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Assessment of Vegetation Cover in Santiago City Using Remote Sensing

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Abstract

This study examined the changes in vegetation cover in Santiago City, Philippines from 2003 to 2025 through the use of and remote sensing, demonstrating urbanization impacts on green space and evaluating the capabilities of remote sensing for the assessment and management of urban vegetation. This study revealed an increase in built-up areas due to conversion of agricultural land, suggestive of an urbanization trend, which may have implications for food security and ecological health. An analysis of tree cover loss (2001-2023) presented a non-linear deforestation trajectory, along with considerable increases, which corresponded with rising greenhouse gas emissions, emphasizing the environmental results of land-use change. This research illustrates the vital impact of remote sensing in monitoring of vegetation instabilities and developing platforms to assess ecological impacts of urbanization (e.g., habitat fragmentation or urban heat island effects) and as resources for sustainable urban planning strategies, in order to prioritize environmental integrity and enhance urban ecological strategies.

Keywords: remote sensing, vegetation cover, urbanization, urban planning, urban heat island

1. Introduction

Different forms of vegetation offer various benefits, particularly those that promote ecological health in urban planning and sustainability issues, specifically in the case of Santiago City, Philippines. These well-known characteristics are beneficial in air purification, temperature regulation, and habitat conditions for biodiversity. The assessment of vegetation status and patterns in Santiago City is essential to mitigate the environmental effects, particularly when the city is experiencing rapid urbanization and land-use changes. For such analysis, remote sensing allows for a better and more comprehensive view of vegetation cover (Hernández et al., 2016; Grez & Zaviezo, 2024).

Vegetation cover measures the share of land covered with plants, parks and streets, for instance. It is measured regarding the association between land use and other environmental parameters like temperature and evapotranspiration (Zhang et al., 2022). Remote sensing improves vegetation indexing by processing vast amounts of data and helping to identify spatial relationships. Vegetation indices like normalized difference vegetation index

(NDVI) assess vegetation health from satellite imagery (Sutrisno et al., 2024; Sabathier, 2023; Pons, 2017). Included in this technology is the identification of vegetation loss and planning for the restoration of green space.

Some studies indicate the relationship between plant cover and urban environmental factors, mainly land surface temperature (LST) reduction, mitigating the effects of urban heat islands (UHI) effects (Chang, 2014). This holds for Santiago City, where urban expansion has drooping green spaces. Other essential functions of vegetation perform include stormwater management and flooding control in built-up areas.

The advantages of vegetation cover also extend to socioeconomics. Community gardens, grown from vegetation patches, can contribute to food security and urban biodiversity (Martinuzzi et al., 2018). Combined planning through vegetation mapping can efficiently address urban problems such as air pollution. Urban greenery improves air quality by removing pollutants and lowering harmful gas concentrations, which benefits the residents (Baró et al., 2014; Drillet et al., 2020). Moreover, green spaces foster social interaction and well-being (Moura & Fonseca, 2020).

Despite the acknowledged value of vegetation evaluation, few studies on specific approaches and results exist in the Philippines, especially in urban areas such as Santiago City. Most studies report general ecological impacts or rural conditions while ignoring localized urban vegetation patterns. Therefore, the full potential of remote sensing for urban vegetation appraisal remains underexploited, limiting effective urban green space management.

1.1 Theoretical Framework

This study is rooted in understanding urban ecology and the impact of urbanization on the environment and vegetation covers. Thus, the theoretical foundation of this study is drawn to Urban Principles for Ecological Landscape by Cadenasso & Picket (2008), which imply that the following are the primary ecological principles of cities: 1) Cities are ecosystems; 2) Cities are geographically varied; 3) Cities are dynamic; 4) Natural and human processes interact in cities; and 5) Ecological processes continue to exist and play a significant role in cities.

According to the first central concept, urban areas—or simply "cities"—are ecosystems. This could be a surprise if ecosystems are considered primarily closed, homeostatic, and rigidly self-maintaining systems. In actuality, however, these presumptions are not included in the description of the core ecosystem. An ecosystem is the interplay between a physical and biotic complex inside a study area's boundaries. This is the substance of Tansley's initial concept of the ecosystem from 1935. It is the core that has persisted to inspire current study and application.

Cities are geographically varied states where social structures and processes may be built on top of the biophysical template established by the fundamental structures of surfaces, plants, and buildings. Demographics, ethnicity, and education are examples of social structures. In contrast, wastewater or traffic flows in various infrastructure networks are examples of social processes. Thus, social structures and processes act upon and respond to a biophysical template of surfaces, buildings, and flora. The following two concepts will examine the dynamics and interactions between anthropogenic biophysical components in more detail. One of the most noticeable characteristics of urban ecosystems is the intricacy of the many types of heterogeneity and how they interact.

Cities are dynamic, and there is also a time component to the geographical heterogeneity described above. Changes dynamically influence urban form and morphology in the structures and change inside and between cities and other ecosystems. Numerous factors may influence changes in the constructed structures, vegetation, and surfaces, as well as the process networks and rates. Vegetation succession is one of the causes. The texture of a city's landscape is shaped over time by the tendency of more significant, slower-growing plants to take center stage. Large trees may be planted in private yards and public rights of way in older communities and suburban areas. Large trees are susceptible to death and ageing over extended periods.

Natural and human processes interact in cities, stating that the nature of city structure is outlined by the ideas discussed. The principles have shown the intricacy of the elements of urban ecosystems, their potential spatial patterning, and the existence of coarse and fine-scale dynamics within the many types of patch mosaics present across metropolitan regions. The fourth principle's subject is the interplay between the biophysical and anthropogenic components.

Ecological processes continue to exist and play a significant role in cities; many experts consider cities to be social and engineering constructs where natural processes may be rightfully disregarded. Primarily, scientists have disregarded cities. to compensate for this oversight, a growing amount of urban ecology research concludes that ecological processes are present in the urban patchwork. Urban green areas' abilities to promote biodiversity, lessen temperature extremes, and allow stormwater penetration are now widely acknowledged urban ecological services. Thus, studies have shown that areas with higher vegetation cover tend to experience lower land surface temperatures (LST) and improved air quality, which are critical for urban sustainability.

To sum up, this study is rooted in the theoretical principle of Cadenasso & Picket (2008), stressing the importance of urban vegetation in ecological and human activities. This study emphasized the assessment of vegetation cover to understand better urbanization's effect on temperature, air quality, and overall environmental health. Using remote sensing, this study described and analyzed the vegetation cover in Santiago City, highlighting the vital contribution to urban sustainability despite the urbanization challenges.

1.2 Conceptual Framework

The study utilized the qualitative research design. The schematic diagram below represented the framework of the study.

