built	Total
Frst	41,699	11,105	567	159	78	1011	30	54,648
Wood	69,677	223,273	15,985	6064	157	8230	189	323,575
Bush	7419	61,248	27,117	5026	142	12,594	0	113,547
Wet	1038	5929	1843	4233	50	356	4	13,452
Water	46	155	12	73	672	26	0	985
Cult	16,912	74,092	7956	27,146	1022	22,611	0	149,739
Built	221	1734	349	343	21	989	1529	5185
Total	137,011	377,537	53,829	43,043	2143	45,816	1752	661,131

#### 4. Discussion

The observed land use and land cover (LULC) changes in the Kidunda Catchment over the 30-year period (1994-2024) reveal significant and accelerating landscape transformations with serious implications for hydrological integrity, ecosystem services, and the sustainability of the planned Kidunda Dam. The most notable trend is the widespread decline of natural ecosystems particularly forest and wetland cover coupled with a sharp expansion of cultivated and built-up areas. These results mirror patterns reported in other Tanzanian catchments, such as the Wami Ruvu and Great Ruaha basins (Msofe et al., 2019; Ngondo et al., 2022; Twisa et al., 2020a), reinforcing concerns about widespread land degradation in ecologically critical water source areas. The decline in forest cover and wetland areas are particularly alarming, as these land cover types are instrumental in maintaining hydrological balance. Forests serve as natural sponges, enhancing infiltration and baseflow while reducing surface runoff and sedimentation (Chidodo et al., 2025; Kashaigili & Majaliwa, 2013). Wetlands act as water reservoirs and filters, sustaining dry-season flows and improving water quality through nutrient and sediment retention (Mutayoba et al., 2018). Their degradation not only compromises ecological health but also undermines the performance of downstream infrastructure such as the proposed Kidunda Dam, increasing the risk of sediment accumulation, reduced storage capacity, and erratic inflows. Similar challenges have been observed in other large water infrastructure projects across sub-Saharan Africa, where upstream land degradation has diminished long-term functionality (Amasi et al., 2021; Kidane & Alemu, 2015).

The spatial analysis also reveals that cultivated land has become the dominant land use, increasing by over 226%, with most conversion originating from forest, wetland, and woodland areas. This trajectory aligns with many land cover change assessments (Doggart et al., 2020; Thonfeld et al., 2020) and underscores the pressure from agricultural expansion driven by both subsistence needs and commercial interests. The LULC transitions observed to follow specific pathways: woodland to cropland, wetland to cropland, and forest to cropland dominate the matrix. These transitions are strongly linked to anthropogenic drivers identified during fieldwork and community consultations, including population growth, increased demand for farmland, and weak regulatory enforcement. These drivers are consistent with findings from Doggart et al. (2020), Msofe et al. (2019), KissinGer et al. (2012) and Kangalawe & Lyimo (2010), who emphasized that limited livelihood diversification to meet demand of growing population push communities toward unsustainable land use practices such as unsustainable agriculture and encroachment into protected zones.

Community-based interventions emerge as a vital complement to top-down conservation policies. The effectiveness of participatory land use planning, agroforestry, soil and water conservation, and controlled grazing was repeatedly emphasized by local stakeholders during FGDs and key informant interviews. Such strategies have demonstrated success in other Tanzanian contexts (Tenge, 2005; Theodory & Kitole, 2024; Mgonja & Massawe, 2024). However, the success and sustainability of these interventions depend on several enabling conditions. These include access to training and extension services, availability of initial resources or incentives for implementation, and strong institutional support at the local level. Without these, many well-intentioned interventions risk being short lived or poorly adopted. As such, these approaches should be mainstreamed into catchment-wide planning and integrated into national water infrastructure development frameworks, including the operational strategies of the proposed Kidunda Dam.

