TEMPORAL ANALYSIS OF URBAN EXPANSION AND ENVIRONMENTAL IMPACT IN DARWIN, NT, AUSTRALIA USING LANDSAT 8 IMAGERY WITH GIS AND REMOTE SENSING TECHNIQUES.

Contents

Abstract

Globalization is a common observation in the modern world, however, the rate of urban sprawl is considerably high in regions such as Darwin, NT, Australia. This has led to rapid development mainly due to unorganized growth, a higher rate of immigration, and population growth. This growth brings about other effects on land use and land cover, making these changes core in policies formulated for exploiting natural resources and assessing environmental changes. In Darwin, urbanization has effectively shrunk the agricultural land base and water reserve largely and has given rise to several environmental problems including, a reduction in air quality, increased rates of runoff and flooding, a rise in localized temperature, and worsening water quality.

Thus, geospatial technologies and remote sensing methodologies are widely used for monitoring and identifying the changes in land use. This research focuses on detecting land use change for the year 2016-2023 in Darwin using Landsat 8 imagery. Since GIS and remote sensing methods are used in the study, the findings of this research thus show the dynamics of urban growth and its effects on the environment and can benefit any planning agency and or organization planning for the sustainable development of the region.

Introduction

Consequently, understanding land use and land cover change processes, which is one of the major causes of the global environment change, forms a core actuality of sustainable development conversation. Many researchers have examined the land use/land cover change from different dimensions in an attempt to understand the drivers of change, the chronology of change, and effects of change. Concerning the occupation of new land, the extension of built-up regions, and especially the conversion of rural land for residential and commercial purposes especially in the metropolitan periphery is regarded as a symbol of regional economic advancement.

More than ever before, the rates of change of the land use and cover predominantly in the developing world are defined by factors such as; sizable urban sprawl, land desertification, or converting agricultural land for shrimp farming at the kingpin of environmental costs (Sankhala and Singh, 2014). These do not only affect the local and regional environments through which they diffuse, but they also affect the global environment. Land cover changes as a result of human activities have implications for the global carbon cycle and thus result in man-solution-atmospheric CO_2 enhancement (Alves & Skole, 1996). Such changes should be closely observed to establish their effects on the terrestrial ecosystems, as well as in planning for the sound utilization of land resources (Muttitanon & Tripathi, 2005).

Growth monitoring entails identifying as well as quantitatively characterizing alterations in the properties of land cover as well as land use with the application of multi-temporal images acquired at different time instances. The assumption that one can make on the use of remote sensing data when used in change detection is that these will be changes that cannot be attributed to normal fluctuations. Many scholars have endeavored to find adequate techniques for discerning land cover and land-use changes in different landscapes (Shalaby & Tateishi, 2007). Usually, this comprises the processing of two registered, aerial, or satellite multi-spectral images of similar geography captured at different times to detect alterations (Radke et al., 2005).

Satellite remote sensing is an effective tool for examining land-use change at coarse, medium, or high resolution, and it is relatively cheaper in comparison to other methods (El-Raey et al., 1995). Remote sensing data is rather important because of its possibilities to provide a synoptic view of a large area, to repeat its coverage many times, and to collect data in real-time.

Satellite data in digital format allows computation of various LC/LU categories which is a crucial part of supporting networking for the maintenance of data necessary in the study of urbanization and land use change (Mukherjee, 1987). A geographic information system is a decision support system that is useful in helping in the process of urban planning. Integration of GIS modeling is common in studies on urban sprawl consequences to inform on the impacts on the natural environment. GIS is one other method of uncovering spatial patterns of urban sprawl since distances of the developed new urban growth from the town center and roads can be easily calculated, (Gar-On Yeh & Xia, 2001).

This research aims to derive a land use/land cover map of Darwin, the capital city of the Northern Territory in Australia. Over the past decades, urban population growth has been recorded as very rapid in Darwin, especially in built-up regions. This research will also compare the changes in vegetation cover due to urbanization over various periods thus advancing the knowledge of the progression of urbanization and its impacts on the vegetation cover.

