Mapping the Extent of Land Degradation in East Baton Rouge Parish

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Abstract

Land degradation poses a significant threat to the sustainability of ecosystems and agricultural productivity, particularly in regions undergoing rapid urbanization. In East Baton Rouge Parish, the pressures of urban expansion and shifting land use patterns have intensified the degradation of natural landscapes. This study examines land degradation in East Baton Rouge Parish, Louisiana, over a 30-year period, with a specific focus on the impact of urban expansion on vegetation health. Using remote sensing techniques, including the Normalized Difference Vegetation Index (NDVI) and the Soil-Adjusted Vegetation Index (SAVI), this research quantifies the extent and spatial distribution of land degradation, highlighting shifts in land use and land cover. Results show a -13.62% decrease in closed forest areas, primarily attributed to urban expansion, alongside a 3.47% increase in built-up areas. This transition has led to increased impervious surfaces, which exacerbate soil erosion, reduce biodiversity, and raise flood risks due to altered hydrological patterns. The 9.88% increase in open forest suggests partial vegetation regrowth or thinning of dense forest, though it does not fully counterbalance the ecological losses from closed forest reduction. These findings emphasize the need for targeted restoration efforts, such as reforestation and green infrastructure, to mitigate further degradation. This study offers critical insights for policymakers and environmental planners aiming to mitigate land degradation and promote the long-term sustainability of East Baton Rouge Parish's ecosystems.

1.0 Introduction

Land degradation is a growing environmental issue that undermines the biological and economic productivity of ecosystems around the globe. It is characterized by a decline in land health due to various factors, including soil erosion, deforestation, urbanization, and unsustainable farming practices (AbdelRahman, 2023). Currently, degradation impacts roughly 24% of the world's land area (Sutton et al., 2016). The consequences of this process are significant, affecting ecosystem resilience, biodiversity, water quality, and food security, and thus impacting both human and ecological communities (Pacheco et al., 2018). Urbanization-related land degradation poses distinct challenges, as it transforms natural landscapes into urban areas, increasing impermeable surfaces, disrupting water cycles, and diminishing vegetation cover, which can lead to heightened soil erosion and loss of habitats (Ferreira et al., 2018).

The problem of land degradation is most prominent in developing countries in Asia and Africa, where rapid population growth, unsustainable agricultural practices, and lack of effective land management have resulted in severe land degradation (Ewunetu et al., 2021; Oduniyi & Tekana, 2021). In India, for example, about 105.48 million hectares of land are affected by various forms of degradation (Singh et al., 2023). Similarly, in Africa, land degradation is a major threat in many regions, including the rapidly urbanizing coastal cities (Abebaw, 2019; Aniagboso & Iwuchukwu, 2013). In West Africa, degradation processes have led to the loss of arable land and biodiversity, with severe consequences for local communities (Fredua, 2014).

While land degradation is a global issue, regions undergoing rapid urbanization, such as East Baton Rouge Parish in Louisiana, are particularly vulnerable to its impacts. Known for its diverse ecosystems, which include wetlands, forests, and agricultural landscapes, the parish faces increasing pressures due to population growth, infrastructure development, and commercial expansion (Couvillion et al., 2011). The expansion of urban areas has led to increased land use and significant strain on natural resources, diminishing vegetation health throughout much of the parish. This reduction in green spaces and the fragmentation of habitats contribute to environmental problems, such as soil erosion, increased water runoff, and a decrease in biodiversity (Reed & Wilson, 2004). In ecologically vulnerable areas like East Baton Rouge Parish, where wetlands are vital for flood control, water filtration, and providing habitats, these issues are especially alarming.