## 5. Conclusion

This study assessed three decades of land use and land cover (LULC) changes within the Kidunda River Catchment, revealing profound transformations with direct implications for water resource sustainability and the viability of the planned Kidunda Dam. The findings demonstrate a sharp decline in forest (60.11%) and wetland (68.75%) areas, coupled with an extensive expansion of cultivated land (226.82%) and built-up areas (196.03%). These transitions are driven by a complex interplay of socio-economic factors, including population growth, agricultural pressure, and weak enforcement of land use regulations. The conversion of ecologically sensitive land cover types particularly forests and wetlands into farmland and settlements has significantly undermined the watershed's natural ability to regulate hydrological functions such as infiltration, baseflow maintenance, and sediment retention.

To ensure the sustainability of the Kidunda Catchment and the effective operation of the proposed Kidunda Dam, it is recommended to adopt an integrated catchment management approach aligned with national water strategies, and to strengthen participatory land use planning at the community level to protect forests, wetlands, and riparian zones. Scaling up sustainable land management practices such as agroforestry, terracing, and controlled grazing will help restore degraded areas and enhance water retention. Improved enforcement of land use regulations is crucial for promoting long-term stewardship. Supporting alternative livelihoods can reduce pressure on natural resources, while robust hydrological monitoring systems will provide essential data for adaptive dam and watershed management. Lastly, further research is needed to better understand the impact of land cover transitions on the hydrological response of Kidunda catchment, enabling more targeted and effective interventions.

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### Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

### References

- Amasi, A., Wynants, M., Blake, W., & Mtei, K. (2021). Drivers, Impacts and Mitigation of Increased Sedimentation in the Hydropower Reservoirs of East Africa. *Land, 10*, Article 638. <https://doi.org/10.3390/land10060638>
- Andreasen, M. H., Agergaard, J., Kofie, R. Y., Møller-Jensen, L., & Oteng-Ababio, M. (2022). Urban Encroachment in Ecologically Sensitive Areas: Drivers, Impediments and Consequences. *Buildings and Cities, 3*, 920-938. <https://doi.org/10.5334/bc.210>
- Belgiu, M., & Drăguț, L. (2016). Random Forest in Remote Sensing: A Review of Applications and Future Directions. *ISPRS Journal of Photogrammetry and Remote Sensing, 114*, 24-31.
- Chidodo, S., Zhang, L., Zarei, A., & Feger, K. H. (2025). Remote Sensing-Based Assessment of Four Decades of Land Use/Land Cover Change in the Sigi River Watershed, East Usambara Mountains, Tanzania. *Frontiers in Remote Sensing, 6*, Article 1594331.
- Chilagane, N. A., Kashaigili, J. J., Mutayoba, E., Lyimo, P., Munishi, P., Tam, C. et al. (2021). Impact of Land Use and Land Cover Changes on Surface Runoff and Sediment Yield in the Little Ruaha River Catchment. *Open Journal of Modern Hydrology, 11*, 54-74. <https://doi.org/10.4236/ojmh.2021.113004>
- Coates, D., & Smith, M. (2012). Natural Infrastructure Solutions for Water Security. *Water and the Green Economy, 1*, 167-181.
- Congedo, L. (2013). *Semi-Automatic Classification Plugin for QGIS* (pp. 1-25). Sapienza University. <http://www.planning4adaptation.eu/>
- Congedo, L. (2016). *Semi-Automatic Classification Plugin Documentation*. Release 6.0.1.1. Technical Report.

