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Land Use and Land Cover Changes Analysis in Sedawgyi Dam for Sustainable Resource Management Using Geospatial Techniques

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Abstract— *This study investigates land use and land cover (LULC) changes in the Sedawgyi Dam catchment and irrigated areas in central Myanmar over a 20-year period (2002–2022) using remote sensing data and geospatial analysis tools. By employing NDVI analysis and the Maximum Likelihood Classification (MLC) method on Landsat satellite imagery, the research quantifies significant shifts in land cover types, including reductions in dense vegetation and agricultural land, alongside increases in urban and sparse vegetation areas. These transformations have major implications for watershed hydrology and water resource management, as urbanization and vegetation loss directly impact infiltration, surface runoff, and sedimentation in the dam's reservoir. The results provide a spatially explicit basis for integrating LULC dynamics into inflow modeling and highlight the need for adaptive water management strategies. The findings support the implementation of Integrated Water Resource Management (IWRM) frameworks to balance ecological, agricultural, and urban water demands.*

Keywords— *Land Use, Sedawgyi Dam, Remote Sensing, NDVI, Maximum Likelihood Classification, GIS.*

I. Introduction

Land use and land cover (LULC) change is one of the most significant drivers of environmental transformation globally, exerting profound impacts on hydrological systems and water resource infrastructure. Reservoirs, critical for water storage, flood control, irrigation, hydroelectric power generation, and domestic water supply, are among the most affected components. Changes in land use patterns, such as urbanization, agricultural expansion, deforestation, and industrial development, directly influence the quantity, timing, and quality of water entering these reservoirs. A major consequence of LULC change is the alteration of surface runoff and infiltration dynamics. For instance, converting forested or vegetated areas into urban or agricultural land typically increases the extent of impervious surfaces, which accelerates surface runoff, reduces groundwater recharge, and leads to more frequent and intense peak flows into reservoirs. These hydrological shifts heighten the risk of flash flooding and place additional stress on reservoir operations and infrastructure. Furthermore, climate variability can exacerbate the impacts of LULC changes, making it increasingly important to understand their combined effects on reservoir systems. Monitoring and analysing LULC changes through remote sensing, geographic information systems (GIS), and hydrological modelling tools is essential for predicting and mitigating their impacts. Such assessments enable informed decision-making in watershed management, land-use planning, and the development of adaptive strategies to preserve the functional integrity and ecological health of reservoirs.

The Sedawgyi Dam, located in central Myanmar, plays a critical role in supporting multiple water-dependent sectors, including irrigation, domestic water supply for Mandalay City, and hydropower generation. However, over the past two decades, both the dam's catchment and its irrigated command area have undergone significant land use and land cover (LULC) changes. Satellite-based analyses reveal that between 2002 and 2012, dense vegetation within the catchment area declined by more than 750 km², accompanied by a notable increase in sparse vegetation and urban expansion. In the irrigated zones downstream, built-up land expanded by over 420 km², while agricultural land area declined substantially. These transformations have important implications for the dam's hydrological performance, water quality, and long-term operational sustainability, particularly in the context of balancing irrigation demand, domestic supply, and hydropower production.

These LULC changes have profound implications for the hydrological inflow to the Sedawgyi Reservoir. The replacement of vegetated areas with impervious surfaces reduces infiltration and groundwater recharge, increases surface runoff, and often results in higher peak flows and lower base flows. In parallel, vegetation degradation and soil exposure contribute to heightened soil erosion and sediment delivery into the reservoir, reducing its effective storage capacity and increasing the frequency and cost of dredging and maintenance [4] [5].