Data and Methodology

This study focuses on monitoring urban growth and land use change detection in Darwin, NT, Australia, using GIS and remote sensing techniques. The required satellite imagery for the study was obtained from the USGS Earth Explorer, and all data processing and analysis were conducted in ArcGIS Pro.

3.1. Data Collection

Landsat 8 satellite imagery for the study area was downloaded from the USGS Earth Explorer. Images were selected based on cloud cover criteria (less than %) for two periods: 2016-2019 and 2020-2023. These periods were chosen to capture recent urban growth and land use changes, providing a comprehensive temporal framework for the analysis.

3.2. Image Preprocessing

Preprocessing involved several crucial steps to ensure data quality:

Geometric Correction
This step aligned the images with known ground control points to ensure spatial accuracy, correcting any distortions caused by sensor movement or terrain variations.

Atmospheric Correction
Digital numbers were converted to top-of-atmosphere reflectance values to correct for atmospheric effects, ensuring that the data was comparable across different times and conditions.

Cloud Masking
Cloud masks were applied using the QA bands provided with Landsat 8 imagery to exclude cloud-covered pixels, thus improving the reliability of the analysis by focusing only on clear-sky observations.

3.3. Study Area Delineation

The boundaries of Darwin were delineated using administrative data from the Northern Territory Government Spatial Data Repository. This provided a precise and accurate geographic extent for the study, ensuring that the analysis focused exclusively on Darwin's relevant urban and peri-urban areas while excluding irrelevant surrounding regions.

3.4. Projection and Spatial Referencing

All datasets were reprojected to the UTM Zone 52S coordinate system, which is well-suited for the geographic location of Darwin. This projection minimizes distortion, particularly over small to medium-sized study areas, and ensures that spatial measurements and analyses are accurate and reliable.

3.5. NDVI Calculation

The Normalized Difference Vegetation Index (NDVI) was calculated for each epoch using the formula: NDVI = (NIR - Red) / (NIR + Red). For Landsat 8, the NIR (Near Infrared) band is band 5, and the Red band is band 4. NDVI is a key indicator of vegetation health and was used to assess changes over time. Higher NDVI values indicate healthier vegetation, providing a clear measure of vegetation dynamics in response to urban growth.

3.6. Epoch Analysis

Median composites were created for the periods 2016-2019 and 2020-2023. This process involved calculating the median value of each pixel across all images within each period, reducing the impact of outliers and temporary changes, and providing a more robust representation of typical land cover conditions during each epoch.

3.7. Classification of Images

The images were classified using a combination of supervised classification methods and Support Vector Machine (SVM) algorithms.

Supervised Classification

The maximum likelihood algorithm was used to classify the images based on training sets provided by field knowledge. This method involved selecting representative samples of each land cover type to guide the classification process, ensuring a more accurate and reliable categorization of the land cover.

Support Vector Machine (SVM)

Following the initial supervised classification, the SVM classifier in ArcGIS Pro was applied to refine the results. SVM is a robust machine learning algorithm that effectively handles the complexity and variability of land cover data, enhancing the accuracy of the final classification.

3.8. Land Use and Land Cover Mapping

The classified images were used to generate detailed land use/land cover maps. These maps depicted the distribution of different land cover types, such as agricultural land, built-up areas, barren land, and water bodies. This step was crucial for understanding the spatial extent and distribution of various land cover classes and their changes over time.

3.9. Change Detection Analysis

Change detection analysis was performed by comparing NDVI values and classified land cover maps between the two epochs. Raster algebra was used to calculate differences in NDVI, highlighting areas of significant change. This analysis provided insights into the dynamics of urban growth and its impact on vegetation and land cover.

3.10. Spatial Join and Attribute Data

Spatial joins were conducted to integrate different data layers and attribute information. This included joining land cover data with administrative boundaries and other relevant datasets and enhancing the analysis by providing contextual information such as population density, infrastructure development, and land use policies.

3.11. Mapping and Visualization

The processed data and results were visualized using thematic maps in ArcGIS Pro. These maps included standard cartographic elements such as legends, scale bars, and north arrows to ensure clarity and usability. Thematic maps effectively communicated the spatial distribution and temporal changes in land cover, aiding in the interpretation of the results.