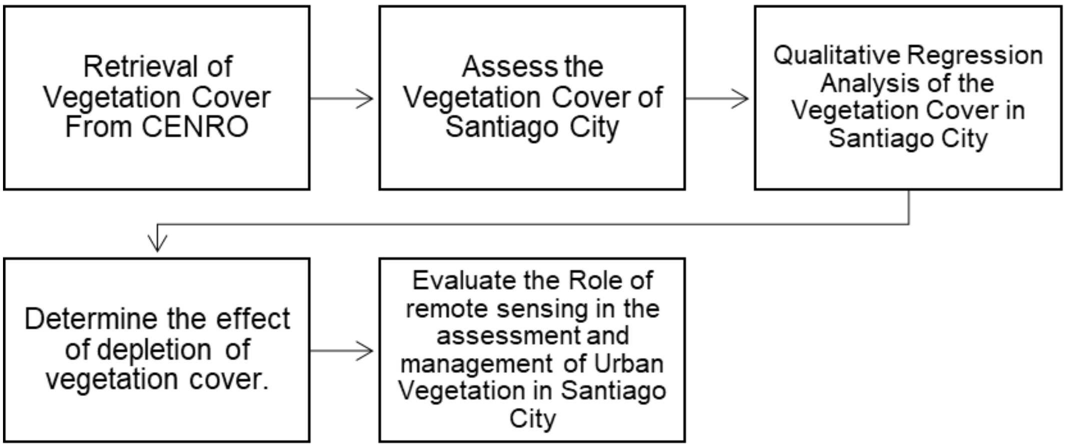


Figure 1. Paradigm of the Study

This study utilized visual representation as the conceptual framework above, which served as a guide in conducting this study. Using remote sensing to assess the vegetation cover in Santiago City is essential for spatial analysis, which helped the researcher visualize and determine the vegetation pattern. The researcher used qualitative regression analysis to assess the changes in vegetation patterns from 2003 to 2020. After analyzing the depletion of the vegetation cover, the researcher determined the effects of urbanization on different factors and evaluated the role of remote sensing.

1.3 Statement of the Problem

This study explored the assessment of vegetation cover in Santiago City through remote sensing technology. Therefore, this study aimed to answer the following questions:

Specifically, this study sought to answer the following questions:

1) How has the vegetation cover condition in Santiago City, changed?
2) What are the effects of urbanization on the depletion of green spaces?
3) How can Remote Sensing help in the assessment and management of urban vegetation in Santiago City?

1.4 Scope and Limitations

This study is limited only to the data provided by the Community Environment and Natural Resources Office through Remote Sensing technologies that was collected in the year 2001-2025, focusing in Santiago City, Philippines 3311. The primary focus of this study is to assess the vegetation cover of Santiago City using Remote Sensing. This will be used to evaluate the change in vegetation cover over time, identify the effect of vegetation cover depletion on ecological health, and determine the role of Remote Sensing in improving the assessment and management of urban vegetation.

2. Review of Related Literature and Studies

This chapter presented various studies that supports, defines, and gives further information on the characteristics, effect and benefit of the assessment of vegetation cover using Remote Sensing.

Santiago City, Philippines, is considered one of the most rapidly growing cities in the Philippines, and many new establishments were built in the previous years. Thus, assessing vegetation cover is essential in promoting ecological health and sustainability. Researchers have revealed that urban vegetation is vital due to its benefits, which include air purification, temperature regulation, and enhancing the quality of life. In the study of Dobbs et al., they highlighted the importance of sustainable urban vegetation management in achieving the sustainable development goals; they claimed that the urban vegetation is sometimes ignored in urban management planning, which led to environmental problems (Dobbs et al., 2017). Food security and biodiversity are the common benefits of urban vegetation, especially in low-income places (Martinuzzi et al., 2018). Thus, integrating vegetation in urban planning can address the identified challenges affecting future generations.

Remote Sensing can help assess the vegetation cover in the desired location. These tools are used to analyze the spatial changes in vegetation over time and how they affect urban ecological health, which is crucial in understanding the changes in urbanization. The development of vegetation indices was used to determine the changes in vegetation covers in metropolitan areas through satellite imaging to demonstrate and monitor the vegetation dynamics (Zhang et al., 2020). In addition, a proposed model to assess urban structural changes illustrates the importance of remote sensing in urban vegetation management (Hernandez et al., 2016). Remote sensing applications are essential to process large datasets to understand vegetation patterns better, which will benefit effective urban planning and management.

The common phenomenon of people experiencing rapid urbanization is the urban heat islands (UHIs); this has been a major problem affecting the people in the community. The UHI are areas with trapped and retained heat, precisely where buildings and establishments are built compared to the natural environment. Using urban vegetation is essential to alleviate the effect of UHIs through planting more trees in urban places. Many researchers claim that the higher the vegetation cover, the lower the land surface temperature (LSTs), which weakens the effect of UHI.

For instance, the study conducted by Peng et al. revealed a substantial negative significance difference between vegetation cover and the UHI effect in major cities, which claimed that the vegetation cover can lessen the heightened temperatures in hours of daylight (Peng et al., 2011). Thus, urban vegetation significantly helps in mitigating the problems in UHI in urbanized places. In the case of Santiago City, the city only established establishments where some planners forgot the importance of vegetation cover to lessen the heat index in the city.

In addition, Wahyudi and Jumadi (2024) highlighted that if vegetation density declines, it directly affects the increase in land surface temperatures, which is the primary factor promoting UHI effects (Wahyudi & Jumadi, 2024). Their research revealed that places with less vegetation cover experience an increase in heat that affects public health, energy consumption, and citizens' general living standards.

These findings highlighted the central significance of maintaining and enhancing urban green space as a sustainable strategy to counterattack the temperature increases accompanying urbanization, produce more habitable cities, and enhance environmental resilience. Greening by investing in green spaces, trees, and parks as part of city planning can cool the city, representing a proven method of resisting the harmful effects of UHIs.

Furthermore, urban green spaces also have significant socio-economic values and environmental benefits; studies have shown that urban green areas encourage social interaction and benefit community well-being. Procházka et al. drew attention to the contribution of green spaces to social organization and urban population quality of life (Procházka et al., 2011). This is especially so in the case of Santiago City, where city planning has to account for environmental and social aspects of green space management. Singh et al. added that integrated planning via vegetation mapping can easily manage urban issues such as air pollution, enhancing public health performance (Singh et al., 2022).

Despite the acknowledged significance of urban vegetation, there is a lack of studies at the localized level targeting individual urban cities such as Santiago City. Most available studies generalized ecological effects without considering individual vegetation patterns and issues in the urban environment. For example, although research by Corbane et al. considered urban greenness in multiple cities, it tends to neglect localized measurements that might underpin specific interventions (Corbane et al., 2018). Such a gap calls for more specific research that applies remote sensing to assess the urban vegetation dynamics of Santiago City.

The effects of urbanization on vegetation cover were far-reaching, as seen from several studies that have reported the reduction of green spaces in urban regions. Fahmi's study of land cover changes in Batu City indicated a general trend in which urbanization results in high decreases in vegetation cover (Fahmi, 2022). This is also reflected in the work of Justo et al., who highlighted the need to quantify urban land cover to determine its effects on climate adaptation (Justo et al., 2022). Loss of vegetation not only impacts ecological balance but also reduces the ability of urban spaces to handle stormwater and reduce flooding, according to various researchers (Martinuzzi et al., 2018; Procházka et al., 2011).

