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Original Article

GEOSPATIAL ANALYSIS OF LAND USE AND LAND COVER (LULC) CHANGES IN SRI JAYEWARDENEPURA KOTTE FROM 1989 TO 2024: A GIS-BASED APPROACH TO ASSESSING URBANIZATION AND ENVIRONMENTAL DYNAMICS

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Abstract

In the context of rapid urbanization, land transformation has become a significant issue, mainly in rapidly developing areas. This study explores an extensive geo-spatial analysis of land use and land cover changes in Sri Jayewardenepura Kotte, Sri Lanka, over the period from 1989-2024. By utilizing a GIS-based methodological framework and multi-temporal Landsat imagery, the study examines temporal changes in land use and land cover in Sri Jayewardenepura Kotte from 1989 to 2024, focusing on the dynamics of vegetation, built-up areas, and water bodies, and to assess the relationship between urbanization and environmental changes over the study period by integrating spatial land use and land cover (LULC) data with demographic and urban development information. The features, variations, and trends of urbanization and the environmental dynamics are analyzed through the application of three remote sensing-based indices: the Normalized Difference Vegetation Index, Normalized Difference Built-Up Area Index, and Normalized Difference Water Bodies Index. The study reveals a significant expansion of built-up areas, especially after, because of the population growth of the region. Vegetation cover explores a temporal stability assisted by urban green initiatives promoted after 2017, a result of unregulated urban expansion and unsustainable environmental management. This study emphasizes the consequences of integrating geospatial technologies in urban planning and policy making to encourage sustainable development and mitigate the unfavorable environmental practices.

Keywords: Environmental dynamics, Geospatial analysis, Land use and land cover, Sri Jayewardenepura Kotte, Urbanization

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1. INTRODUCTION

Land is a complex and dynamic combination of factors, including geology, topography, hydrology, soils, microclimate, and communities of plants and animals. They are constantly interacting under the influence of climate and of people's activities (Hudson,1995). Recently, land-use/cover changes have become a key issue of global research, and it has become a debate among academicians, researchers, policy makers, and governments. Land use refers to the form of human activity or economic purpose on a piece of land, and land cover changes indicate the type of changes on the surface of the Earth (Lillesand & Kiefer,1994). With an increase in population and an increase in human settlements, urbanization, and industrialization, and the change in all categories of land use, have led to tremendous changes in the landscape. (Rawat et al., 1996). Sri Jayewardenepura, the country's administrative capital, represents fast urbanization, reflecting larger regional tendencies. Over the previous decades, the city has undergone remarkable changes from natural landscapes to urban sprawl (Subasinghe et al., 2021). GIS and remote sensing are commonly used to map and analyze impervious surfaces to understand urban expansion and vegetation patterns (Lu & Weng, 2006). The main question of this research is how spatial and temporal patterns of land use and land cover (LULC) change in Sri Jayewardenepura Kotte from 1989 to 2024, and it aims to identify the changes and to map and analyze the LULC changes in Sri Jayewardenepura Kotte from 1989 to 2024, including GIS-based methods. Even though there are some studies focusing on Colombo and other parts of the Western Province, there are a few comprehensive analyses of Sri Jayewardenepura using modern geospatial indices such as NDVI (Normalized Difference Vegetation Index), NDBI (Normalized Difference Built-Up Index), and NDWI (Normalized Difference Water Index). This research gap highlights the key necessity for a detailed spatial and temporal analysis that is related to the region's specific dynamics. This research will explore a scientific basis for government programmes such as the Megapolis development project to plan for long-term urban growth and to get an idea for long term vegetation cover and the water bodies in the Sri Jayewardenepura area. It will also serve as a resource for academics and investors interested in urban ecology, geospatial technology, and sustainable development approaches.

2. LITERATURE REVIEW

Land Use and Land Cover (LULC) changes are widely recognized as one of the most urgent environmental challenges, driven by both natural and human activities. Such transformations alter the radiation budget of biodiversity, water resources, and greenhouse gas emissions, thereby affecting the local weather system and the biosphere (Hamud et al., 2019; Gidado et al., 2018). Studies have consistently shown that LULC change is inevitable, but careful monitoring through geospatial techniques can enable governments, institutions, and environmental managers to use resources more sustainably (Gidado et al., 2018).