Despite these known risks, the integration of LULC change analysis into inflow prediction and dam management planning in Myanmar remains limited. Most operational decisions at Sedawgyi Dam continue to rely on historical inflow data, assuming static land cover conditions that no longer reflect the current landscape. As urbanization and land degradation intensify, this assumption introduces increasing uncertainty and risk in water allocation across sectors. To address this critical gap, the present study conducts a LULC change analysis of the

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Sedawgyi Dam catchment from 2002 to 2022 using multispectral Landsat imagery and supervised classification techniques, including NDVI and Maximum Likelihood Classification (MLC). By quantifying changes in vegetation cover, urban extent, and bare land, the study aims to provide key insights into how land cover dynamics have likely influenced inflow volume and timing. These findings are intended to support improved inflow modeling, sediment control strategies, and integrated water resource management at Sedawgyi Dam.

II. Material and Methods

A. Study Area

The Sedawgyi Dam is situated at 21°57' N latitude and 96°05' E longitude, at an elevation of approximately 74 meters above mean sea level. It is located near the Chaungmagyi River, in the northern part of the study area. More than 68,000 acres of farmland in the Mandalay Region, encompassing Mandalay, Mattayar, Patheingyi, and Amarapura Townships, are irrigated by the dam. About 330,000 acre-feet of water is available for reuse each year out of a total storage capacity of over 360,000 acre-feet. In addition to irrigation, the dam supplies domestic water to several townships in Mandalay City, including Aungmyaethazan (AMTZ), Chanayethazan (CATZ), Mahaaungmyae (MHA), Chanmyathazi (CMTZ), and Pyigyitagon (PGTG). Furthermore, the dam supports a hydropower generation capacity of 25 MW. The catchment area of Sedawgyi Dam encompasses regions within Mogok, Nawnghkio, and Changgyi. The catchment area and irrigated areas is illustrated in Figure 1.

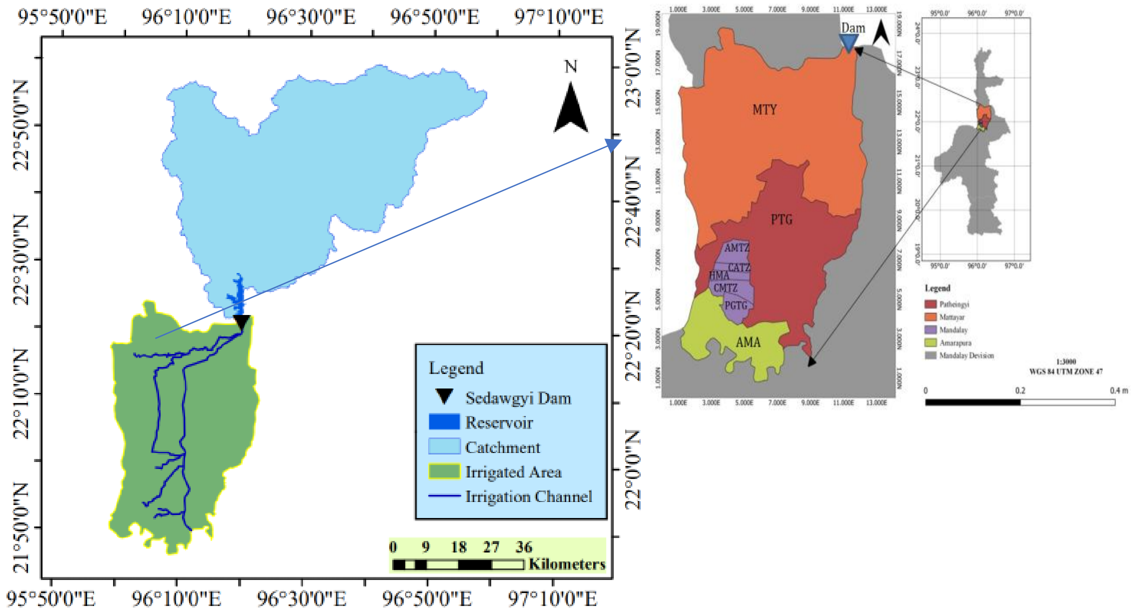

Figure 1. Location of Study Area

B. Data Acquisition

In order to demonstrate and analyze satellite imagery, such as Landsat images, Sentinel, or MODIS and ancillary data such as topographic maps, DEM, administrative boundaries, and ground-truth data are used to get spatial interpretation from these images which are mainly depend on the location of the study area, time interval, required spatial resolution, and temporal coverage.