Indeed, evaluating vegetation cover in Santiago City, Philippines, is inevitable in addressing issues ensuring outside urban growth. Combining GIS and remote sensing technology will provide helpful information regarding vegetation dynamics in urban planning and management. Additionally, the socio-economic benefits of urban greenery refer to its contribution to improving community health and the surrounding environment. While the city tackles the challenges of urbanization, focused studies, and localized diagnoses will be instrumental in ensuring optimal utilization of urban green areas.

3. Methods

This chapter focused on the research design, locale of the study, data gathering instruments, data gathering procedure, and statistical treatment of data.

3.1 Research Design

This research utilized a qualitative research design using remote sensing technology to determine vegetation cover in Santiago City, Isabela, Philippines. Integrating satellite image analysis with remote sensing tools, the researcher sought to describe and map changes in vegetation over time. Temporal analysis revealed the impacts of urbanization on green spaces.

3.2 Research Locale

The emphasis here is on Santiago City, where rapid urbanization has brought extreme changes, presenting a good study case for looking at human activities affecting vegetation cover. The city's diversity of urban and rural environments presents a good landscape for studying vegetation dynamics.

3.3 Research Instrument

The researcher used the vegetation cover data from the Community Environment and Natural Resources Office (CENRO) in Santiago City. The researcher wrote a letter to the Officer-In-Charge of the Community Environment and Natural Resources, San Isidro Isabela Mr. Wenceslao R. Catillo. The data provided were treated using remote sensing study and compared through the available online resources, including Geoportal PH and Google Earth. Remote sensing technology such as Google Earth provided advanced spatial analysis and visualization of the processed data to interpret vegetation changes comprehensively. Furthermore, the researcher used data from the Global Forest Watch Organization to assess the effect of urbanization and depletion of vegetation cover.

3.4 Data Gathering Procedure and Analysis

The data collection procedure denoted the main steps involved in this process. The first is the collection of data from the Community Environment and Natural Resources Office (CENRO), Geoportal PH and Global Forest Organization, spanning from 2000-2023 for a complete temporal analysis. Remote sensing technology was used to map and examine vegetation cover distribution in Santiago City, allowing for the compilation of maps and an assessment of the temporal changes. Finally, regression analysis evaluated the relationship between vegetation cover and urbanization indicators such as population density and built-up area. The implications of these findings explored for the urban ecological health margins, with visualization and summaries prepared to report implications for environmental management and urban planning.

Generally, this approach placed forth a specific approach for estimating vegetation cover in Santiago City from remote sensing techniques, with knowledge of urbanization drives on vegetation dynamics.

4. Result and Discussion

This chapter presented the data gathered as analyzed and interpreted in response to the problems raised. They are supported by figures and tables with textual interpretations.

4.1 Changes of Vegetation Cover Condition in Santiago City

Vegetation cover maps indicated the changes that happened in the landscape of Santiago City, Philippines, from 2003 to 2025 using the data retrieved from Land Class DENR Region 2 Shapefiles. The map presented significantly shows the rapid change in land use over time. It is visible from the data that “Annual Crop” was the standard vegetation cover in Santiago City. Thus, the changes have shown that urban development became a trend in the city’s development, and the reclamation of the vegetation cover was greatly affected by urbanization and possible environmental changes. Furthermore, this study presented the changes in vegetation cover in Santiago City over time, including the data’s potential implications.

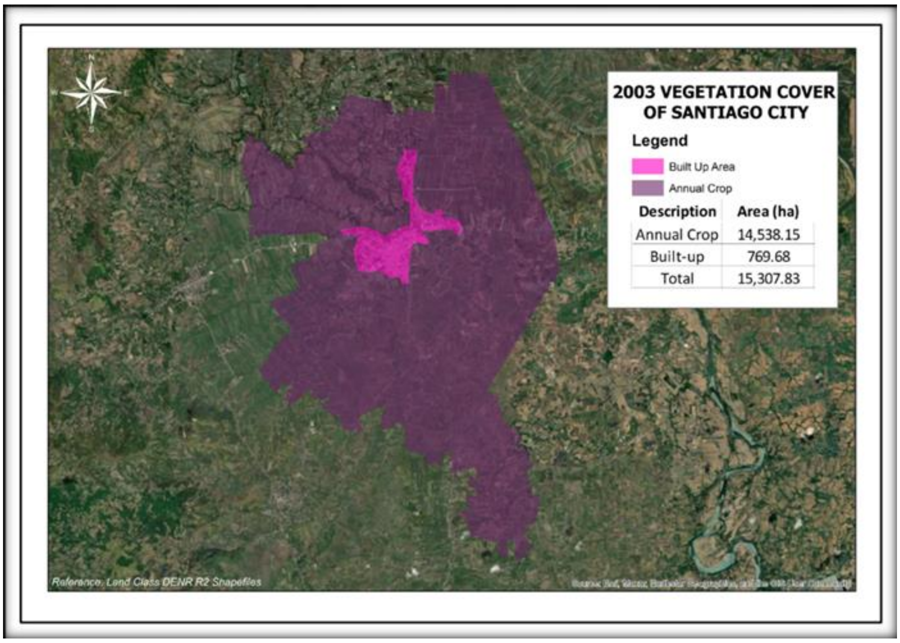


Figure 2. Vegetation Cover of Santiago City 2003 Retrieved from CENRO

The figure above represented the vegetation cover and land use of Santiago City in the year 2003. The researcher retrieved the presented data from the Community Environment and Natural Resources Office of Santiago City. The map was divided into two types, which include the “Annual Crop” and “Built-up”, which are represented through two colors: purple (annual crop) and pink (built-up area). Annual crops dominated the land cover in Santiago City, which has a land area of 14,538.14 hectares or 95.27%, indicating that Santiago City mainly relies on agriculture. Furthermore, 769.68 hectares or 4.73% were then considered as the built-up area, which showed the city’s urban development in 2003.

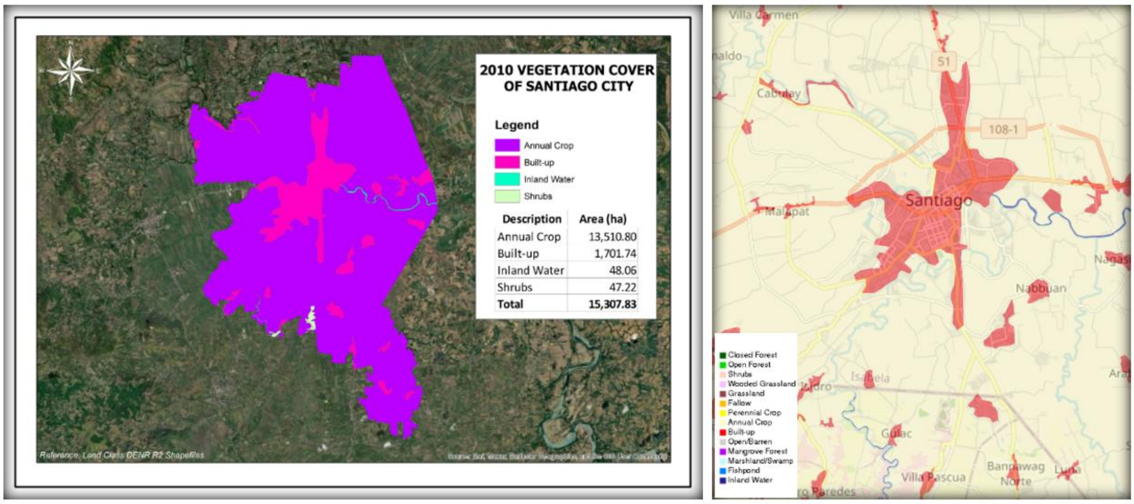


Figure 3. Vegetation Cover of Santiago City 2010 Retrieved from CENRO (Left) and Geoportal PH (Right)