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Urban development has been a major driver of land cover changes, which have had a significant impact on ecosystem functioning. Research has shown that these transformations directly affect land surface temperatures and vegetation indices as land use patterns change. Agricultural projects have been a major cause of deforestation, and urban development has also led to increased surface temperatures (Olorunfemi et al., 2018; Duan et al., 2025). Geospatial tools and remote sensing indicators, including the Normalized Difference Vegetation Index (NDVI) and the Normalized Difference Building Index (NDBI), are particularly important for examining urban sustainability and environmental degradation. They have also become crucial for assessing such dynamics (Subasinghe et al., 2021). The use of these methods emphasizes the urgent need for sustainable planning to balance development with environmental conservation (Duan et al., 2025).

The impact of rapid urbanization is also more evident in Sri Lanka. For example, the Galle Municipal Council area has recorded a 42.3% increase in uncultivated surface area between 1996 and 2022, while its green cover has decreased by 22.5%. This is a clear indication of the intensified Urban Heat Island (UHI) effect and increasing environmental risks (Wijesinghe et al., 2024). The Colombo district also witnessed similar transformations, where environmental criticism increased from 1997 to 2008 and decreased slightly between 2008 and 2017, a period associated with government urban planning efforts. To capture these dynamics, studies can use multi-geographic indicators such as NDVI, NDBI, Land Surface Temperature (LST), and Environmental Criticality Index (ECI) (Subasinghe et al., 2021).

Population pressure, particularly residential, commercial, and forest conversions, has been identified as a major factor in shaping land use changes (Seevarethnam et al., 2018). These demographic pressures are often reflected in the reduction of urban green spaces. For example, green cover in central Colombo decreased from 14,288km^2 (73% of the total area) in 2013 to 9,096km^2 (48%) by 2023. Both the central and peripheral regions have been experiencing losses (Jayasinghe & Hemakumara, 2025). Recent studies using Sentinel-2 satellite imagery further demonstrate the value of geospatial analysis in identifying LULC changes. This is particularly important for managing land resources in environmentally sensitive areas such as the lower reaches of river basins (Rathnayake et al., 2024).

3. Methodology and Methods

This study employed a quantitative research methodology to investigate changes in vegetation cover, built-up areas, and water bodies.

3.1. Study Area

This study was based on the Sri Jayewardenepura Kotte Divisional Secretariat Division in the Colombo District of Sri Lanka. Due to rapid urbanization and environmental concerns, this area has undergone significant LULC changes over the years. This DSD area covers 20 GNDs, which are urbanized and

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suburbanized areas. It has become an ideal study area for studying and analyzing urbanization trends, vegetation cover patterns, and water bodies distribution in the period of 1989-2024. The period 1989-2024 was chosen to capture long-term changes in land use and urbanization, allowing analysis of trends over 35 years and based on the availability of Landsat imagery.

3.2 Data Collection Methods

This study primarily used secondary data, including satellite images from the United States Geological Survey Database (USGS). This study mainly focused on specific chosen years, including 1989, 1997, 2007, 2017, and 2024 NDVI, NDBI, and NDWI maps. The Landsat images used included Landsat 5 for the years 1989, 1997, and 2007, Landsat 8 for the year 2017, and Landsat 9 for the year 2024. All images were collection-2-level-2 surface reflectance products with a spatial resolution of 30 m and were atmospherically corrected. The demographic data were primarily obtained from the Department of Census and Statistics, Sri Lanka, based on the chosen years of the study. The datasets include total population, density, and urban growth, which were integrated into the spatial analysis to examine the relationship between demographic changes and land use patterns. Also, urban development plans from government records, research articles, and literature reviews were referred to.

3.3 Image Processing and Geospatial Analysis

The geospatial analysis and data processing were basically performed using QGIS 3.36 software. NDVI (Normalized Difference Vegetation Index), NDWI (Normalized Difference Water Index), and NDBI (Normalized Difference Built-Up Index) were calculated using respective Landsat images for the years 1989, 1997, 2007, 2017, and 2024. The following equations were used to calculate NDVI, NDBI, and NDWI.