1. Satellite Imagery: To perform the land use analysis, 30-m resolution satellite imagery was acquired from Landsat, Sentinel, and MODIS. The selection of specific satellite data was based on the study area's size, required spatial resolution and temporal coverage. Specifically, multispectral images from Landsat 8 OLI, covering the years 2002, 2012 and 2022, were obtained from the United States Geological Survey (USGS) at (https://earthexplorer.usgs.gov). Thus, these images were processed using ArcGIS 10.8, Google Earth Pro and ERDAS Imagine 14 software to create LULC maps which were essential for analyzing changes in different land use classes across the study period of 20 years span in this study.
2. Ancillary Data: Additional data including Digital Elevation Model (DEM), topographic maps, administrative boundaries and ground-truth data are collected from field surveys that are used to support the classification process. These ancillary data were sourced from the Myanmar Information Management Unit (MIMU).

C. Image Preprocessing

According to the Crist and Cicone (1984) stated that the tasseled cap concept to Landsat TM data and found that the six bands of reflected data effectively occupy three dimensions, defining planes of soils, vegetation and a transition zone between them. Using ground reference data, it is frequently possible to "calibrate" TVI (NDVI) values to the green biomass present on a pixel-by-pixel basis. Usually, separate calibration relationships must be established for each cover type present in an image.

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These relationships may then be used in such applications as "precision crop management" or precision farming to guide the application of irrigation water, fertilizers, herbides and so on. Similarly, TVI values have been used to aid in making ranch management decision when the TVI data correlate with the estimated level of forage present in pastures contained in an image [04Tho]. Table I displays about the NDVI Range of the land use classes.

TABLE I. NDVI CLASS RANGE [5]

Class	NDVI Range
Water	– 0.28 - 0.015
Built-up	0.015 - 0.14
Barren land (bare land)	0.14 - 0.18
Shrub and Grassland (agricultural land)	0.18 - 0.27
Spare vegetation	0.27 - 0.36
Dense vegetation	0.26 - 0.74 and greater

D. Gaussian Maximum Likelihood Classifier

The Maximum Likelihood Classification (MLC) method was employed to classify the LULC for the three time periods. MLC is a well-known and precise method that assumes a multivariate normal distribution for each spectral class. This method uses both mean vectors and covariance matrices to identify and classify land cover types. The accuracy of MLC is dependent on the precise estimation of these parameters. Geometric correction procedures were applied to minimize spatial distortions and ensure accurate spatial registration of the imagery within the GIS environment, as detailed in Table II.

E. Digital Image Classification

Crist and Cicone extended the tasseled cap concept to Landsat TM data and found that the six bands of reflected data effectively occupy three dimensions, defining planes of soils, vegetation and a transition zone between them. The third feature, called wetness, relates to canopy and soil moisture. The vegetation transformation, namely, the transformed vegetation index (TVI) is computed using the Equation 1.

$$\mathrm{TVI} = \left[\frac{\mathrm{DN}(\mathrm{nearIR}) - \mathrm{DN}(\mathrm{red})}{\mathrm{DN}(\mathrm{nearIR}) + \mathrm{DN}(\mathrm{red})} + 0.5\right]^{0.5} \times 100 \qquad (1)$$

where,

DN (nearIR) = digital number in the near-IR band

DN (red) = digital number in the red band

Using ground reference data, it is frequently possible to "calibrate" TVI values to the green biomass present on a pixel-by-pixel basis. Usually, separate calibration relationships must be established for each cover type present in an image. These relationships may then be used in such applications as "precision crop management" or precision farming to guide the application of irrigation water, fertilizers, herbicides and so on. Similarly, TVI values have been used to aid in making ranch management decision when the TVI data correlate with the estimated level of forage present in pastures contained in an image [5].