Figure 3 above presented the vegetation cover of Santiago City, Philippines, in 2010, retrieved from two sources. The researchers retrieved the map to the left from the Community Environment and Natural Resources Office, and the right map was retrieved from the Geoportal PH. The two maps revealed that most of the land cover is the annual crop, occupying 13,510.80 hectares or 88.26%, indicating that Santiago is mainly agricultural land despite urbanization. In addition, it is also noticeable that there is a significant build-up of establishments in the city with 1,701.74 hectares or 11.11%; this build-up was mainly seen in the city center. Furthermore, it is also seen on the map as the Inland Water (48.06 hectares) and Shrubs (47.22 hectares). This implies that Santiago City is still considered an agricultural land due to the division of vegetation cover presented on the map despite of the urbanization.

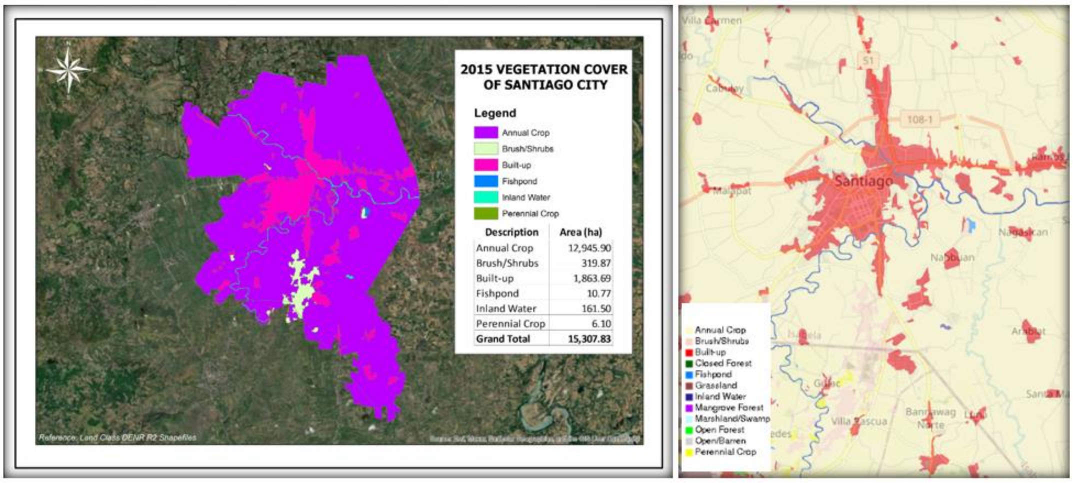


Figure 4. Vegetation Cover of Santiago City 2015 Retrieved from CENRO (Left) and Geoportal PH (Right)

Figure 4 displayed the vegetation cover and urbanization built-up of Santiago City in 2015, which is represented in different colors according to its classification. The maps exposed that the annual crop occupies most of the map, with a land area of 12,045.90 hectares or 78.69%. The built-up occupying is also noticeable as the second most significant part of the land use in the map with a land area of 1,863.69 hectares or 12.17%. In addition, brush/shrubs (319.87 ha), inland water (161.50 ha), fishpond (10.77 ha), and perennial crops (6.10 ha) are the other components of the land in Santiago City. This implies that in 2015, although the city aimed to widen urbanization, land use was still diverse.

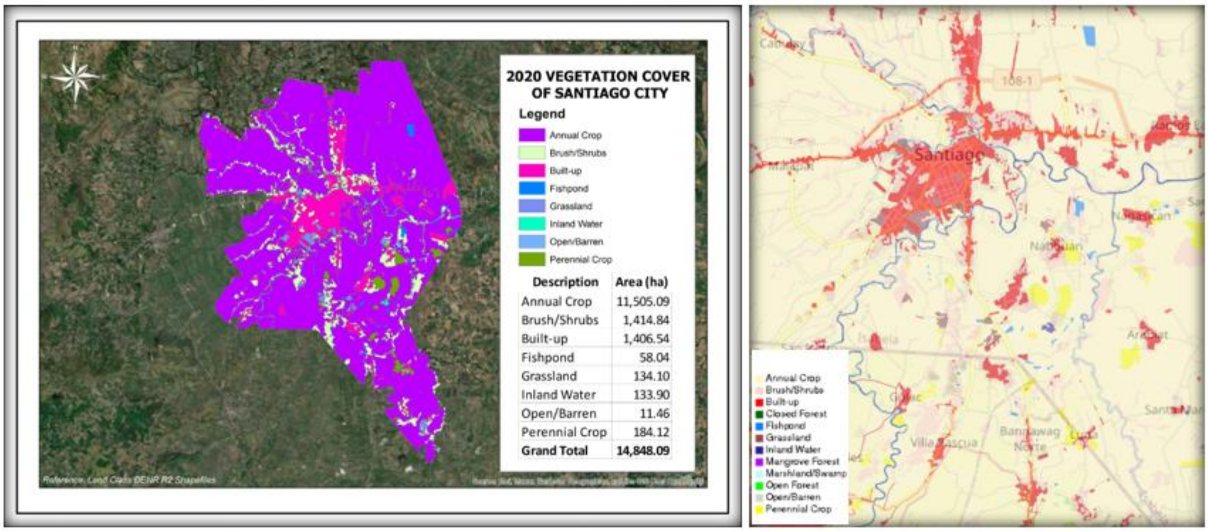


Figure 5. Vegetation Cover of Santiago City 2020 Retrieved from CENRO (Left) and Geoportal PH (Right)

The land use of Santiago City became more complex in 2020; different classifications were provided using color-coded legends. The most dominant land cover was the "annual crop," with 11,505.09 hectares or 77.49%, which attests that Santiago City is still considered agricultural land. Furthermore, 1,406.54 hectares, or 9.47%, are built up due to urbanization. The results indicate that regardless of the urbanization in the city, the city's primary source of income is still agricultural land.