Table 1: Spectral Index Equations (NDVI, NDBI, and NDWI) Used in the Study

Name	Equation	Average Range
NDVI	Landsat 5, NDVI = (Band 4 – Band 3) / (Band 4 + Band3) Landsat 8-9, NDVI = (Band 5 – Band 4) / (Band 5 + Band 4)	Max: 0 (non - vegetated areas) Min: 0.86 (Dense vegetation)
NDBI	Landsat 5, NDBI = (Band 5 - Band 4) / (Band 5 + Band 4) Landsat 8 ,9, NDBI= (Band 6 – 5) / (Band 6+ Band 5)	Max:0.38(high /medium dense area) Min: -1(low/non-build up zones/water bodies)
NDWI	Landsat 5, NDWI = (NIR – SWIR) / (NIR + SWIR) Landsat 8,9, NDWI (Band 3- 5) / (Band3 + Band 5)	Max: 0 or close to 0 (Water bodies) Min: - 0.87 (non - water surface)

The Raster calculator tool in QGIS was used to compute these indices for each time period. The processed raster was classified and converted into thematic maps to visualize the spatial distribution of vegetation, built-up areas, and water surfaces.

3.4 Data Analysis and Visualization

For data analysis, statistical values and index values of NDVI, NDBI, and NDWI were calculated in QGIS using the zonal statistics tool for each year. These values were exported to Microsoft Excel for further analysis and visualization. Bar charts were created based on the mean values of the indices to visualize the changes and temporal trends of vegetation, built–up areas, and water surfaces over time.

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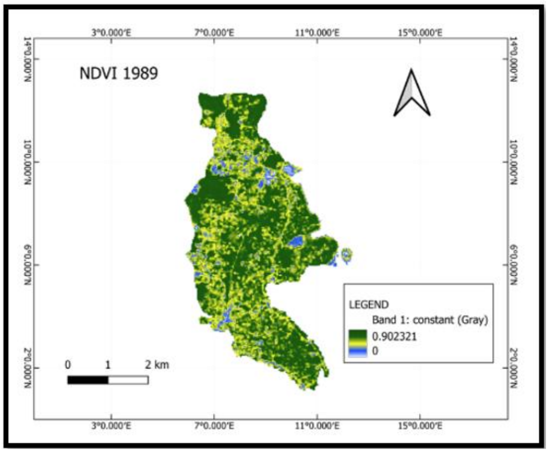
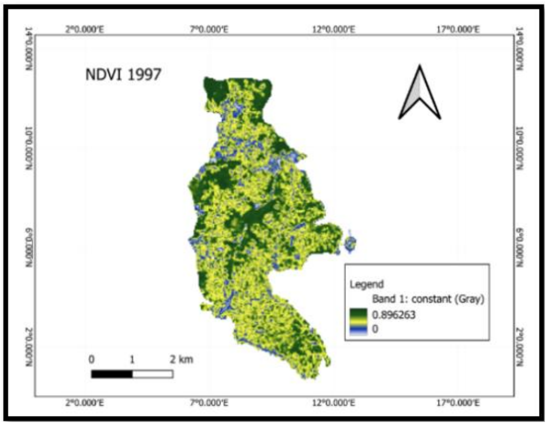
4. RESULTS AND DISCUSSION

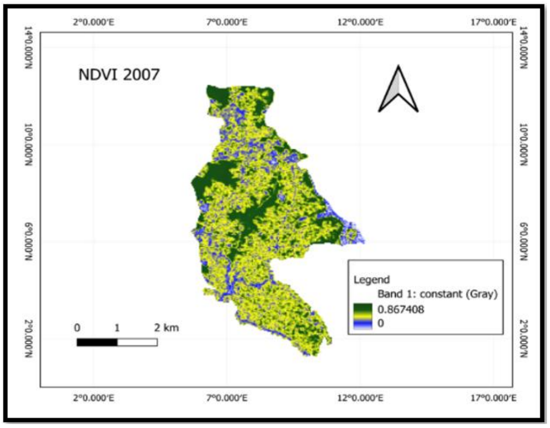
4.1. Pattern and the Distribution of the Vegetation Cover