III. RESULTS AND DISCUSSION

A. Catchement Area Change (2002-2022)

The evaluation of land use and land cover (LULC) changes in the Sedawgyi Dam region has been enhanced using GIS spatial analysis tools. These instruments made it easier to classify and process digital images by integrating data from topographic maps, Google Earth Pro imagery, and Universal Transverse Mercator (UTM) maps for the surrounding towns. This method allowed for accurate representation and differentiation of land use classes, such as marking water bodies in blue and dense vegetation in dark green. The digital image classification technique was further improved by the False Color Composite (FCC) analysis of NDVI data. The analysis of land use and land cover (LULC) changes in the Sedawgyi Dam region reveals significant temporal transformations across the catchment and irrigated areas over the past two decades. Figures 2 and Figure 3 visually present the LULC map observed in the Sedawgyi catchment area.

B. Irrigated Area Changes

Temporal LULC analysis is conducted for the catchment and irrigated areas of the Sedawgyi Dam for 2002, 2012 and 2022 using pivot-table standardization methods. Results indicate significant transformations over two decades, decreases in agricultural and dense vegetation areas and increases in built-up spaces due to urbanization. These results indicate the substantial impact of socio-economic changes on land use patterns.

The use of GIS tools not only provides a visual representation of these changes but also quantitatively measures area changes in different land use types. For instance, the catchment area experienced notable shifts such as a significant reduction in bare land and an increase in sparse vegetation, whereas irrigated area increases in built-up areas and a decline in agricultural land.

TABLE II. SPECTRAL CLASSES RESULTING FROM CLUSTERING A FORESTED SCENE [5]

Spectral Class	Identity of Spectral Class	Corresponding Desired Information Category
Possible Outcome 1		
1	Water	Water
2	Coniferous trees	Coniferous trees
3	Deciduous tree	Deciduous tree
4	Brushland	Brushland
Possible Outcome 2	Turbid water	Water
1	Clear Water	
2	Sunlit conifers	Coniferous trees
3	Shaded hillside conifers	
4	Upland deciduous	Deciduous trees
5	Lowland deciduous	
6	Brushland	Brushland
7		
Possible Outcome 3	Turbid water	Water
1	Clear Water	
2	Coniferous trees	Coniferous trees
3	Mixed	
4	coniferous/deciduous	Deciduous trees
5	Deciduous trees	
6	Deciduous/brushland	Brushland

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Such insights are critical for tailoring IWRM approaches to align with the evolving demands and ensuring efficient and sustainable water resource management for the Sedawgyi Dam. And Figure 4 and Figure 5 also present the LULC maps observed in the Sedawgyi irrigated area. The changes of land use practices show, as depicted in the tables and graphs, Sedawgyi irrigated area is affected by dynamic nature of land use influenced by urbanization, agricultural shifts and socio-economic factors.

C. Land Use Change Analysis

With the aid of the analytical function of Arc GIS, training sample manager develops the difference class of land use into attributed table and exported to the Excel spread sheet. All counted number of the class range with related area and pixel number are compounded by using pivot-table standardization method. Tables III and IV, along with Figures 6 and 7, present the results of the LULC types and their corresponding areas for the entire Sedawgyi catchment and the irrigated area.

The data from Table 3 and Figure 6 illustrate a notable shift in the LULC distribution from 2002 to 2022. Dense vegetation, which initially covered a significant portion of the area 1250.10 km^2 in 2002, decreased sharply to 496.98 km^2 by 2012, before slightly increasing to 1185.98 km^2 in 2022. This trend highlights potential afforestation or natural regeneration in the latter decade. Spare vegetation, on the other hand, increased substantially from 104.82 km^2 in 2002 to 1219.21 km^2 in 2022, suggesting land degradation or the transition of dense vegetation into less productive states. Bare land exhibited a significant reduction of over 1200 km^2 from 2002 to 2022, reflecting the expanding vegetative cover or land conversion for other uses. Water bodies have minor fluctuations, increasing slightly, which could be due to the hydrological interventions or rainfall variations.