While existing research on land degradation frequently concentrates on rural and agricultural settings (Cheng et al., 2022; Abebaw, 2019; Xiao et al., 2018), the degradation of urban-adjacent ecosystems has not been extensively explored. These areas, where urban development meets natural landscapes, face unique pressures from mixed land use, pollution, and urban expansion, which can intensify ecological degradation. By focusing on East Baton Rouge Parish, an area where urban growth is increasingly affecting surrounding natural landscapes, this study maps the extent of land degradation in the past 30 years to identify areas in need of immediate intervention.

Numerous studies on land degradation rely on short-term data, which hinders the ability to discern prolonged degradation trends, especially those affected by incremental climate change and consistent urban expansion (Huang & Kong, 2016; Arroyo-Ortega et al., 2022). Through the analysis of land cover and vegetation health data, this study offers a longitudinal evaluation. The prolonged duration of the study facilitates the identification of enduring trends and variations in land health, providing essential insights for debates on sustainable urban development and environmental sustainability.

This study employs remote sensing techniques to map and quantify land degradation across East Baton Rouge Parish over a 30-year period. By analyzing vegetation indices such as the Normalized Difference Vegetation Index (NDVI) and the Soil-Adjusted Vegetation Index (SAVI) (Montfort et al., 2020; Shoshany et al., 2013; Ewunetu et al., 2021), this research seeks to provide a comprehensive overview of land degradation patterns, highlighting areas that have experienced significant declines in vegetation health. Through spatial analysis, the study aims to identify degradation hotspots and explore the link between land use changes and ecological degradation. The findings are intended to inform policy and guide sustainable urban planning, emphasizing the need for interventions to restore degraded areas and promote the resilience of East Baton Rouge Parish's ecosystems.

2.0 Study Area Description

East Baton Rouge Parish, located in the southeastern part of Louisiana, spans approximately 470 square miles and includes both urban and rural landscapes. As the home of Baton Rouge, Louisiana's state capital and its second-largest city, East Baton Rouge Parish is a region characterized by a mix of residential, commercial, industrial, and natural areas. The parish is bounded by the Mississippi River on its western side, which not only shapes its geography but also contributes significantly to the area's ecological and economic dynamics.

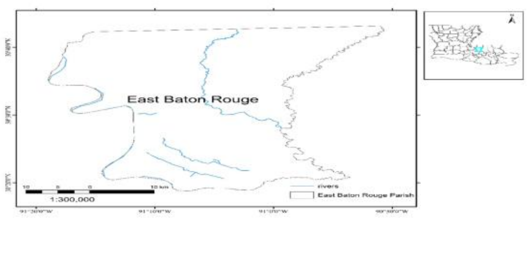

Fig 1. Map of East Baton Rouge Parish

2.1 Demographics and Urban Growth

East Baton Rouge Parish is home to over 440,000 residents, reflecting steady population growth driven by urban expansion and economic development. The parish's largest city, Baton Rouge, is a significant urban center, featuring a densely developed infrastructure network that includes residential neighborhoods, industrial zones, and commercial districts. This growth has led to an increased demand for land, resulting in the conversion of natural landscapes into built-up areas, especially in the central and southern parts of the parish. This urban expansion has had profound implications for local ecosystems, with land use pressures encroaching on previously forested and agricultural lands.

2.2 Ecological Importance

The parish hosts diverse ecosystems, including wetlands, forests, and agricultural lands, which play critical roles in maintaining biodiversity, regulating water cycles, and supporting agricultural productivity. Wetlands within the parish act as natural buffers, helping to absorb floodwaters from the Mississippi River and reducing the risk of flooding in adjacent urban areas. Additionally, forested areas contribute to air and water purification, carbon sequestration, and provide habitats for a variety of wildlife species. However, the rapid pace of urbanization poses a threat to these ecosystems, as the replacement of natural landscapes with impervious surfaces disrupts natural processes, leading to increased surface runoff, reduced groundwater recharge, and habitat loss.