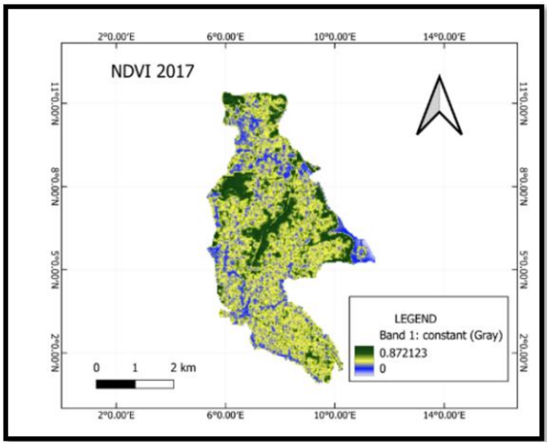
The analysis of NDVI (Normalized Difference Vegetation Index) maps for Sri Jayewardenepura Kotte from 1989, 1997, 2007, 2017, and 2024 reveals significant temporal and regional fluctuations in plant cover (Figure 1).

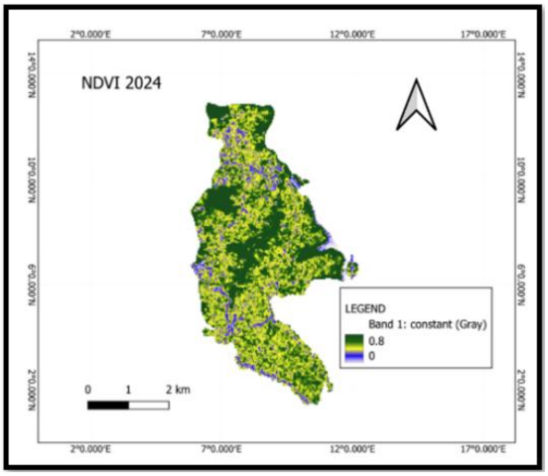
Figure 02: NDVI Distribution Maps of the Study Area from 1989 to 2024











In 1989, the NDVI maps show that areas such as Diyawanna Oya, Kolonnawa wetlands, Thalangama wetlands, urban suburbs, and their surrounding areas had more green cover

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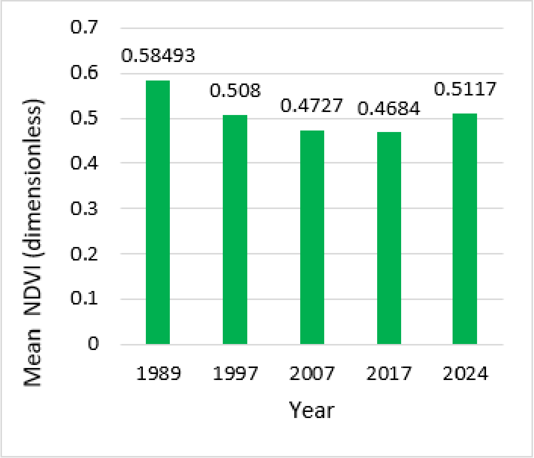
and vegetation cover. Most of the vegetation is natural, with significant areas covered by wetland forests and agricultural lands. Although most of this area has vegetation cover, it also shows areas with limited development without vegetation cover. By 1994, this situation had changed, and the vegetation cover had decreased due to the development of urban infrastructure in Sri Jayewardenepura Kotte and its surrounding areas. While natural ecosystems in areas such as the Thalangam swamps, Kolonnawa wetlands, and the surrounding areas have remained, the other areas the green cover have gradually declined due to urban renewal in areas such as the Pelawatta and Rajagiriya. By 2007, it can be seen that the intensity of urbanization in the central urban areas during these periods had decreased compared to before. This has been led by the development of commercial and residential facilities. But the surrounding areas of Thalangama wetlands and Kolonnawa wetlands show dense vegetation, and the areas around Diyawanna Oya. Some efforts have been made to apply various ways to recover the declining green cover by 2017, with signs that this plan would be implemented between 2017 and 2024. In that instance, throughout time, the development of Diyatha Uyana, the improvement of Diyasaru Uyana, the Baddagana wetlands, the Kibulawala wetlands, the planting of trees on both sides of the road, and the presentation of urban greening concepts show an increase in the NDVI values of urban green spaces over that time period. There is a widespread increase, especially in areas such as Pitakotte, Ethulkotte, Thalawathugoda, Pelawatta, and Nawala, which are associated with urbanization.