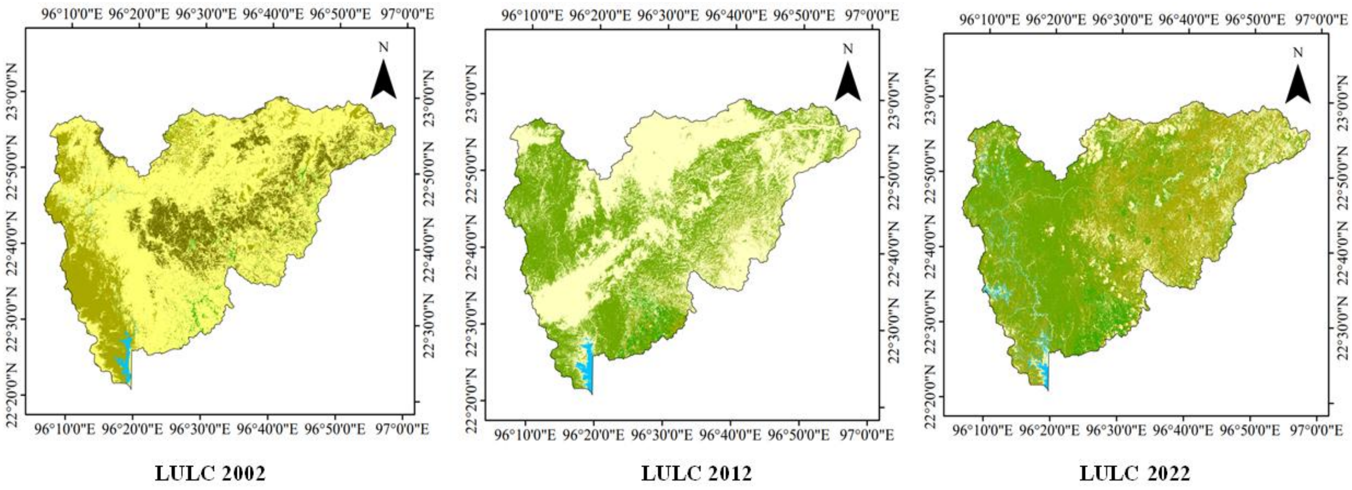

Figure 2. LULC Maps for Sedawgyi Catchment

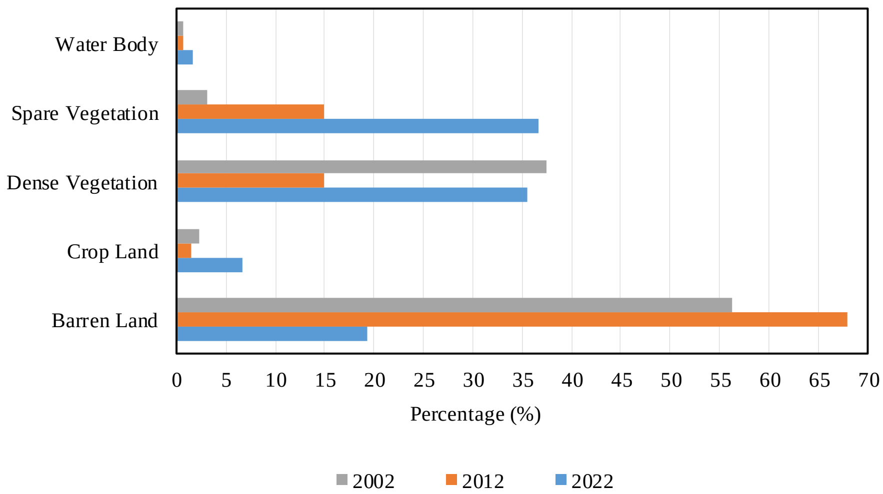