3.12. Validation and Accuracy Assessment

The accuracy of the classification and change detection results was validated using ground truth data and high-resolution imagery where available. This step involved comparing the classified results with known land cover types observed on the ground, ensuring the reliability of the findings. This validation process provided confidence in the results and demonstrated the robustness of the methodology.

Results

4.1 Land use land cover images

Figures 1, 2, and 3 present the images acquired during pre-processing and supervised classification, which depict the land cover and land use of the study area. The land use pattern of the research area is revealed by these photos. The urban built-up area is represented by the color red, the agricultural area by the color yellow, and the deciduous forest by the color light green. On the other hand, the light brown hue depicts the arid region, the blue color depicts the water bodies, and the dark green color portrays an evergreen forest.

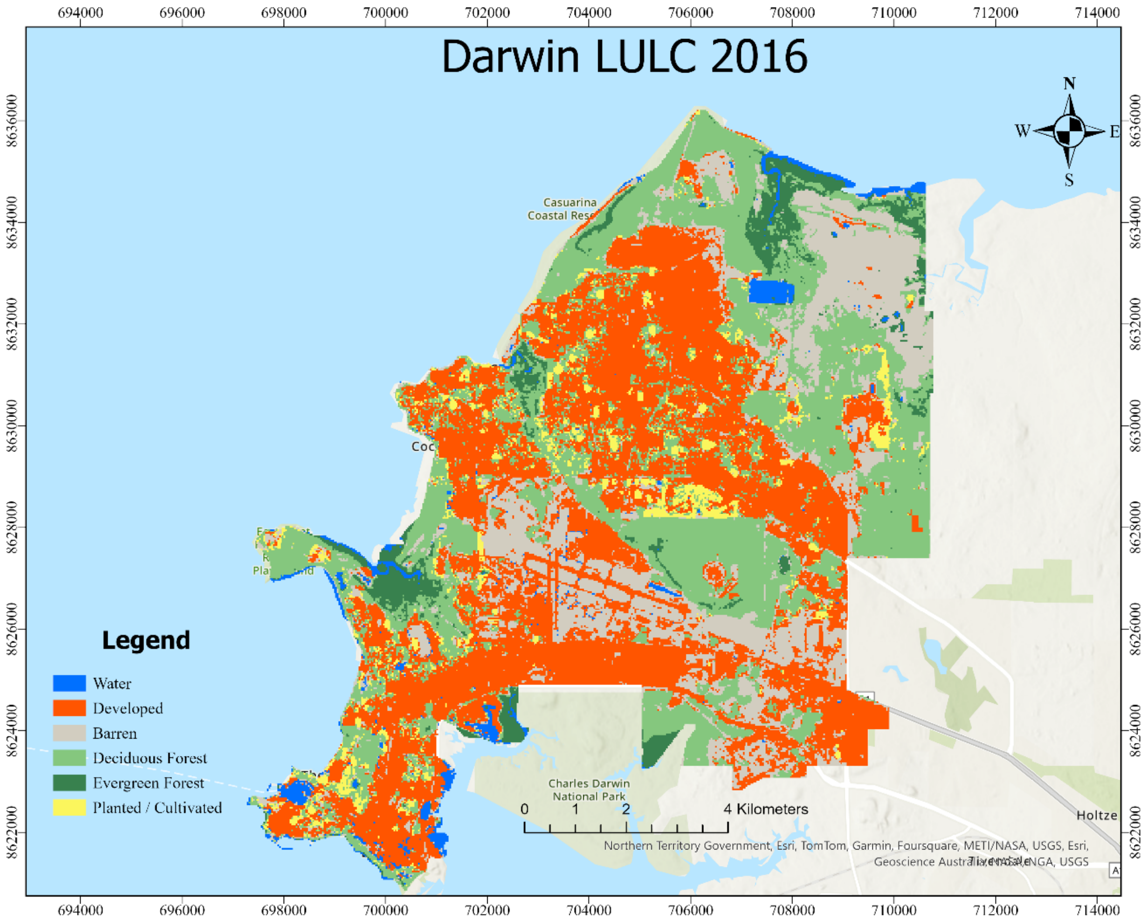

Figure 1: LULC 2016

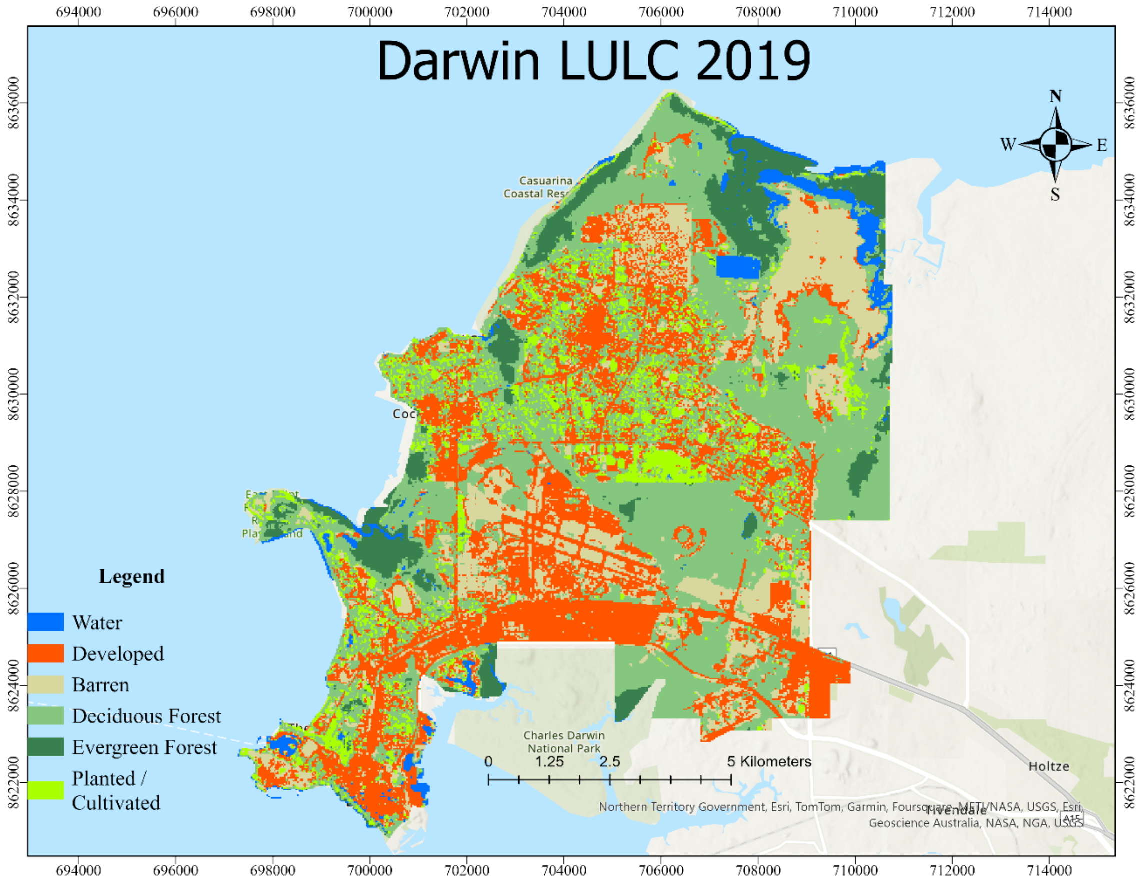

Figure 2: LULC 2019

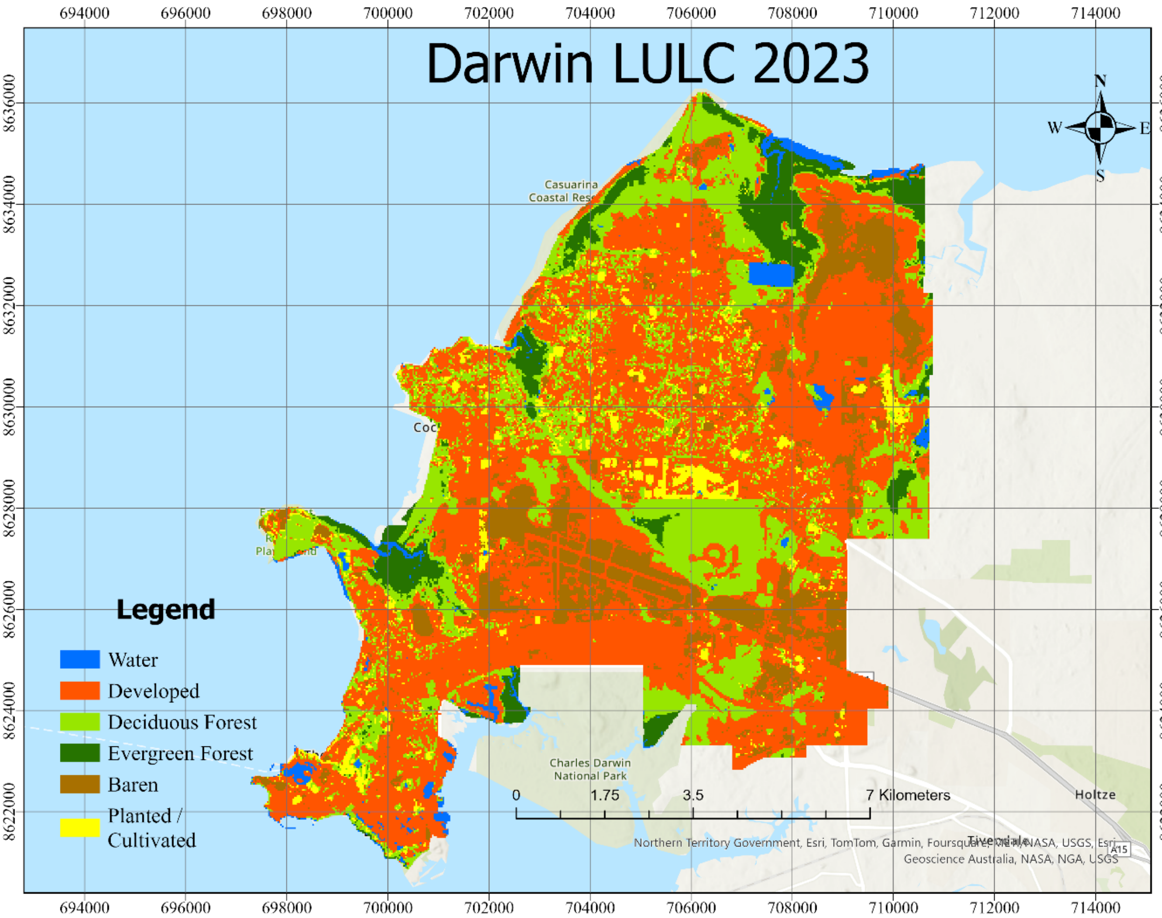

Figure 3: LULC 2023

4.2 Normalized Difference Vegetation Index (NDVI)

The NDVI analysis for Darwin, NT, Australia, from 2016 to 2023 reveals significant changes in vegetation cover. During the 2016-2019 epoch, NDVI values ranged from 0.688847 to 0.0856771 in 2016 and from 0.651439 to 0.108518 in 2019. These values indicate a diverse range of vegetation health across the study area, with higher NDVI values suggesting regions of dense, healthy vegetation, primarily in less urbanized outskirts. Conversely, lower NDVI values highlight areas with sparse or degraded vegetation, typically found in more urbanized zones.

In the 2020-2023 epoch, NDVI values ranged from 0.603256 to -0.00559047 in 2023, showing a noticeable decline in vegetation health. The maximum NDVI value in 2023 (0.603256) is lower than in previous years, indicating a reduction in areas with dense vegetation. The minimum NDVI value dropping to slightly negative values (-0.00559047) suggests an increase in non-vegetated surfaces, such as built-up areas or bare soil, reflecting significant urbanization. This decline in vegetation cover corresponds with the rapid urban growth and unorganized development activities in Darwin.