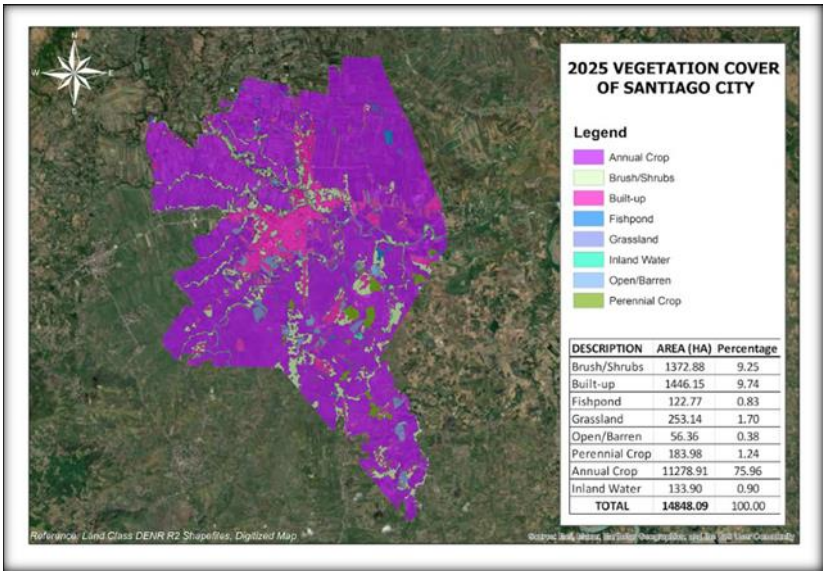


Figure 6. Vegetation Cover of Santiago City 2025 Retrieved from CENRO

The vegetation cover map for Santiago City in 2025 presented that annual crop is the dominant land cover with a large proportion of 75.96% (11278.91 hectares) in the study area. The second biggest portion was built-up at 9.74% (1446.15 hectares), and the next largest was brush/shrubs at 9.25% (1372.88 hectares). Other land cover types, which comprised lesser percentages, including grassland, perennial crop, fish pond, open/barren land, and inland water. The data revealed a landscape that is heavily dependent on agriculture with urbanization and some natural vegetation and semi-natural vegetation making up fractions of land cover. This trend indicates that Santiago City and its economy and associated land use are dependent on agriculture but urbanization is also a significant part of the landscape change.

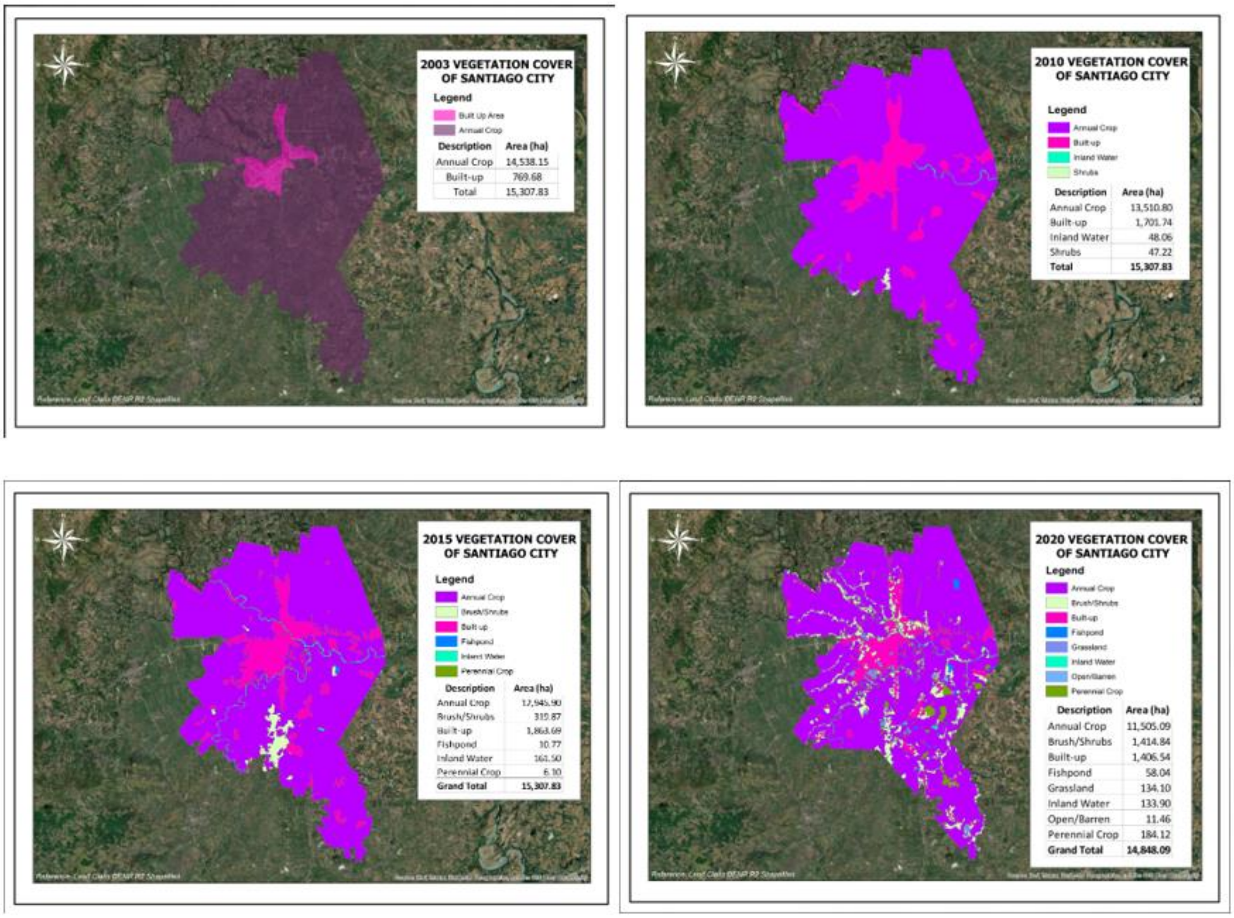
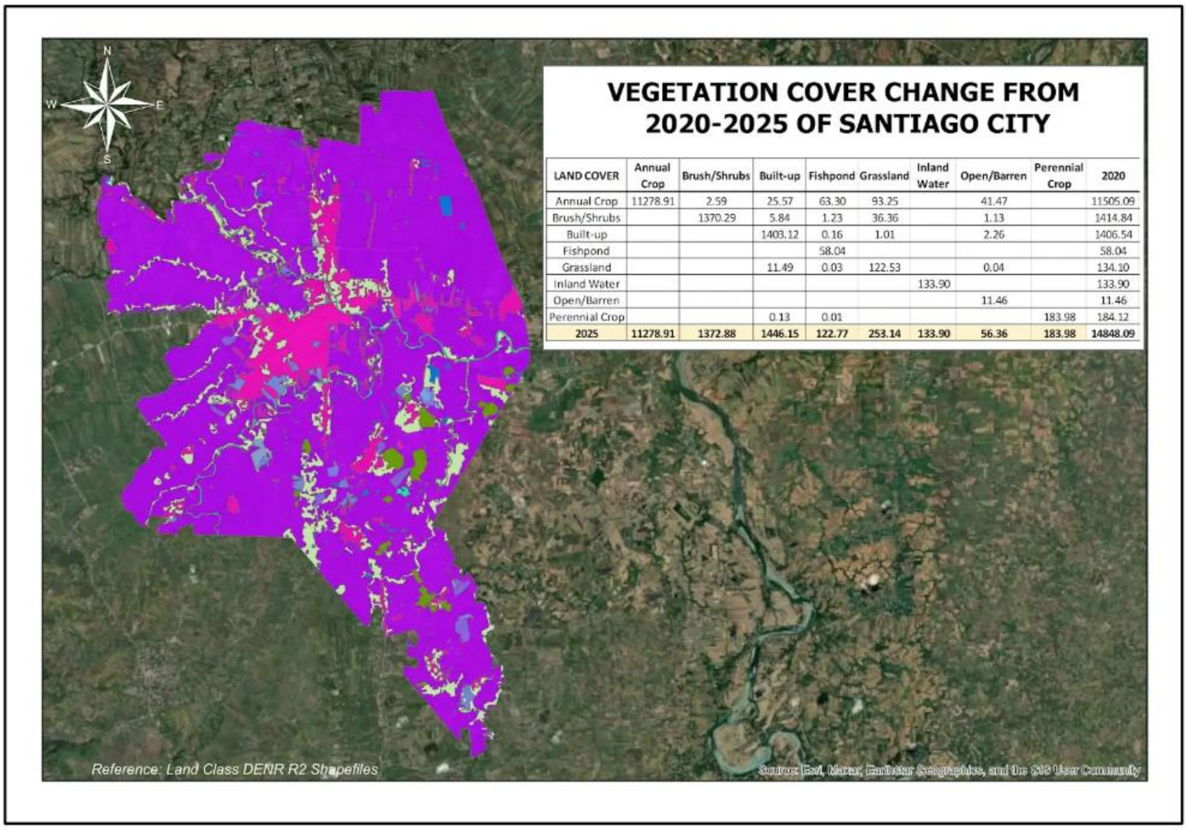