Figure 3. LULC Area Percentage for Sedawgyi Catchment

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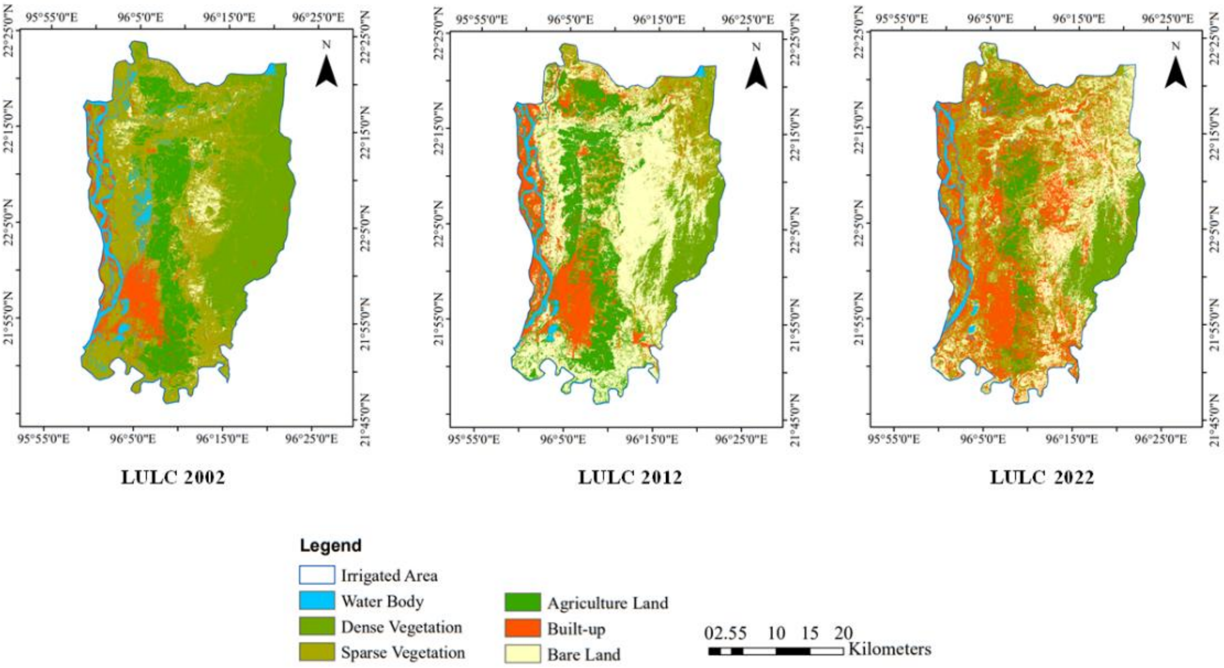