2.3 Climate and Environmental Challenges

East Baton Rouge Parish has a humid subtropical climate, with hot, humid summers and mild winters. This climate supports diverse vegetation but also heightens the region's vulnerability to soil erosion and land degradation, especially when natural vegetation is removed. Heavy rainfall events, common in this climate, can intensify soil erosion in areas where vegetation has been cleared for development, further stressing the land. Additionally, the region faces the environmental challenges of air and water pollution, particularly due to industrial activities along the Mississippi River and the increase in impervious surfaces associated with urban expansion.

2.4 Relevance of Study Area for Land Degradation Analysis

East Baton Rouge Parish serves as an important case study for understanding the impacts of urban-induced land degradation in a rapidly growing urban environment surrounded by ecologically sensitive areas. The transformation of land cover types due to urban expansion and population growth offers an opportunity to analyze how land degradation manifests in an urban-adjacent ecosystem. By focusing on East Baton Rouge Parish, this study aims to provide insights into the specific challenges and dynamics of land degradation in regions where urban pressures intersect with valuable natural landscapes, contributing to sustainable urban planning and land management.

3.0 Methodology

This study employed a dual-method approach, using the Soil-Adjusted Vegetation Index (SAVI) and Normalized Difference Vegetation Index (NDVI) derived from Landsat satellite imagery to identify and map potential degraded lands in East Baton Rouge Parish. The methodology consists of several stages, from data acquisition to the identification of potential degraded areas.

3.1 Data Acquisition and Preprocessing

3.1.1 Satellite Imagery Selection:

Landsat 5 and Landsat 9 Level 1 satellite images were selected for this study due to their extensive temporal coverage and reliable spectral resolution for vegetation analysis. Landsat 5 images cover the earlier years of the study period (1994), while Landsat 9 provides recent data (2024), ensuring consistency in observations over time.

3.1.2 Image Preprocessing:

The raw satellite images were preprocessed to ensure data quality and comparability. Preprocessing steps included radiometric and atmospheric corrections to remove noise and enhance image clarity. The images were then georeferenced to align accurately with ground coordinates, ensuring spatial accuracy in the analysis. This preprocessing ensures that variations in vegetation indices reflect actual changes in land cover and not artifacts from atmospheric interference or sensor discrepancies.

3.2 Vegetation Indices Calculation

3.2.1 Normalized Difference Vegetation Index (NDVI):

The Normalized Difference Vegetation Index (NDVI) was calculated to measure vegetation health and density across the study area. NDVI uses the following formula:

$$NDVI = \frac{(NIR-Red)}{(NIR+Red)} \quad (1)$$

For Landsat 5, NDVI was computed using Bands 3 (red) and 5 (near-infrared), and for Landsat 9, Bands 4 (red) and 5 (near-infrared) were used. NDVI values range from -1 to +1, with higher values indicating denser vegetation and lower values indicating sparse or non-vegetated areas.

3.2.2 Soil-Adjusted Vegetation Index (SAVI):

The Soil-Adjusted Vegetation Index (SAVI) was used to assess vegetation health, particularly in areas where bare soil may impact vegetation measurements. SAVI is an enhancement over the Normalized Difference Vegetation Index (NDVI) as it includes a correction factor, *L*, to account for soil brightness. This adjustment factor helps reduce the influence of exposed soil in regions with sparse vegetation, providing a more accurate indication of vegetation health.

3.2.3 Calculation of the Soil Adjustment Factor (L)

In this study, the soil adjustment factor *L* was calculated using the following formula:

$$L = \frac{NDVI*2}{1+NDVI} \quad (2)$$

where:

- NDVI is the Normalized Difference Vegetation Index

L adjusts the SAVI calculation based on the NDVI value of each pixel, making it sensitive to vegetation density. In areas with higher NDVI values (indicating dense vegetation), LLL will be smaller, while in areas with lower NDVI values (indicating sparse vegetation or exposed soil), LLL will be larger. This adaptive adjustment helps ensure that SAVI accurately reflects vegetation conditions across varying land cover types.