Figure 7. Changes of Vegetation Cover of Santiago City from 2003 to 2020

The four (4) illustrations show the land use in Santiago City, Philippines, in 2003, 2010, 2015, and 2020. In this span of year, the "annual crop" has consistently been the primary land use in the city. On the other hand, the "built-up" has gradually increased throughout the years, indicating that there has been a slight change in urbanization. It is also noticeable from the map that 2010 the "built-up area" is noticeably expanded, while the "annual crop" decreased slightly. There is a slight change in land use from 2015 to 2020; the decrease in "annual crop" indicates a shift towards urbanization. The gradual change of land use from agricultural land to urban environment indicates changes for a wider urbanization trend that is being observed globally. Urbanization was defined as the conversion of agricultural and natural landscape into urban settings, which affects biodiversity and ecological sustainability (Jing et al., 2015).

The implications of this study do not simply relate to the immediate observations of land use, but they also strike at global problems caused by rapid urbanization such as food security, sustainability, and environmental health. The decrease in agricultural land required consideration of, and possibly a redesign of, food production practices and the urban planning process itself. The possibility of a decrease in agricultural yield due to diminishing cropland may further worsen in urban pressure; this creates a cycle of dispute of land-use practices (Kanav et al., 2024). Urban ecosystems also been disrupted as urbanization invades on ecological networks, suggesting that an ecological oversight framework is needed in the urban planning process (Handayani et al., 2018).



LAND COVER	Annual Crop	Brush/Shrubs	Built-up	Fishpond	Grassland	Inland Water	Open/Barren	Perennial Crop	2020
Annual Crop	11278.91	2.59	25.57	63.30	93.25		41.47		11505.09
Brush/Shrubs		1370.29	5.84	1.23	36.36		1.13		1414.84
Built-up			1403.12	0.16	1.01		2.26		1406.54
Fishpond				58.04					58.04
Grassland			11.49	0.03	122.53		0.04		134.10
Inland Water						133.90			133.90
Open/Barren							11.46		11.46
Perennial Crop			0.13	0.01				183.98	184.12
2025	**11278.91**	**1372.88**	**1446.15**	**122.77**	**253.14**	**133.90**	**56.36**	**183.98**	**14848.09**

Figure 8. Analysis of Vegetation Cover Changes from 2020-2025 of Santiago City

The figure shows the change in vegetation cover in the area of Santiago City, from 2020 to 2025. The left shows the spatial distribution of land cover types; the table to the right shows the amount in hectares for each category. Among the table, we can see that the values for "Built-up" among others have increased from 1403.12 hectares in 2020 to 1446.15 hectares in 2025. This increase will most likely come from a reduction in the other land cover types. The land of "Annual Crop" land decreased from 11278.91 hectares in 2020 to 11278.91 hectares in 2025, and "Brush/Shrubs" land has gone down from 1370.29 hectares to 1372.88 hectares. Overall, we can see a trend towards urbanization possibly converting agricultural and natural vegetation lands to developed areas.

The implications of the land cover change results are complex and multi-faceted. Built-up expansion may cause habitat fragmentation and habitat loss, with potential effects on local biodiversity (Forman, 1995). The loss of agricultural land may hint at implications for local food production, security, and accessibility (Pingali, 2012). In addition, urbanization can have effects on the local climate and weather (Oke, 1982), and may lead to urban heat islands. The slight increase in "Brush/Shrubs" may suggest minor stem successional processes and/or reforestation in certain regions, but not to the extent where built-up is outweighed by other land cover types. The consistent "Fishpond," "Grassland," "Inland Water," "Open/Barren," and "Perennial Crop" areas emphasize that the main land cover relationship during this period is defined by agricultural and shrubland changing to built-up.

A variety of options for land use can help with developing sustainable land uses in Santiago City. First, creating stricter zoning requirements can help manage urban growth and make some valuable agricultural land and natural habitat land off limits. This may include creating agricultural zones and protected land (Beatley, 2000). Second, embracing mixed-use development and vertical growth in existing urban areas can help to accommodate growth without the outward sprawl into undeveloped land (Grant, 2013). Creating green infrastructure such as urban parks, green roofs, and permeable pavements could minimize some of the environmental costs of urbanization such as the losses associated with stormwater runoff and the urban heat island (Gill et al., 2007). Lastly, support for sustainable agriculture as well as local farmer support can enhance agricultural efficiency while minimizing the environmental degradation associated with agriculture.

4.2 Effects of Urbanization and Depletion of Vegetation Cover

Urbanization significantly adds to the loss of environmental, economic, and biological green areas. Urbanization is driven by population increase and industrial expansion, and it transforms natural landscapes into developed settings, resulting in the destruction and decrease of green areas. This pattern is evident among other urbanized areas in Santiago City and reflects other widespread activities globally. Urbanization accelerates the decline in green space by changing agricultural and natural lands into urban developments. Studies show urbanization expands into agriculture, consuming the habitats crucial for biodiversity and ecosystem services. Urban expansion generally happens on city borders, destroying important ecosystems (Mensah, 2014). Most importantly, the other faces of urban green areas cause low productivity of different species, thus raising biodiversity loss (Lotfata, 2021).

Urbanization also fragments green space. Urban growth separates them, reducing their ecological viability and returns to the people (Li et al., 2019). It is equally important to call for ecologically sensitive urban planning to focus on reduced green spaces because that would mitigate physical health by hampering air treatment facilities and carbon sequestration (Zhu et al., 2019). Reduced green spaces threaten community health in urban locales because of exacerbated heat and air quality issues. Nguyen et al. (2020) explore the relationship between habitat segmentation and lost vegetation while postulating the required restorative nature experiences for disappearing green spaces (Strohbach et al., 2012; Wang et al., 2022).