Figure 4. LULC Maps for Sedawgyi Irrigated Area

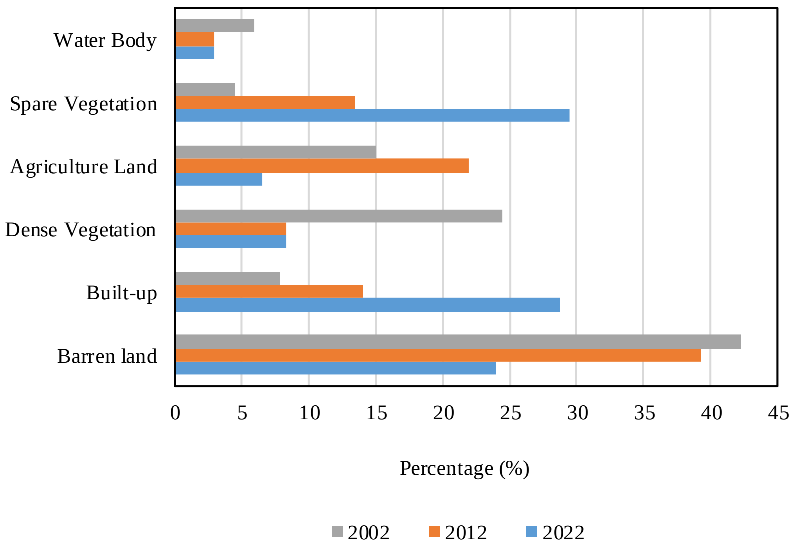

Figure 5. LULC Area Percentage for Sedawgyi Irrigated Area

In the irrigated area, built-up land expanded dramatically from 157.23 km^2 in 2002 to 577.83 km^2 in 2022, demonstrating rapid urbanization. This increase correlates with the decline in agricultural land from 440.98 km^2 in 2012 to 131.16 km^2 in 2022, indicating a conversion of farmlands into urban spaces. Sparse vegetation increased significantly, while dense vegetation showed a steep decline, suggesting deforestation or a change in vegetation density due to the human activities. Water bodies slightly decreased, indicating potential water resource stress or changes in irrigation patterns.

The increasing built-up areas and decreasing agricultural land in the irrigated regions highlight the growing dominance of urban water demand over irrigation needs. The reduction in dense vegetation could impact evapotranspiration rates and runoff patterns, altering the dam's inflow. The presented data emphasize the need for a revised water allocation strategy. Integrating these LULC trends into the Sedawgyi Dam's IWRM approach is vital for aligning water distribution with current and future land use patterns. Strategies should address urban water demands while safeguarding ecological balance in the catchment areas.

D. Recommendations

Based on the findings of this study, the following recommendations are proposed to enhance water resource management and ensure long-term sustainability of the Sedawgyi Dam:

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1. Implement Integrated Water Resource Management (IWRM): It is recommended that IWRM principles be adopted to align water allocation with dynamic land use changes and support balanced development across urban, agricultural, and environmental sectors.
2. Integrate Real-Time LULC Data into Inflow Models: To improve the accuracy of inflow predictions, existing hydrological models should be updated to incorporate current satellite-derived land cover data, replacing outdated static assumptions.
3. Strengthen Urban Planning and Zoning Policies: Authorities should enforce land use regulations and urban development guidelines to control unplanned expansion, particularly in areas critical to water catchment and reservoir operations.
4. Promote Reforestation and Vegetation Restoration Programs:Restoration of degraded land through afforestation and conservation initiatives is esse ntial to enhance infiltration, reduce runoff, and maintain ecosystem services within the watershed.
5. Enhance Monitoring and Early Warning Systems Using GIS: It is advisable to develop a GIS-based monitoring system capable of detecting land use changes and forecasting their impact on water resources, enabling proactive and informed management.
6. Engage Stakeholders in Scenario-Based Planning: Effective water governance should involve active participation from local communities, government agencies, and agricultural users in developing adaptive strategies based on simulated scenarios.

TABLE III. AREA CHANGES IN SEDAWGYI CATCHMENT

Row Labels	2002 Sum of Area (km^2)	2012 Sum of Area (km^2)	2022 Sum of Area (km^2)	LULC Change (2002-2012) (km^2)	LULC Change (2002-2022) (km^2)
Bare Land	1874.64	2260.73	646.08	386.10	1228.56
Agriculture Land	78.85	51.50	224.90	– 27.35	– 146.05
Dense Vegetation	1250.10	496.98	1185.98	– 753.12	64.12
Spare Vegetation	104.82	497.71	1219.21	392.88	– 1114.38
Water Body	22.81	24.31	54.99	1.50	– 32.18
Grand Total	3331.22	3331.23	3331.16		

TABLE IV. AREA CHANGES IN SEDAWGYI IRRIGATED AREA

Row Labels	2002 Sum of Area (km2)	2012 Sum of Area (km2)	2022 Sum of Area (km2)	LULC Change (2002-2012) (km2)	LULC Change (2002-2022) (km2)
Bare Land	850.97	789.85	482.89	– 61.12	368.08
Built-up	157.23	281.98	577.83	124.75	– 420.61
Dense Vegetation	493.14	168.02	168.18	– 325.12	324.96
Agriculture Land	301.44	440.98	131.16	139.54	170.28
Spare Vegetation	90.63	270.77	593.25	180.14	– 502.63
Water Body	118.57	60.33	58.65	– 58.24	59.92
Grand Total	2011.97	2011.93	2011.96		