These results underscore the critical need for sustainable urban planning and land management strategies in Darwin. The observed decline in vegetation health due to urban expansion highlights the importance of preserving existing green spaces and implementing environmentally friendly construction practices. Sustainable development measures, such as integrating green infrastructure and promoting urban forestry, can help mitigate the adverse effects of urbanization on vegetation health. Continuous monitoring of NDVI trends is essential for informed decision-making and ensuring the sustainable growth of Darwin while maintaining environmental quality.

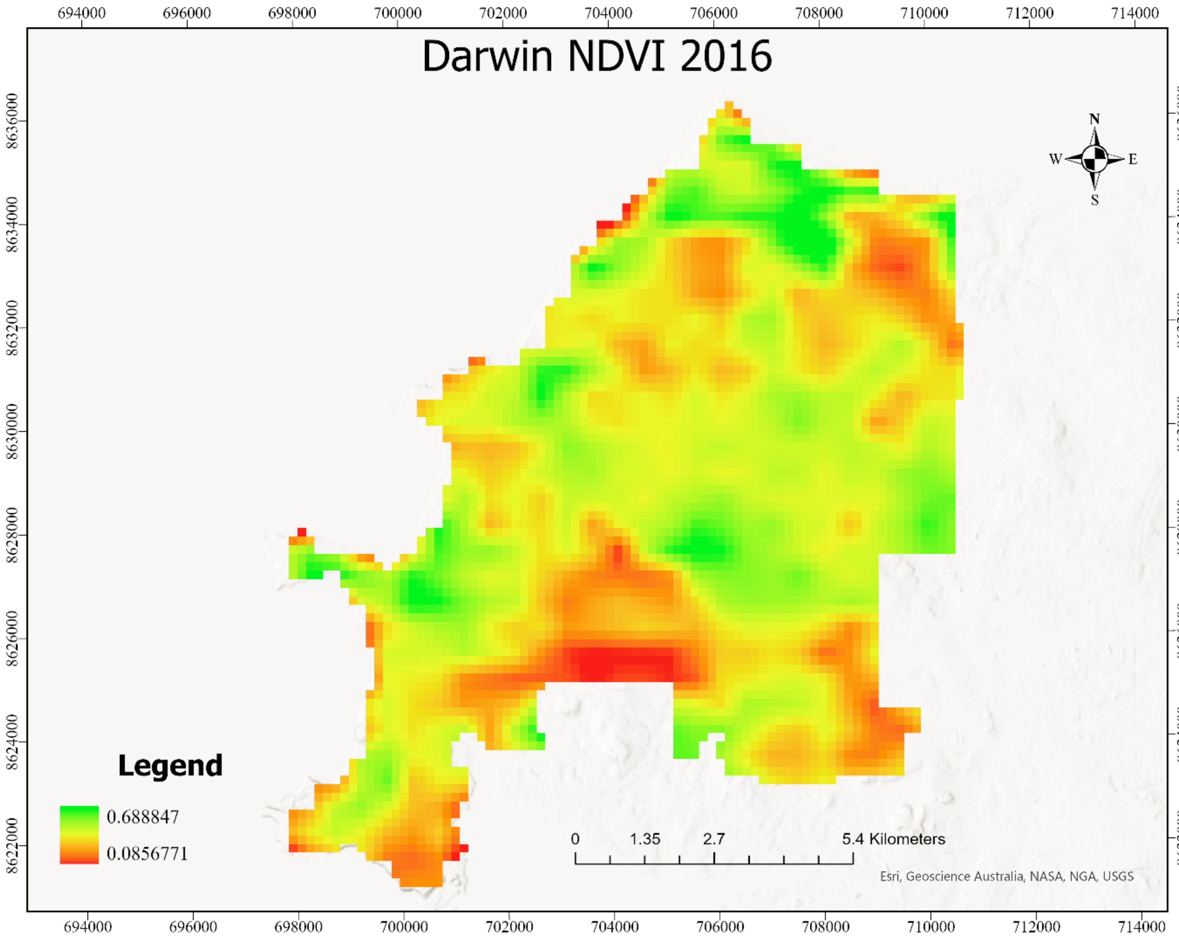

Figure 4: NDVI 2016