Figure 03: Temporal Variation of Mean NDVI Values in the Study Area from 1989 to 2025



The graph shows trends in vegetation density and cover by displaying the mean NDVI values for Sri Jayawardenepura Kotte from 1989 to 2024. These values reveal a significant long-term decline in vegetation health between 1989 and 2017 due to environmental or land use stress, such as deforestation and urbanization. However, the period from 2017-2024 highlights a recovery period of vegetation health, which increased by 0.4684 to 0.5117, indicating successful conservation efforts.

4.2. Expansion of Built - Up Areas

Low or non-built-up zones, which are primarily made up of open spaces, marshes, or vegetation, are shown on the maps as blue regions, which indicate (-1) NDBI value. The medium-to high-density built-up regions, which indicate residential and commercial developments, are represented by the yellow to orange areas, which indicates (0.38) NDBI value.

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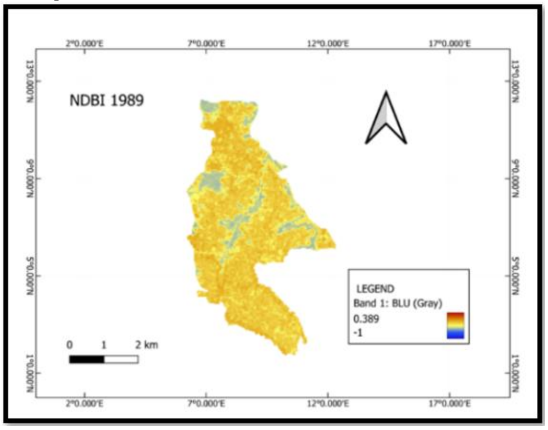
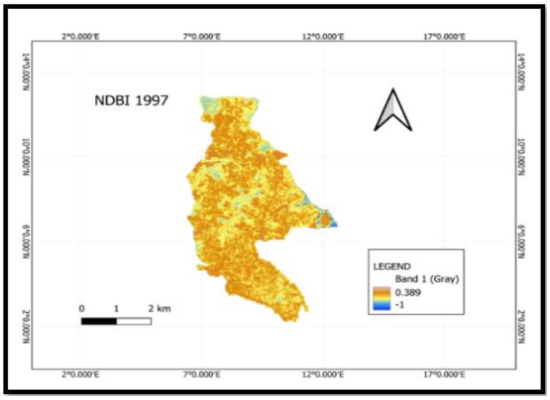
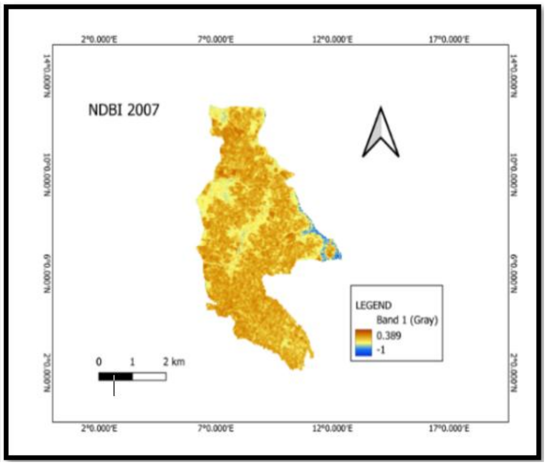
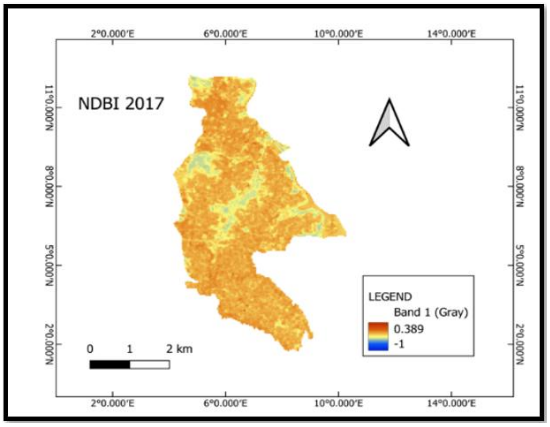
According to the 1989 NDBI maps, Kotte and other surrounding areas show low human population and sparse construction activities. These areas show low levels of urbanization and underdeveloped infrastructure. The number of built-up areas was limited, and construction was concentrated around areas such as Rajagiriya and Ethulkotte. The parliamentary complex, small-scale residential and commercial development zones, in Nawala and Ethulkotte areas, which were already built during this period, are notable for their low-density housing and limited infrastructure.