Remote sensing technology are used to evaluate urbanization's impacts on green areas. These technologies allow planners to observe vegetation changes over time and build adaptive strategies. Afriyani et al. (2023) describe how these methods might be used to monitor urban expansion and its effects on green spaces. Urbanization leads to habitat loss, fragmentation, and decreased ecological viability. In urban planning, remote sensing technology improve the possibilities for sustainable management of green areas, preserving their contributions while maintaining ecological integrity. Thus, it is important to evaluate the effect of urbanization and depletion of vegetation cover in various factors.

Effect of Depletion of Green Spaces in Santiago City

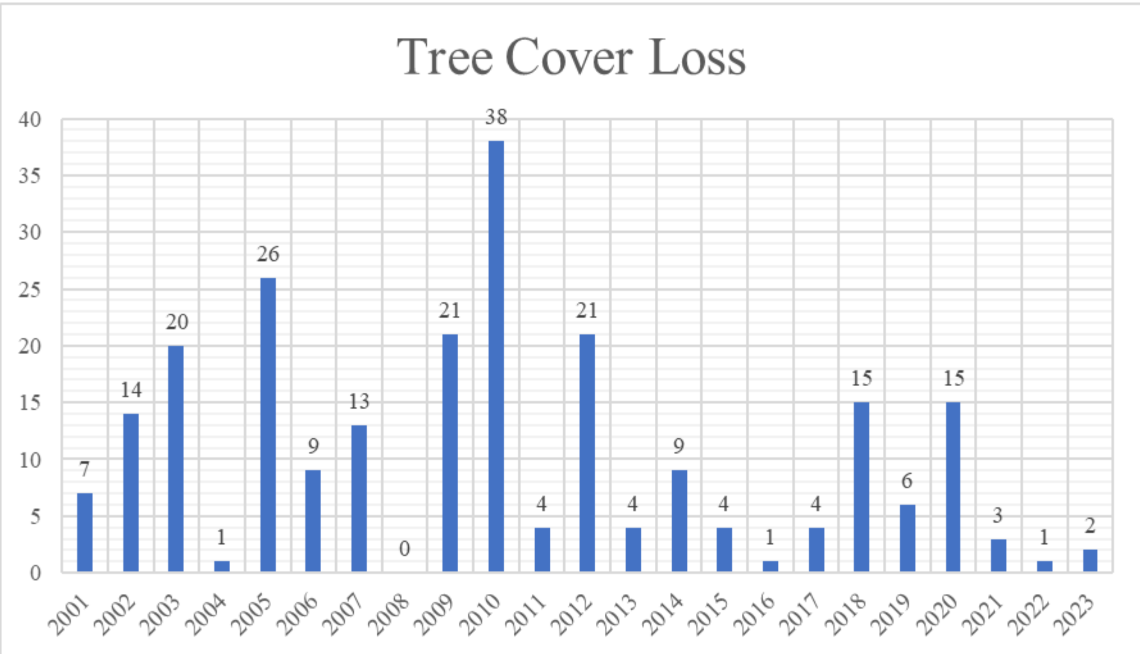


Figure 9. Tree Cover Loss in 2000-2023

The figure shows annual tree cover loss (in hectares) for Santiago City, Isabela, Philippines, from 2001 to 2023, with total losses of 239 hectares over the period. The data captures times of significant deviation from the annual rate of deforestation, with spikes in 2010 at approximately 38 ha and 2005 at approximately 26 ha indicating years of significant deforestation. Furthermore, there are many years with little to no losses in tree cover, including 2004, 2016, and 2022 with losses of only 1 hectare in each of those years. The variation in loss indicated deforestation in Santiago City is not a logically, linear process and could be the result of developments or activities that prompted localized areas of clearing in specific years and contributed to the overall decline in tree cover loss.

The graphic shows the loss of tree cover in Santiago City, Isabela, Philippines, between 2001 and 2023. The pattern points to periodic rises and falls of deforestation from 2001 to 2023, with large losses noted in 2005, 2009, 2010, and 2012. The Global Watch Forest Organization revealed that Santiago City lost a total of 239 hectares of tree cover (7.2% since 2000) corresponding to 124 kilotons of CO2e emissions. This suggests that there are negative implications for the environment, which are related to urbanization and development. Although deforestation is not linear, the significant spikes in tree cover loss suggest pressures of urbanization associated with land-use conversion for housing, infrastructure, or agriculture. The tree cover loss trend could make the area more susceptible to climate change impacts, loss of biodiversity, and a loss of ecosystem services. Therefore, it is important to consider innovative land use planning as well as sustainable urban planning as part of development efforts.

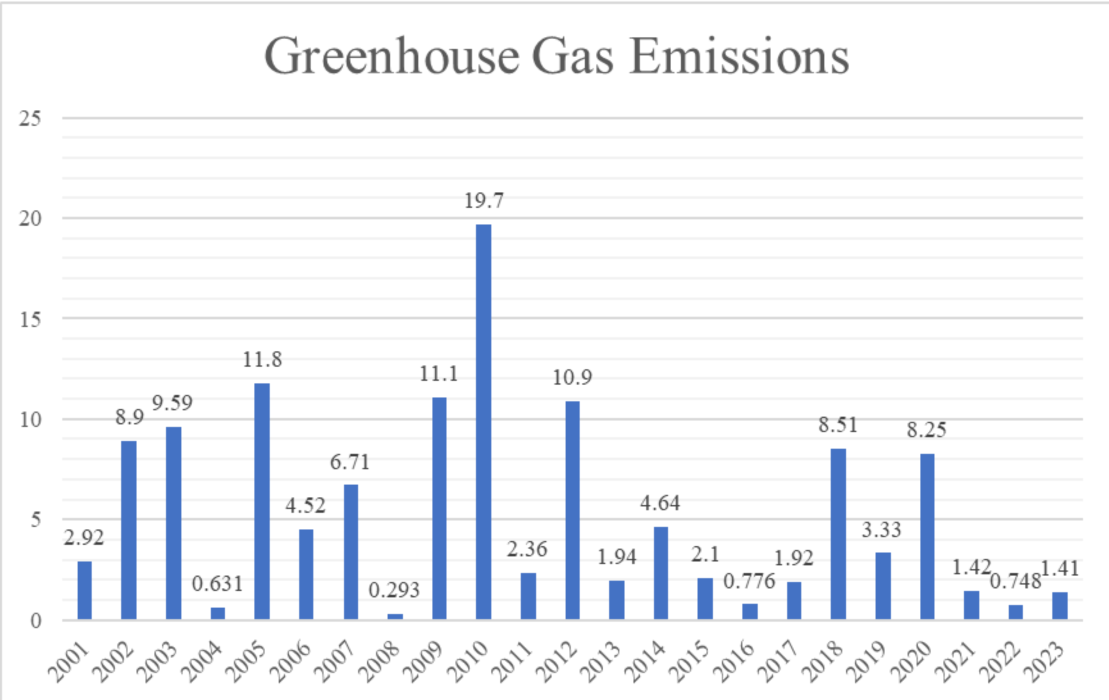


Figure 10. Greenhouse Gas Emissions (2000-2023)

Figure 10 lists the annual greenhouse gas emissions (in kilotons of CO2e) for Santiago City, Isabela, Philippines from 2001 to 2023. The emissions vary considerably in terms of magnitude over the years. The smallest emissions occurred in 2008 (0.293 kt) and in 2016 (0.776 kt), while the largest emissions occurred in 2010 (19.7 kt) and 2005 (11.8 kt). In total, the city released 124.468 and a reported decrease in emissions over the 23-year period. The total accumulated value suggests that the city has exhausted an overall significant amount of greenhouse gas emissions. The data implies that emissions represent a highly dynamic process, for example development and deforestation rates and land-use changes, may have a large impact as well.