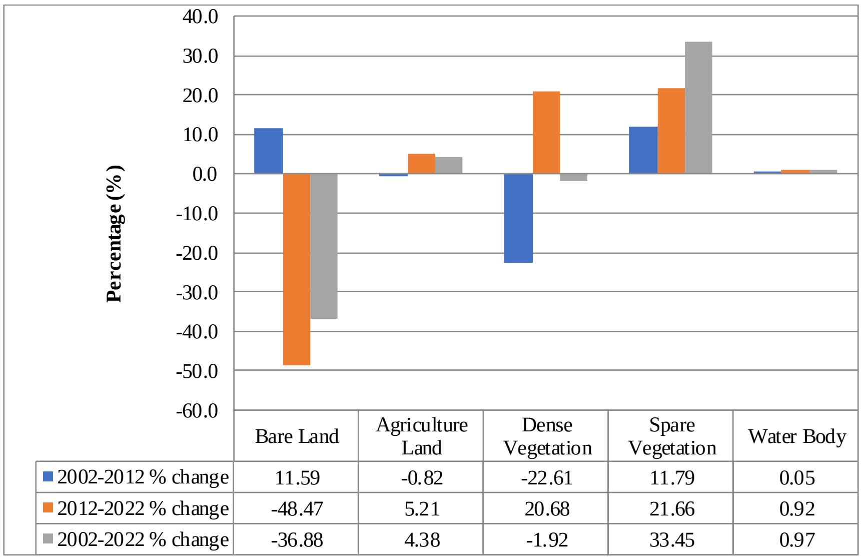
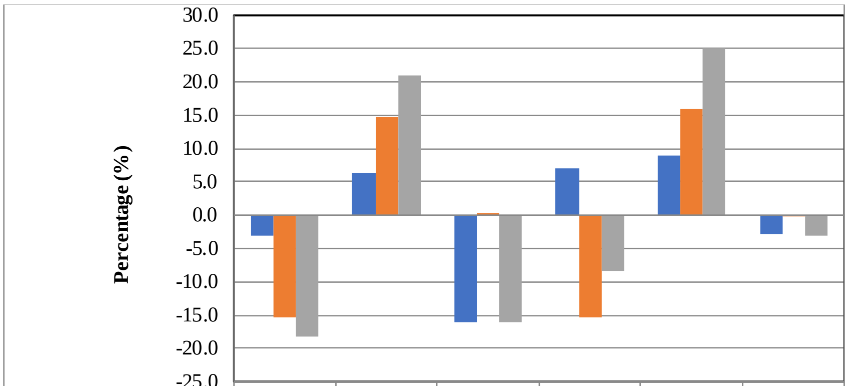


Figure 6. LULC Changes for Sedawgyi Catchment



	Bare Land	Built-up	Dense Vegetation	Agricultur e Land	Spare Vegetation	Water Body
2002-2012 % change	-3.04	6.20	-16.16	6.94	8.95	-2.89
2012-2022 % change	-15.26	14.70	0.01	-15.40	16.03	-0.08
2002-2022 % change	-18.29	20.91	-16.15	-8.46	24.98	-2.98

Figure 7. LULC Changes for Sedawgyi Irrigated Area

IV. Conclusion

The assessment of LULC changes in the Sedawgyi Dam region reveals substantial alterations over the past two decades, notably a decrease in dense vegetation and agricultural land, and a sharp rise in built-up areas due to urban expansion. These changes, driven by socio-economic development and land degradation, have disrupted hydrological patterns in the region, affecting inflow dynamics and reservoir capacity. The study highlights that traditional water resource planning methods that assume static land use conditions are no longer adequate. Instead, dynamic, data-driven approaches incorporating real-time LULC data are essential. Integrating remote sensing with GIS tools provides a powerful means to track and understand these shifts, enabling more accurate forecasting and better-informed water management decisions. This research supports the urgent need for adaptive and integrated approaches to water resource planning at Sedawgyi Dam, underpinned by continuous monitoring and scenario-based evaluation.

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