3.2.4 SAVI Calculation

With *L* calculated for each pixel, the SAVI is then computed as follows:

$$SAVI = \frac{(NIR-Red)}{(NIR+Red+L)} * (1 + L) \quad (3)$$

where:

- NIR represents the near-infrared reflectance band, which is highly reflective in healthy vegetation,
- Red represents the red reflectance band, which is absorbed by chlorophyll in healthy plants, and
- L is the soil adjustment factor, calculated as described above.

3.3 Supervised Classification and LULC Mapping

3.3.1 Supervised Classification Process

A supervised classification algorithm was applied to categorize each pixel within the study area into one of the predefined land cover classes. During this process, a false color composite was used to enhance the spectral separability of different land cover types, improving the algorithm’s ability to distinguish between vegetation, built-up areas, and water bodies. The classification relied on NDVI values derived from the imagery, ensuring that each land cover class was accurately identified.

3.3.2 LULC Map Generation

The Land Use and Land Cover (LULC) map was created based on the results of the supervised classification. This map illustrates the spatial distribution of various land cover types across the study area, providing a visual tool to assess land cover patterns. By comparing LULC maps from different time periods, significant shifts in land cover—such as forest loss or urban expansion—were be identified, highlighting regions likely experiencing land degradation or environmental stress.

3.4 Trend Analysis of SAVI

To assess vegetation health changes over time and identify potential land degradation, a trend analysis of the Soil-

Adjusted Vegetation Index (SAVI) was performed. This trend analysis helps track how SAVI values fluctuate across different time periods, highlighting areas where vegetation may be declining, indicating possible land degradation.

3.4.1 SAVI Trend Calculation

The SAVI trend for the 30-year interval was calculated using the following formula:

$$SAVItrend = \frac{SAVI\ 2024 - SAVI\ 1994}{SAVI\ 1994} \qquad (4)$$

where:

- $SAVI_{2024}$ represents the SAVI value in the most recent time period
- $SAVI_{1994}$ represents the SAVI value from the earlier time period.

This formula provides the relative change in SAVI between two time periods. A negative SAVI trend value indicates a decline in vegetation health, which may suggest degradation, while a positive SAVI trend value suggests an improvement or stability in vegetation cover.

3.4.2 Spatial Mapping of SAVI Trends

The calculated SAVI trend values were spatially mapped to visualize the distribution of vegetation changes across the study area. This spatial analysis helps identify specific regions where degradation is likely occurring, enabling targeted intervention efforts. Areas with a high frequency of negative SAVI trends were highlighted as priority zones for restoration or further investigation.

3.5 Identification of Potential Degraded Lands

The final step involved integrating the results from the SAVI trend analysis and the LULC classification to identify areas of potential land degradation. Regions with a decline in SAVI values, combined with land cover changes indicating reduced vegetation health, were marked as potential degraded lands. These areas are likely impacted by environmental stressors, such as urbanization, soil erosion, and habitat fragmentation.

3.6 Data Analysis and Validation

3.6.1 Statistical Analysis

Descriptive and inferential statistical analyses were performed to validate the findings. The changes in LULC classes and trends in SAVI and NDVI values were statistically analyzed to confirm the significance of the observed patterns. Pearson's correlation was used to assess the relationship between urban expansion (increased built-up areas) and the decline in vegetation indices.

3.6.2 Validation with Ground Truth Data

The classification and identification of degraded lands were validated using ground truth data obtained from high-resolution imagery. This validation step ensured the reliability of the classification and trend analysis results by confirming that identified degraded lands corresponded to actual land degradation observed on the ground.

3.6.3 Interpretation and Mapping of Results

The final results were interpreted and mapped to provide an overview of land degradation patterns in East Baton Rouge Parish. The maps and trend analysis charts were used to visualize the spatial extent of degraded lands, highlight areas most affected by urbanization, and assess the environmental impacts of land cover changes. These maps provide insights into high-priority areas for restoration and support decision-making for sustainable land management.