The data revealed the greenhouse gas emissions associated with vegetation cover in Santiago City, Isabela, Philippines, from 2001 to 2023, which corresponds to the loss of tree cover discussed above. The Global Watch Forest Organization revealed an average of 5.41 kilotons (kt) of CO2e was released per year, resulting in a cumulative greenhouse gas emission of 124 kt of CO2e. The emissions chart shows many of the same rises and falls as the tree cover loss, with emissions peaking in 2004, 2009, 2010, and 2019 in response to the loss of tree cover. The data suggests that high tree cover loss results in higher emissions, implying that deforestation has an environmental cost. As urbanization causes deforestation, urbanized areas add carbon to the atmosphere, which ultimately contributes to climate change. The spikes in emissions that follow the aforementioned patterns of tree cover loss demonstrate urbanization activities—land clearing for development (roadway and housing) and agriculture—are a driver of emissions after deforestation. Santiago City confronts the opportunity to develop while maintaining environmental stewardship, and as such, it is imperative to develop strategies to reduce deforestation rates and enhance carbon storage capabilities to limit their carbon footprint.

4.3 The Assessment and Management of Urban Vegetation in Santiago City using Remote Sensing Technology

Remote sensing (RS) technologies are crucial for measuring and managing urban vegetation in Santiago City by offering thorough data-analysis and supporting decisions in urban analytics. RS tools enhance the ability to monitor and manage urban vegetation in a detailed manner, improving urban environmental quality and fostering sustainability practices.

Remote sensing datasets provide important temporal and spatial information needed to understand vegetation dynamics in urban environments, like Santiago. These datasets provide the ability to consider land cover change over time, allowing for the development of trends in urban growth and climate effects and distribution of vegetation. The utilization of time series satellite datasets can effectively estimate changes in urban vegetation coverage (Abdalla, 2024; Ruan et al., 2019). Brandalise et al. argued the importance of remote sensing technologies in urban environmental planning to describe and predict the causes of urban growth and impacts on vegetation (Brandalise et al., 2019). Technologies such as these offer a higher-level view of urban growth and interactions on natural ecosystems as shown in Wojciech Gilbert and Shi's review of urban expansion in Lagos (Gilbert & Shi, 2023).

The combination of remote sensing technologies also increases monitoring of urban biodiversity. This combination provides assessment of ecological health and strategies for conservation of the tree covers. Such capabilities are essential in managing urban green space in Santiago, as they provide adequate information to promote biodiversity and conservation of existing vegetative cover (Oppong et al., 2023). Evidence has demonstrated that urban vegetation can improve air quality, decrease urban heat, and improve resilience to urban living (Xu & Wei-wei, 2013; Santamouris & Osmond, 2020).

Evaluating the influence of urbanization on vegetation phenology, researchers demonstrated how urban heat islands (UHIs) result in accelerated shifts in the growing seasons, ultimately resulting in health and productivity changes of urban vegetation. For example, Zipper et al. discussed the consequences of UHI on plant phenology and its implications for larger water and nutrient cycles across urban ecosystems (Zipper et al., 2016). As noted, in a setting with RS data, researchers are able to describe changes in phenology across urban areas, and develop adaptive management strategies that track observed changes.

Remote sensing also supports the spatial analysis needed for urban planning, particularly about green infrastructure integration. By assessing the types of vegetation present and layering that with the urban environment, planners will be able to make better decisions on ideal locations for new green spaces, serving to maximize ecological functions such as climate enhancement and improving air quality (Mohammed et al., 2022). Additionally, this work is explained in Ruan et al.'s research, which also expands upon how remote sensing methods can help quantify the role of urban vegetation in carbon uptake (Ruan et al., 2019; Zhang et al., 2023). Thus, it is vital that to leverage high-resolution, remote-sensing data for the assessment of urban ecological quality to support policymakers and urban planners to better engage in environmentally sustainable planning practices (Huang et al., 2022).

To summarize, using remote sensing represents dynamic and comprehensive tools for the assessment and management of urban vegetation located in Santiago City. The ability to monitor vegetation health on a recurring basis, mapping land cover changes, and enhancing opportunities for biodiversity through informed planning are vital elements of how technology can strengthen urban ecological frameworks.

5. Conclusions and Recommendations

5.1 Conclusion

Santiago City has demonstrated a movement toward annual crops since 2003, pointing to a strong agricultural base, but has also shown a clear and trending increase in built-up areas, which is a manifestation of urbanization.

Urbanization, promoted by both population growth and city industrialization, is causing an immeasurable loss and damage of green areas in Santiago City consistent with urbanized areas globally, resulting in habitat loss, declines in biodiversity and ecosystem services, and impairing human health by increasing heat index and air quality issues.

The non-linear pattern of deforestation in Santiago City between 2001 and 2023, representing a loss of tree cover and trees that caused greenhouse gas emissions and climate change, is occurring as a direct result of land use change from urbanization and development, all of which results in increased vulnerability of Santiago City to climate change and environmental degradation. For actually assessing, mapping, monitoring, and managing urban vegetation in Santiago City successfully,

Remote Sensing (RS) bring higher levels of spatial and temporal data documenting vegetation dynamics, land cover change, and biodiversity, which encourages environmental informed planning for green infrastructure and the integration and placement of green infrastructure.

5.2 Recommendation

Based on the conclusion made, the following recommendations are given:

The Local Government Unit must examine the detailed socio-economic factors driving the gains in built-up areas at the expense of agricultural and natural lands that made the observed changes in Santiago City. In this manner, the city planner will be able to identify who among the following infrastructure builders are the most contributor to building infrastructure in that sense, the city planner can also require them to plant more trees in exchange of greenhouse gas emission that they would emit in the building process.

The urban planners and engineers must conduct an in-depth evaluation of the ecosystem services in Santiago City being lost or degraded through urbanization and vegetation loss, and in particular those services (e.g. flooding regulation, air, and water purification) that are of local relevance.

Analyze the impact of urban destruction on the biodiversity of remaining green spaces within Santiago City, focusing on species richness, abundance, and connectivity to inform conservation strategies.

Examine how urban fragmentation affects biodiversity within remaining greenspaces in the city of Santiago, as it relates to species richness, abundance, and connectivity, to inform conservation measures.

Create predictive models using remote sensing to model various urban growth scenarios and the related burdens that may result on vegetation cover, carbon emissions, and ecosystem services in the city of Santiago.

Evaluate existing and potential green infrastructure programs (urban parks) for their impact on mitigating the negative environmental consequences of urbanization in Santiago.

Investigate local stakeholders' perceptions and preferences for land-use change and their role in developing participatory and sustainable land-use plans that support urban development with environmental conservation and food security.

Future researchers must investigate the effect of urban vegetation to prevent the urban heat island, ecological health, food security and other factors that counter the effect of rapid urbanization.

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