- Congedo, L. (2021). Semi-automatic Classification Plugin: A Python Tool for the Download and Processing of Remote Sensing Images in QGIS. *Journal of Open Source Software*, 6, Article 3172. <https://doi.org/10.21105/joss.03172>
- Doggart, N., Morgan-Brown, T., Lyimo, E., Mbilinyi, B., Meshack, C. K., Sallu, S. M. et al. (2020). Agriculture Is the Main Driver of Deforestation in Tanzania. *Environmental Research Letters*, 15, Article ID: 034028. <https://doi.org/10.1088/1748-9326/ab6b35>
- Felix, M. (2015). Future Prospect and Sustainability of Wood Fuel Resources in Tanzania. *Renewable and Sustainable Energy Reviews*, 51, 856-862. <https://doi.org/10.1016/j.rser.2015.06.034>
- Jensen, K., Kesmir, C., & Søndergaard, I. (1996). From Image Processing to Classification: IV. Classification of Electrophoretic Patterns by Neural Networks and Statistical Methods Enable Quality Assessment of Wheat Varieties for Breadmaking. *Electrophoresis*, 17, 694-698.
- Kalogiannidis, S., Kalfas, D., Giannarakis, G., & Paschalidou, M. (2023). Integration of Water Resources Management Strategies in Land Use Planning Towards Environmental Conservation. *Sustainability*, 15, Article 15242. <https://doi.org/10.3390/su152115242>
- Kangalawe, R. Y. M., & Lyimo, J. G. (2010). Population Dynamics, Rural Livelihoods and Environmental Degradation: Some Experiences from Tanzania. *Environment, Development and Sustainability*, 12, 985-997. <https://doi.org/10.1007/s10668-010-9235-y>
- Karasiak, N. (2016). Dzetsaka QGIS Classification Plugin. <https://github.com/nkarasiak/dzetsaka>
- Kashaigili, J. J., & Majaliwa, A. M. (2013). Implications of Land Use and Land Cover Changes on Hydrological Regimes of the Malagarasi River, Tanzania. *Journal of Agricultural Science and Applications*, 2, 45-50.
- Kidane, D., & Alemu, B. (2015). The Effect of Upstream Land Use Practices on Soil Erosion and Sedimentation in the Upper Blue Nile Basin, Ethiopia. *Research Journal of Agriculture and Environmental Management*, 4, 55-68.
- KissinGer, G., Herold, M., & De Sy, V. (2012). *Drivers of Deforestation and Forest Degradation. A Synthesis Report for REDD+ Policymakers*, 48(10.1016). <https://www.cabidigitallibrary.org/doi/full/10.5555/20123360980>
- Lebu, S., Lee, A., Salzberg, A., & Bauza, V. (2024). Adaptive Strategies to Enhance Water Security and Resilience in Low- and Middle-Income Countries: A Critical Review. *Science of the Total Environment*, 925, Article ID: 171520. <https://doi.org/10.1016/j.scitotenv.2024.171520>
- Leech, N. L., Dellinger, A. B., Brannagan, K. B., & Tanaka, H. (2010). Evaluating Mixed Research Studies: A Mixed Methods Approach. *Journal of Mixed Methods Research*, 4, 17-31. <https://doi.org/10.1177/1558689809345262>
- Liu, Y., Wu, G., Fan, X., Gan, G., Wang, W., & Liu, Y. (2022). Hydrological Impacts of Land Use/Cover Changes in the Lake Victoria Basin. *Ecological Indicators*, 145, Article ID: 109580. <https://doi.org/10.1016/j.ecolind.2022.109580>
- Mangi, H. O., Onywere, S. M., Kitur, E. C., Lalika, M. C. S., & Chilagane, N. A. (2022). Hydrological Response to Land Use and Land Cover Change on the Slopes of Kilimanjaro and Meru Mountains. *Ecohydrology & Hydrobiology*, 22, 609-626. <https://doi.org/10.1016/j.ecohyd.2022.08.002>
- Mbungu, W. B. (2017). *Impacts of Land Use and Land Cover Changes, and Climate Variability on Hydrology and Soil Erosion in the Upper Ruvu Watershed, Tanzania*. Ph.D. Thesis, Virginia Tech.
- Mgalula, M. E., Majule, A. E., Saria, A. E., & Mwakisunga, B. (2024). Land Use and Land