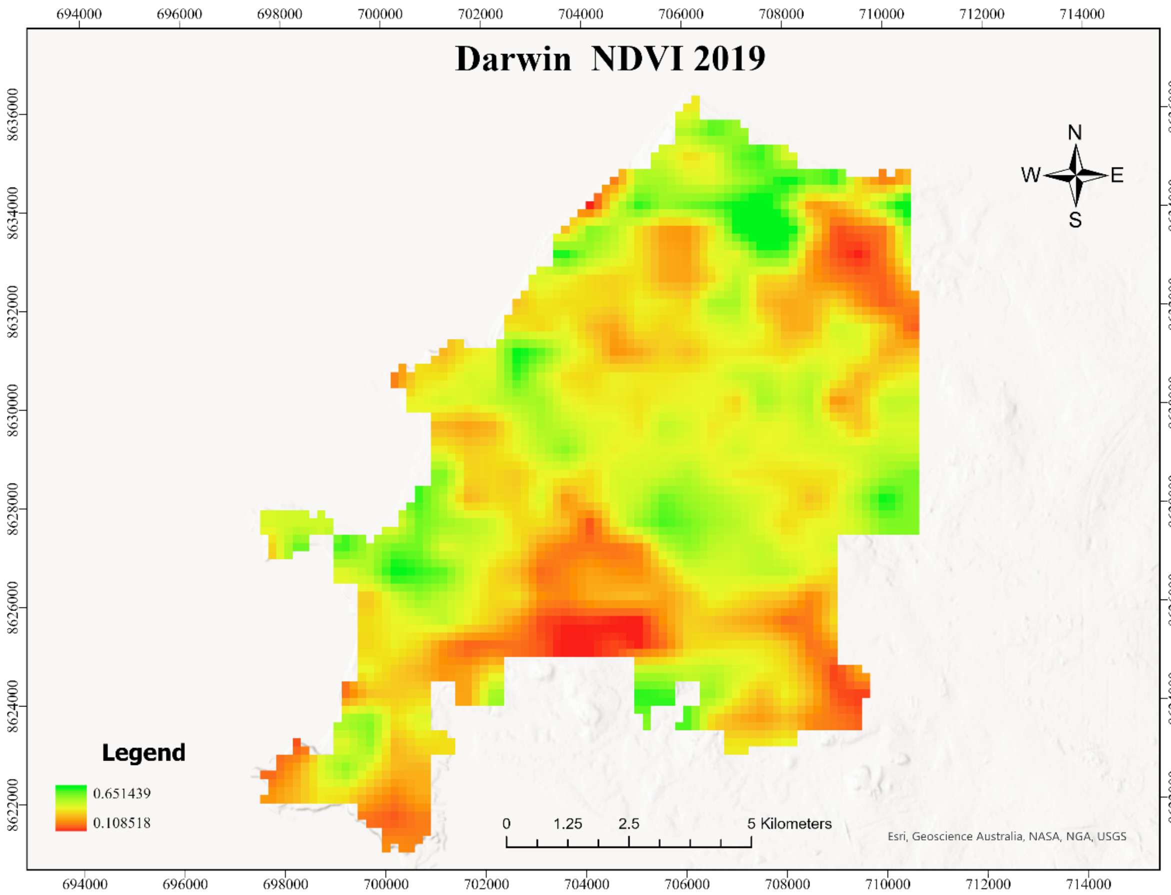

Figure 5: NDVI 2019

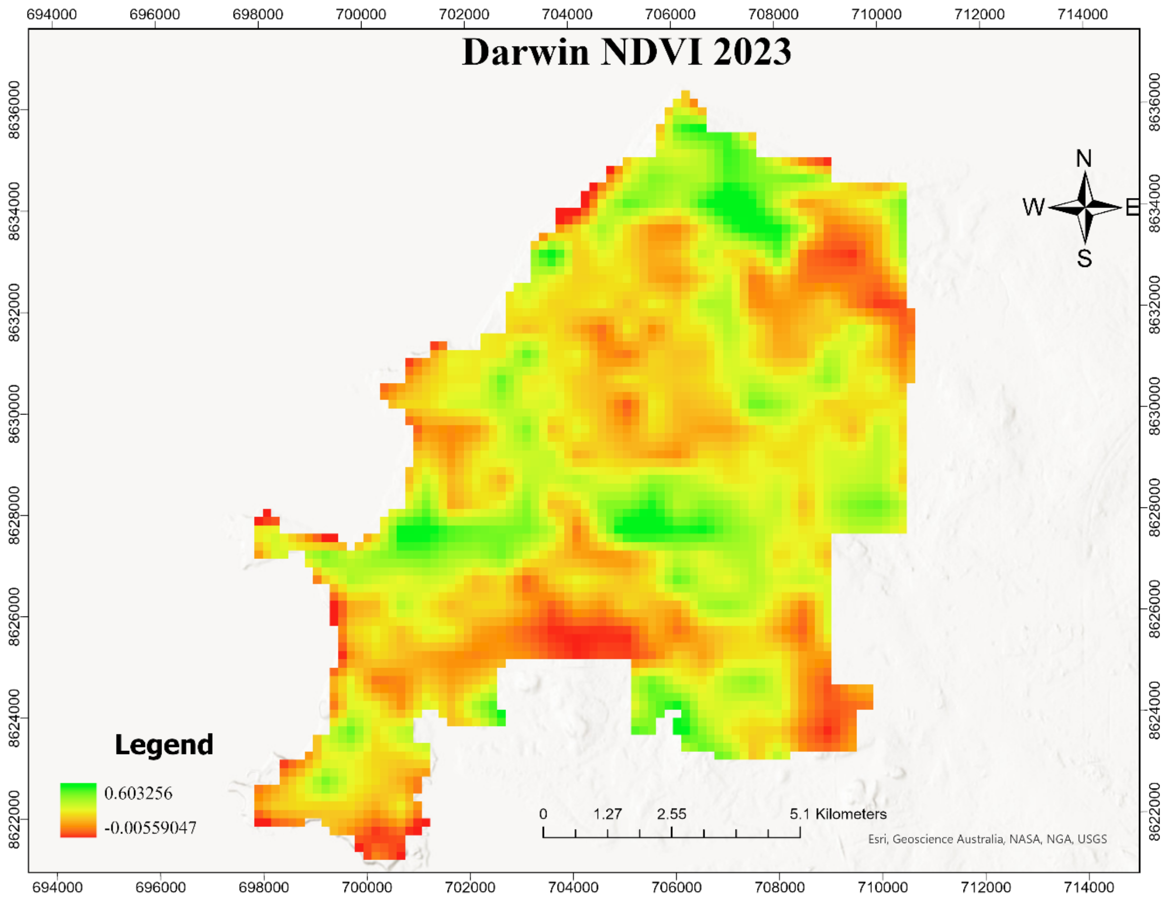

Figure 6: NDVI 2023

Conclusion

This study has utilized Landsat 8 satellite imagery and advanced GIS techniques to monitor urban growth and assess land use and land cover changes in Darwin, NT, Australia, over the periods 2016-2019 and 2020-2023. The NDVI analysis revealed a significant decline in vegetation health, with the maximum NDVI values decreasing from 0.688847 in 2016 to 0.603256 in 2023. This trend highlights the ongoing urban expansion and its detrimental impact on local vegetation.

The results underscore the urgent need for sustainable urban planning and land management practices to mitigate the adverse effects of rapid urbanization. The increase in non-vegetated surfaces and the corresponding decline in vegetation cover call for strategies that incorporate green infrastructure, conservation of existing natural areas, and environmentally friendly urban development practices.

Continuous monitoring of land use changes using remote sensing and GIS technologies is crucial for providing the data needed to make informed decisions. These insights can guide policymakers, urban planners, and environmental managers in developing and implementing policies that balance urban growth with environmental sustainability, ensuring the long-term ecological health and livability of Darwin.

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