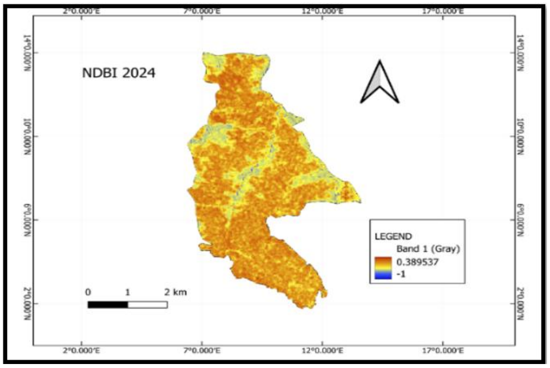
Figure 04: NDBI Distribution Maps of the Study Area from 1989 to 2024











By 1997, the areas showed increased slope values, indicating the development of residential areas and infrastructure facilities. The development of government administrative buildings, the implementation of urban development plans, and the widening

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of roads contribute to increasing urbanization in these regions. Furthermore, the development of middle-income housing in the Rajagiriya, Kotte, Nawala, and Koswatta areas is causing the NDBI value to increase.

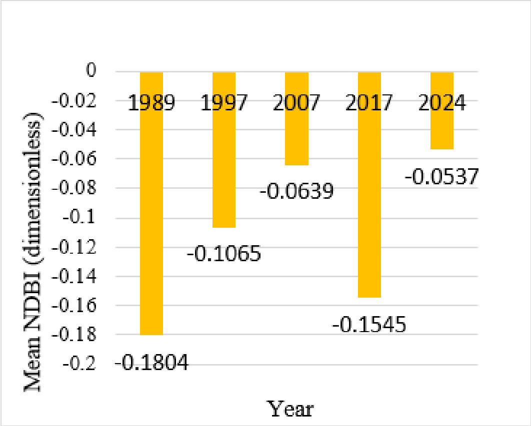
By 2007, densely built-up areas covering the surrounding areas, such as Thalawathugoda, Pelawatta, and Rajagiriya, were showing the intensity of urban growth. The expansion of residential areas, particularly in Thalangama South, the emergence of mixed-use, commercial, and residential centers in the areas around Koswatta, and the establishment of major government offices in the Kotte area and projects like the Thalawathugoda Hokandara Housing complex and Pelawatha housing projects have contributed to the urban influence of the area.

In 2017, during this period, especially in the Nawala, Rajagiriya, and Pelawatte areas, higher NDBI values are shown. However, the development of beautification projects, the concepts of urban greening and development of urban parks (Diyatha Uyana) and wetlands lowered the NDBI value by 2017 as hard surfaces were placed by water and vegetation.

By 2024, rapid urbanization has been demonstrated, especially the rapid emergence of residential settlements, the development of economic and urban infrastructure facilities, and the increase in demand for urban facilities, which have led to rapid urbanization and construction.

The mean values of Sri Jayewardenepura according to the Normalized Difference Built-up Index (NDBI) for chosen years between 1989 and 2024 are displayed in the bar chart. The pattern shows a progressive decline of negative NDBI values over time, indicating urbanization and an increase in built-up area. The lowest NDBI mean value, at -0.1804, was recorded in 1989, indicating low urbanization. This value steadily rose to 0.0639 by 2007. But between 2007 and 2017 temporally decreased. The least negative figure of -0.0537 in 2024 indicates a notable amount of urban development at that time. This steadily increasing trend shows how quickly the region's land use is changing from non-urban to built-up areas.

Figure 5: Temporal Variation of Mean NDBI Values in the Study Area from 1989 to 2025



4.3. Distribution of Water Bodies

According to the geospatial analysis of 1989, 1997, 2007, 2017, and 2024 NDWI (Normalized Difference Water Index) maps, it reveals both decreases and increases in Sri Jayawardenepura Kotte water bodies across the study period. Changes in surface water extent over time and space are represented by the NDWI values, which are produced from satellite photography. Water bodies are represented by positive values (0 or close to 0),