- Cover Changes and Their Driving Forces in Selected Forest Reserves in Central Tanzania. *Trees, Forests and People*, 16, Article ID: 100584. <https://doi.org/10.1016/j.tfp.2024.100584>
- Mgonja, R., & Massawe, P. (2024). The Role of Community-Based Initiatives in Enhancing Water Quality and Livelihoods in Rural Tanzania: A Case Study of Mvomero District. *NG Journal of Social Development*, 15, 1-16. <https://doi.org/10.4314/ngjsd.v15i1.1>
- Msofe, N., Sheng, L., & Lyimo, J. (2019). Land Use Change Trends and Their Driving Forces in the Kilombero Valley Floodplain, Southeastern Tanzania. *Sustainability*, 11, Article 505. <https://doi.org/10.3390/su11020505>
- Mutayoba, E., Kashaigili, J. J., Kahimba, F. C., Mbungu, W., & Chilagane, N. A. (2018). Assessing the Impacts of Land Use and Land Cover Changes on Hydrology of the Mbarali River Sub-Catchment. the Case of Upper Great Ruaha Sub-Basin, Tanzania. *Engineering*, 10, 616-635. <https://doi.org/10.4236/eng.2018.109045>
- Mwanukuzi, P. K. (2008). Using GIS for Decision-making: The Case of Kidunda Dam in Morogoro, Tanzania. *The Geographical Journal*, 174, 161-164. <https://doi.org/10.1111/j.1475-4959.2008.00288.x>
- Näschen, K., Diekkrüger, B., Evers, M., Höllermann, B., Steinbach, S., & Thonfeld, F. (2019). The Impact of Land Use/land Cover Change (LULCC) on Water Resources in a Tropical Catchment in Tanzania under Different Climate Change Scenarios. *Sustainability*, 11, Article 7083. <https://doi.org/10.3390/su11247083>
- Ngondo, J., Mango, J., Nobert, J., Dubi, A., Li, X., & Cheng, H. (2022). Hydrological Response of the Wami-Ruvu Basin to Land-Use and Land-Cover Changes and Its Impacts for the Future. *Water*, 14, Article 184. <https://doi.org/10.3390/w14020184>
- Roy, A., & Inamdar, A. B. (2019). Multi-Temporal Land Use Land Cover (LULC) Change Analysis of a Dry Semi-Arid River Basin in Western India Following a Robust Multi-sensor Satellite Image Calibration Strategy. *Heliyon*, 5, No. 4.
- Singh, N., Hazarika, A., Zhang, J. Z., & Bilan, Y. (2025). Empowering Communities: A Low-cost Approach to Land and Water Management in Developing Countries. *Land Degradation & Development*, 36, 2193-2202. <https://doi.org/10.1002/ldr.5489>
- Tenge, A. J. M. (2005). *Participatory Appraisal for Farm-Level Soil and Water Conservation Planning in West Usambara Highlands, Tanzania*. Ph.D. Thesis, Wageningen University and Research.
- Theodory, T. F., & Kitole, F. A. (2024). Does Rural Water Resource Outcry Elevate Communities' Conservation for Livelihoods in a Pooled Resource? A Case of Mvomero District, Morogoro Region, Tanzania. *Sustainable Water Resources Management*, 10, Article No. 81. <https://doi.org/10.1007/s40899-024-01070-x>
- Thonfeld, F., Steinbach, S., Muro, J., & Kirimi, F. (2020). Long-Term Land Use/Land Cover Change Assessment of the Kilombero Catchment in Tanzania Using Random Forest Classification and Robust Change Vector Analysis. *Remote Sensing*, 12, Article 1057. <https://doi.org/10.3390/rs12071057>
- Twisa, S., Kazumba, S., Kurian, M., & Buchroithner, M. F. (2020a). Evaluating and Predicting the Effects of Land Use Changes on Hydrology in Wami River Basin, Tanzania. *Hydrology*, 7, Article 17. <https://doi.org/10.3390/hydrology7010017>
- Twisa, S., Mwabumba, M., Kurian, M., & Buchroithner, M. F. (2020b). Impact of Land-Use/Land-Cover Change on Drinking Water Ecosystem Services in Wami River Basin, Tanzania. *Resources*, 9, Article 37. <https://doi.org/10.3390/resources9040037>