4.0 Results and Discussion

4.1 Land Use and Land Cover Distribution in 1994

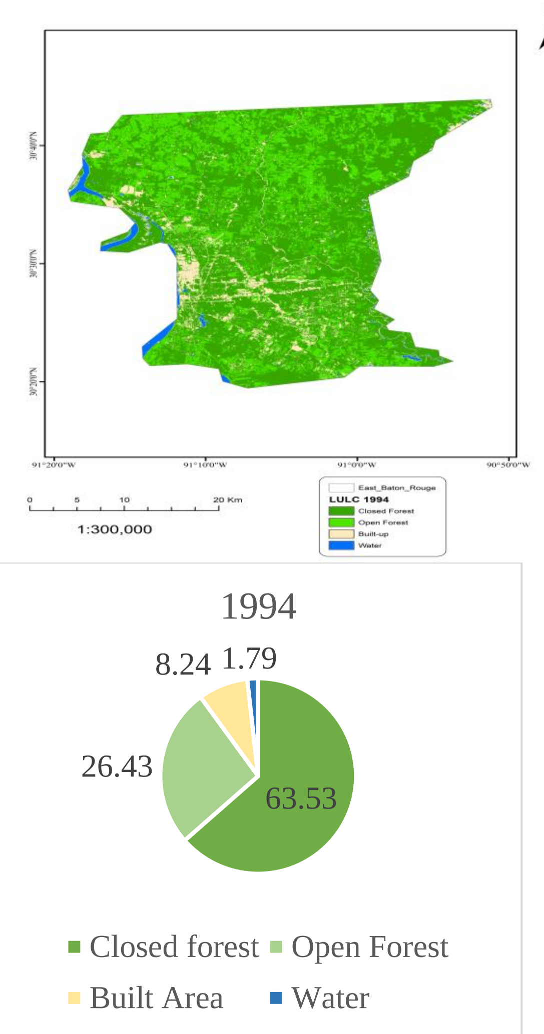

Fig 2. LULC data for EBRP (1994)

The Land Use and Land Cover (LULC) data for East Baton Rouge Parish in 1994 provides quantitative insights into the spatial distribution of various land cover types (see Fig 2)

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Four main land cover types were examined: Closed Forest, Open Forest, Built-up areas, and Water. According to the 1994 LULC map illustrates the spatial arrangement of these land cover types, with closed forest and open forest collectively dominating the landscape. Covering an area of 765,965,700 square meters, closed forest represents 63.53% of the total land area in the parish. This significant proportion highlights the prominence of dense forest cover in 1994, emphasizing its critical role in maintaining the region's ecological stability.

The open forest area extended across 318,650,400 square meters, accounting for 26.43% of the total land area. This category encompasses areas with less dense tree cover, potentially representing transitional or partially disturbed landscapes.

Built-up land, consisting of urban and infrastructure zones, covers 99,335,700 square meters or 8.24% of the total area. This urban footprint indicates the early stages of urban development, concentrated primarily around Baton Rouge.
Water bodies occupy 21,559,500 square meters, making up 1.79% of the parish. These bodies include rivers, lakes, and other water features, which play vital roles in regional hydrology and biodiversity.