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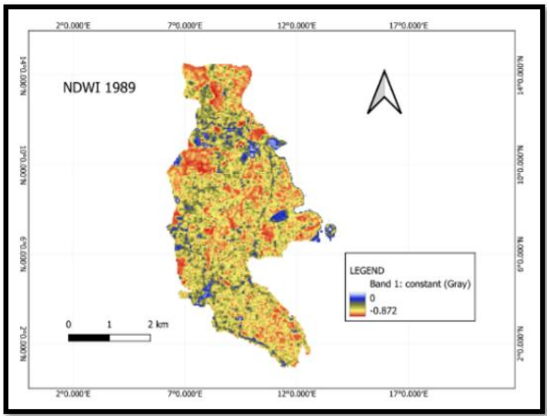
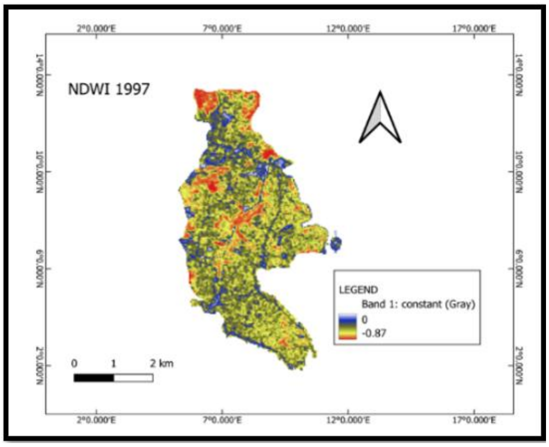
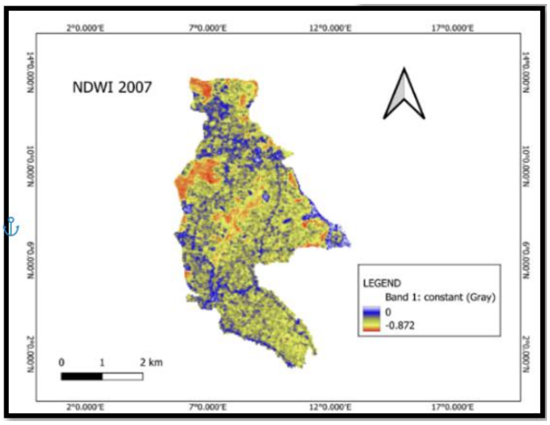
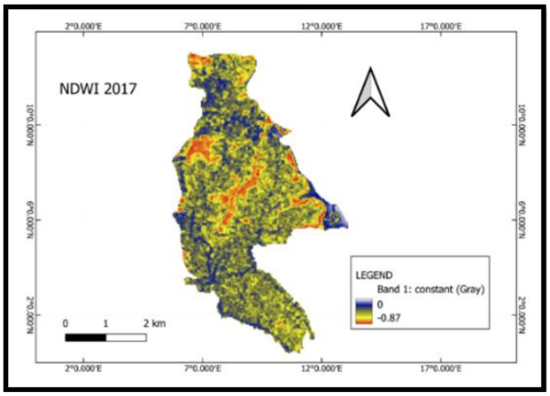
while non-water surfaces, including bare soil, vegetation, and urbanized land, are represented by negative values (-1).

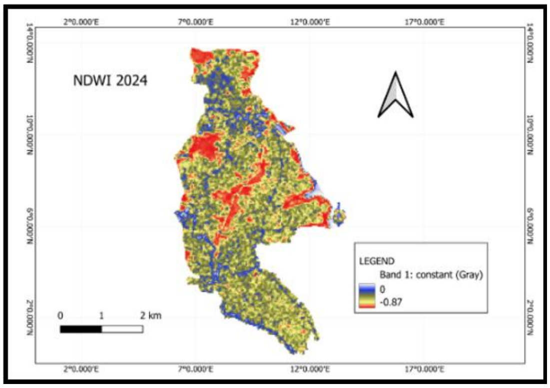
Figure 06: NDWI Distribution Maps of the Study Area from 1989 to 2024











In 1989, water sources included natural primary water sources such as Diyawanna Oya, Kolonnawa Marshes areas, Parliament Lake area, and Thalangama wetlands, shown in the blue zones on the map, and then represent relatively more wetlands and vegetation. Accordingly, there is an ecological balance in those regions. There has been a slight decrease in the size of the waterbodies and surrounding water bodies since 1997. Also, by 2007, there had been an increase in water sources around the Diyawanna Oya, Kolonnawa wetlands, and Thalangama wetlands due to the effects of water conservation for urban demand, wetland restoration, and urban water feature construction. There is a greater spread of water sources in 2017. This will lead to higher NDWI values in the areas where the water is