4.2 Land Use and Land Cover Distribution in 2024

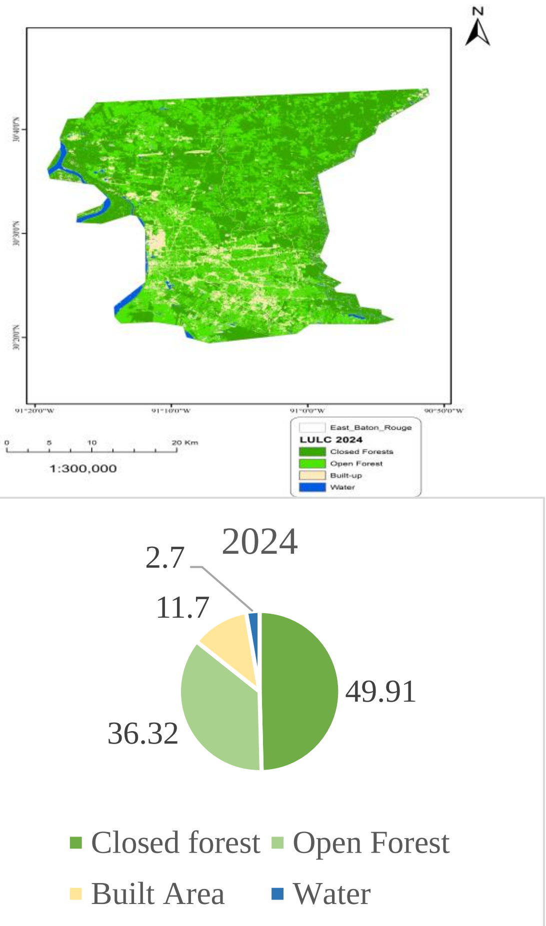

Fig 3. LULC data for EBRP (2024)

The Land Use and Land Cover (LULC) data for East Baton Rouge Parish in 2024 show significant shifts in the distribution of closed forest, open forest, built-up areas, and water bodies over the 30-year period (see Fig 3).

Closed forest areas, which were once the dominant land cover, now occupy 601,755,300 square meters or 49.91% of the total land area. This marks a significant decline from the 63.53% observed in 1994, indicating a progressive loss of dense forest cover over the past 30 years. Open forest areas, in contrast, have increased to 437,788,800 square meters, accounting for 36.32% of the total area. This is an increase from 26.43% in 1994. Urbanization has also significantly influenced the LULC patterns, with built-up areas expanding to 141,068,700 square meters representing 11.7% of the total land area in 2024. Water bodies have seen a slight increase, covering 24,898,500 square meters (2.7%) of the area in 2024, up from 1.79% in 1994.

4.3 Land Cover Changes and Urban Expansion Impacts in East Baton Rouge Parish (1994-2024)

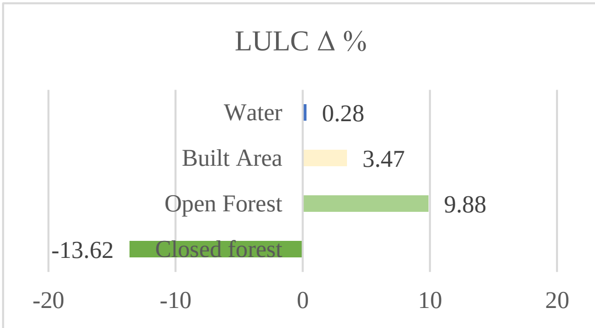

Fig 4. LULC Changes (1994-2024)

Class	Δ in sq. metre
Closed forest	-164210400.00
Open Forest	119138400.00
Built Area	41733000.00
Water	3339000.00

Table 1. LULC changes (1994-2024)

The area covered by closed forest decreased by approximately 164,210,400 square meters, equivalent to a -13.62% change. This reduction indicates a considerable decline in dense forest cover, which was once a dominant land cover type in the parish. The decrease in closed forest can likely be attributed to urban expansion and the conversion of forest land for other uses, including residential, commercial, and infrastructural development. As the most significant loss among all categories, this reduction in closed forest points to a decrease in ecosystem services, such as carbon sequestration, biodiversity support, and soil stabilization, provided by dense forested areas.

Conversely, open forest areas saw an increase of approximately 119,138,400 square meters, representing a

9.88% gain over the study period. This increase may reflect a transition from closed forest to open forest, potentially due to thinning, partial degradation, or selective clearing.

Built-up areas expanded by about 41,733,000 square meters, marking a 3.47% increase from 1994 to 2024. This growth highlights the ongoing urbanization and development in East Baton Rouge Parish, where natural landscapes are increasingly being converted into residential, commercial, and infrastructural zones.

The area covered by water bodies increased modestly by 3,339,000 square meters**,** accounting for a 0.28% change over the period. This small but positive change may be attributed to natural hydrological shifts, coastal erosion or the construction of artificial water features, such as ponds or retention basins, often associated with urban development.

4.4 Potential Degraded Lands

The map (see Fig 5) identifies areas of vegetation health decline through color-coded zones, with negative values indicating a reduction in vegetation cover and positive values suggesting areas of relative stability or minor growth

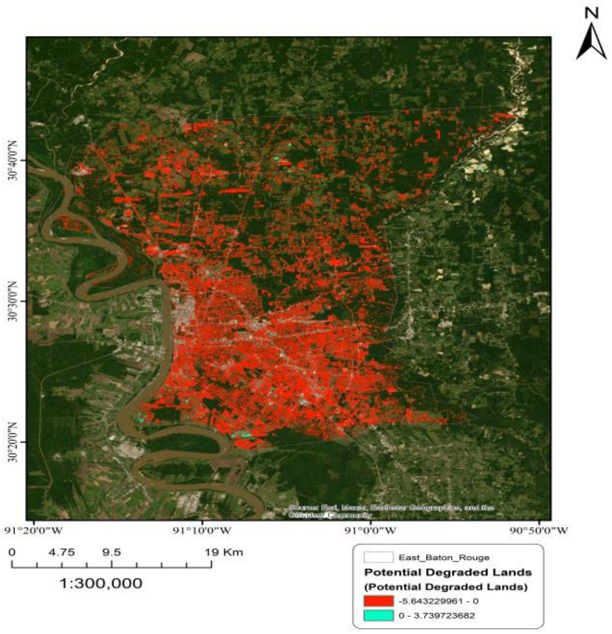

Fig 5. Potential Degraded Lands

The high degradation zones (represented in red) show negative values, reflecting severe declines in vegetation health. The negative figures in these areas indicate a loss of vegetation cover, likely due to urban sprawl and land conversion for infrastructure development. In contrast, the moderately degraded zones (represented in greenish shades) show positive values, reflecting relatively stable or slightly increasing vegetation cover (land degradation neutrality) likely in the form of open spaces, parks, or less densely developed zones. The moderate degradation observed in these zones suggests that ongoing development could lead to further environmental decline if unmanaged.

The distribution pattern of degraded lands across the parish illustrates a clear urbanization gradient, with the most heavily degraded lands concentrated in and around urban centers, while the outer, more rural areas experience less degradation. This pattern suggests that urban expansion is a primary driver of land degradation in East Baton Rouge Parish, transforming densely vegetated areas into fragmented and less resilient landscapes. As urban areas continue to grow, the risk of further degradation expands outward, potentially affecting previously untouched natural habitats in the parish's northern and outer regions.

4.5 Discussion

The decrease in closed forest cover, which experienced a loss of approximately 164,210,400 square meters (equivalent to a -13.62% change), reflects the degradation of dense forest areas due to urban expansion and infrastructure development. Closed forests provide essential ecosystem services, including carbon sequestration, soil stabilization, and biodiversity conservation (Wang et al., 2020). The reduction in closed forest cover thus indicates a potential loss of these services, making the environment more susceptible to erosion, flooding, and habitat fragmentation. This trend aligns with broader urbanization pressures, which replace dense forests with impervious surfaces, leading to disrupted water cycles and increased surface runoff (Ferreira et al., 2018). The observed loss of closed forest is concerning as it emphasizes the diminishing natural resilience of East Baton Rouge Parish in the face of ongoing development.