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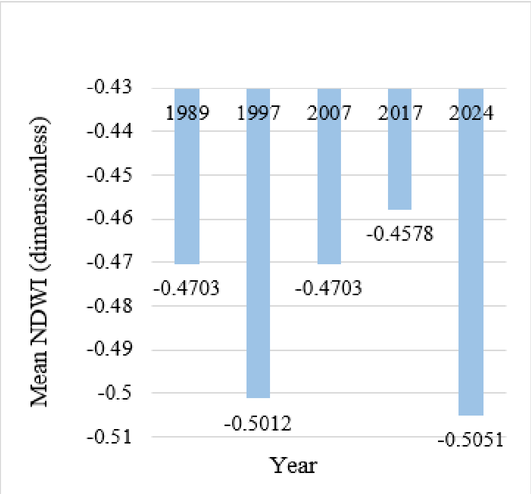
flowing. The water-based infrastructure development programs implemented surrounding Diyawanna Oya, such as Diyatha Uyana, Beddagana, Kolonnawa Wetland Restoration, Water Set Hotel, and other urban planning around the hotel, construction of man-made ponds, and other aquatic water sources for urban beautification projects reflect an increase in water sources in the area over time. But from 2017 to 2024, there was an identified decrease in water bodies in these areas. Especially because of the rapid urbanization, human activities (In order to make space for infrastructural development and urban growth, wetlands and small bodies of water are frequently filled in), poor environmental management, and agricultural expansion have been influenced.

Figure 07: Temporal Variation of Mean NDWI Values in the Study Area from 1989 to 2025



The classification of NDWI states that places with higher moisture content or water bodies are indicated by values near zero, whereas areas with built-up and non-water body areas are represented by negative values further from zero. Although the mean NDWI values have remained negative over time, there has been a tendency toward values getting closer to zero until 2017 (-0.4578), which may indicate that there are more bodies of water or better moisture availability in some places. By 2024, though, the mean NDWI is once more significantly more negative at -0.5051, suggesting that there may be fewer water bodies or a drop in moisture content due to increased land-use pressure.

5. Conclusion

In conclusion, the Sri Jayewardenepura Kotte LULC change research reveals a complex interplay between urbanization, water body dynamics, and vegetation stability throughout time, as well as modest fluctuations produced by green initiatives. NDVI indicates stable vegetation density over many years, with minor fluctuations due to sustainable urban planning and green infrastructure. Since 2017, the implementation of sustainable urban policies has resulted in significant increases in tree cover over the years. There is an increase in built-up areas, as indicated by the shift in NDBI values from -0.1804 in 1989 to -0.0537 in 2024. Between 1989 and 2007, urbanization patterns were horizontally expanded, which was fueled by infrastructural development and population increase. But starting in 2017, urbanization started to level off, with a move toward vertical expansion and densification in the suburban areas and urban core. The NDWI values during this time period reflect the decline in surface water availability. Although the NDWI values have remained negative over time, there has been a tendency toward values getting closer to zero until 2017, which may

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indicate that there are more bodies of water or better moisture availability in some places. By 2024, though, the mean NDWI is once more negative, suggesting that there may be fewer water bodies or a drop in moisture content. As mentioned above, there are differences in the LULC in Sri Jayewardenepura Kotte, and it has mainly influenced by several reasons, including rapid urbanization, poor water management, green space environmental changes, increasing demand for necessities in urban areas, climate change, and population growth.

6. Recommendations

Improving and empowering green urban planning programmes: To further increase green cover in urban areas, the development and construction of green parks, increasing green cover on rooftops, creating community gardens, reducing urban heat island effects, and further increasing green cover by planting vegetation and plants on both sides of the roads can influence increasing the green cover.

Implementing water management programs: Especially after 2017, a low-end value was shown, indicating the need for water management. Therefore, it is important to implement water management systems. For this, it is important to implement water management programs to collect rainwater, recharge groundwater, restore natural water sources, and maintain them properly.

Introducing sustainable public policies and implementing public awareness and community participation programs: Here, it is possible to show the public the importance of a sustainable green environment and the importance of water management, also the importance of the engagement of people coming together and working to improve and manage the green space environment and water resources.

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