In contrast, open forest areas showed an increase of 119,138,400 square meters (9.88%), which results from a transition from dense to less dense forest cover due to thinning or partial degradation. While open forests continue to offer some ecological benefits, such as erosion control and habitat provision, they do so at a reduced capacity compared to closed forests (Lupala et al., 2014). This shift from closed to open forest reflects a potential early stage of degradation, where forest density is compromised under the encroachment of development (Lupala et al., 2014). The increase in open forest area could indicate land cover fragmentation, where remaining forested areas are increasingly divided into smaller, isolated patches. This fragmentation reduces habitat connectivity, posing a threat to biodiversity by limiting movement and genetic exchange among species. Such fragmentation may also decrease the forest's resilience to further disturbances, including climate change and urban expansion (Coates, 2018).

The expansion of built-up areas by 41,733,000 square meters (3.47%) is a clear indicator of urban growth, highlighting the transformation of natural landscapes into residential, commercial, and infrastructural zones. This increase in built-up land reflects population growth and economic development within East Baton Rouge Parish, however, urbanization is coupled with environmental challenges. Built-up areas are characterized by impervious surfaces, which prevent water infiltration, increase surface runoff, and elevate the risk of flooding (Birch & Carney, 2019). Also, the expansion of urban areas reduces available green spaces, contributing to the urban heat island effect, which can raise local temperatures and degrade air quality (Filho et al., 2017). The growth in built-up areas emphasizes sustainable urban planning practices to balance development demands with environmental conservation, especially in regions experiencing rapid urbanization.

Water bodies, though they only showed a slight increase of 3,339,000 square meters (0.28%), play a role in supporting the local hydrology and biodiversity of East Baton Rouge Parish. The marginal increase in water coverage could be due to natural hydrological changes or the construction of artificial water features, such as retention ponds, as part of urban development projects (Hunter et al., 2016). Although limited in extent, water bodies are essential for flood mitigation, water purification, and providing habitats for aquatic species.

The degradation map highlights the spatial distribution of degraded lands, with high degradation zones concentrated around urban centers. The negative values in highly urbanized areas indicate a severe reduction in vegetation health, likely driven by urban sprawl, which converts natural landscapes into built-up areas. The implications of these negative values are significant, as they suggest an urgent need for intervention in highly degraded zones to restore vegetation cover and mitigate further loss of ecosystem services (Dallimer et al., 2011). Restoration strategies, such as reforestation and green infrastructure, could help reduce soil erosion, improve air quality, and moderate local temperatures.

In contrast, the positive values in peri-urban and suburban areas suggest moderate degradation, where vegetation cover is still present but under pressure. These areas may serve as buffers between urban and rural zones, providing critical ecosystem functions that support urban resilience (Su et al., 2014). The presence of moderately degraded lands offers an opportunity for conservation and sustainable management to prevent further degradation.

5.0 Conclusion

This study on land degradation in East Baton Rouge Parish highlights the significant impact of urban expansion on natural landscapes over a 30-year period, marked by a notable decrease in closed forest cover, an increase in open forest, and the expansion of built-up areas. These changes have important implications for biodiversity, soil stability, and ecosystem health, highlighting the urgent need for sustainable land management and conservation strategies. However, the findings are subject to several limitations. The reliance on remote sensing data, which may be affected by resolution and atmospheric conditions, introduces potential inaccuracies in land cover assessment. Additionally, while vegetation indices such as NDVI and SAVI effectively capture vegetation health, they do not fully account for more complex ecological interactions like soil health and socio-economic drivers of land use changes.

Despite these limitations, the study provides valuable insights into the evolving landscape dynamics in East Baton Rouge Parish, emphasizing the need for integrated approaches to urban planning that prioritize environmental resilience. Long-term monitoring, ground-truthing, and the inclusion of socio-economic data will be essential for refining these findings and developing effective interventions to mitigate further land degradation and promote sustainable growth. Through a balanced focus on development and conservation, the parish can safeguard its natural resources and ecosystem services for future generations.

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