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NDVI-Based Assessment of Vegetation Cover in Koronadal City Using GIS and Remote Sensing

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***Abstract* - Over the years, vegetation in cities has been affecting the climate in the valley. A method called Normalized Difference Vegetation Index (NDVI) Assessment combined with Remote Sensing through satellite images is an innovative way to track the changes in vegetation cover in these areas. This study sought to examine alterations in vegetation regions within the Koronadal valley by employing the Normalized Difference Vegetation Index (NDVI) for analysis. The research design involved quantitative descriptive research, utilizing numerical data from NDVI analysis as the foundation for predicting vegetation cover trends over the next decade through linear regression. It also utilized satellite imagery from platforms like Landsat 7, 8, and 9. The results revealed a substantial increase in vegetation cover from (183.41 ± 46.53) km² to (230.73 ± 16.82) km² within Koronadal City between 2003 and 2023. Statistical analysis indicates a significant positive trend in vegetation area expansion over the specified timeframe with a regression (R) value of 0.97. Through NDVI analysis using the QGIS software, the visual diagrams show the increase in vegetation cover, illustrating a consistent rise over decades, emphasizing the government's demonstrated environmental conservation methods. The linear regression indicates a sustained increase in vegetation cover in Koronadal over the next decade. The rise in vegetation cover underscores the successful environmental preservation efforts and highlights the city's growing environmental resilience, emphasizing the need for sustainable land management practices in addressing environmental challenges.**

Keywords: satellite imagery, QGIS, linear regression, Landsat, climate action, technology.

I. INTRODUCTION

Forests are vital for offering fundamental ecosystem benefits such as fresh air, clean water, and habitats for both diverse wildlife and human requirements (Brockerhoff, 2017) [1]. The expanding global population has heightened product demand, placing increased pressure on forests for raw materials (Bringezu, 2011) [2]. According to Austin *et al.* (2017) [3], there is an increase in deforestation from 2000-2012 in tropical regions, predominantly driven by industrial-scale factors. Urbanization also contributes to forest cover decline, especially residential and industrial construction (Sejati *et al.*, 2018) [4]. Moreover, industrial operations such as mining lead to deforestation in approximately two-thirds of tropical nations, underscoring the significance of accounting for both direct and indirect effects in forest conservation efforts (Giljum *et al.*, 2022) [5]. Although largely driven by human activities, natural occurrences like forest fires, droughts, floods, and the proliferation of non-native animal species also play a role in deforestation (Bodo *et al.*, 2013) [6]. Deforestation not only puts risk on biodiversity, but also obstructs the attainment of Sustainable Development Goal (SDG) 13 – Climate Action. The preservation and conservation of forests remain pivotal in the global effort to address the escalating impacts of climate change, given their critical role in carbon dioxide sequestration (Zald, 2016) [7].

As reported by Ang *et al.* (2020) [7], there has been a discernible decline in indigenous flora and a rise in urban development, mining activities, and agricultural expansion in the Philippines between 1994 and 2018. Despite the efforts of the National Greening Program (NGP) spanning the years 2001 to 2018, which aimed to balance afforestation and deforestation (Comiso *et al.*, 2020) [8], no substantial advantages were observed. Damage and restoration of land covers persist, indicating the need for increased awareness.

As discussed in the study of Gandhi *et al.* (2015) [9] the Normalized Difference Vegetation Index (NDVI)-based Change Detection technique demonstrated remarkable efficacy in identifying vegetation changes in Vellore District, India. This contributes significantly to the informed decision-making of policymakers and enhances the anticipation of natural disasters. Moreover, according to Mambo and Makunga (2017) [10], the integrated application of remote sensing and Geographic Information System (GIS) techniques in the Selous Game Reserve located in Tanzania holds considerable potential for identifying and tackling issues related to wildlife

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fragmentation and decline. This integrated approach offers valuable support for wildlife management initiatives.

Additionally, the study carried out by Mahmood and Al-Rawe (2023) [11] where aimed to investigate the spatial and temporal alterations happening within the Abu Ghraib research site in Iraq. Hence, the study employed the NDVI on satellite imagery for the years 2001, 2011, and 2021. In 2001, the study area exhibited a vegetation cover of 37%, which subsequently decreased to 23% in 2011 but experienced an increase to 32% by 2021. In line with the study of Padilla *et al.* (2015) [12], GIS and Remote Sensing were employed to evaluate the ongoing decline in vegetation cover within the Lake Mainit watersheds in Northern Mindanao throughout a 38-year period of utilization. Encompassing the municipalities of Mainit, Alegria, and Jabonga, as well as certain land areas in Kitcharao, the assessment indicated limited indications of disturbance to vegetation cover in Tubay to Malimono regions, with non-vegetated areas predominantly observed at lower elevations surrounding the lakeshores. Additionally, the study documented temporal and spatial variations in land cover attributed to diverse anthropogenic disturbances (Padilla *et al.*, 2015) [13].

Despite the extensive volume of research dedicated to the utilization of GIS, remote sensing, and NDVI for vegetation assessment, a notable research gap remains, especially in localized studies, such as those centered on the Koronadal City, South Cotabato over a ten-year span. Thus, the study sought to examine alterations in vegetation regions within the Koronadal valley by employing the Normalized Difference Vegetation Index (NDVI) for analysis. This was achieved by rendering satellite images from Lansat 7, 8, and 9, in conjunction with Geographic Information System (GIS) applications. Additionally, considering the growing activity of tree planting initiatives and reforestation efforts in Koronadal City, an assessment of these initiatives' impact on vegetation dynamics were included in the study.

Conversely, the research specifically (a) gathered and rendered satellite images of vegetation cover of Koronadal City in 2003, 2013, and 2023 using Landsat 7, 8, and 9; (b) compared the satellite images of 2003, 2013, and 2023 through visual comparison and NDVI assessment; and (c) modeled the vegetation area through linear regression. In response to the findings, it was crucial to strengthen existing government policies. This paper was beneficial to the local government of Koronadal City as it highlighted significant changes in vegetation cover in the valley. Sharing this information with the government could lead to adjustments in policies and actions to address the changing environmental conditions. Moreover, the results of the research could offer valuable insights and data that may aid the government in constructing policies and orchestrating initiatives aimed at accomplishing Goal 13 of the Sustainable Development Goals (SDG): Climate Action.

II. MATERIALS AND METHODS

2.1 Materials

In this study, the researchers utilized various digital tools such as QGIS and Landsat 7, 8, and 9 to gather data in evaluating vegetation coverage using the Normalized Difference Vegetation Index (NDVI). Landsat 7, 8, and 9 served as the primary tool to capture the designated area. Additionally, QGIS assisted in stitching images together, obtaining NDVI values, and creating visual representations of vegetation for the years 2003, 2013, and 2023. Furthermore, the study used a computer for conducting remote sensing and capturing satellite images. These tools were utilized to capture and gather images in the Koronadal Valley, essential for the study's analysis.

2.2 Research Design

The study employed quantitative descriptive research, a non-experimental approach where variables were assessed using numerical measures without the researcher manipulating them. The numerical data points could reveal patterns, relationships, and trends as time progresses (Heath, 2023) [14]. In this study, the NDVI assessment data for years 2003, 2013, and 2023 provided researchers with percentage values that served as the basis for comparison for determining the decrease or increase in vegetation cover in Koronadal City, Philippines.

2.3 Procedure

This section outlines the methodology used to evaluate vegetation coverage across three periods (2003, 2013, and 2023). The research methodology comprises one primary component, as depicted in Figure 1.

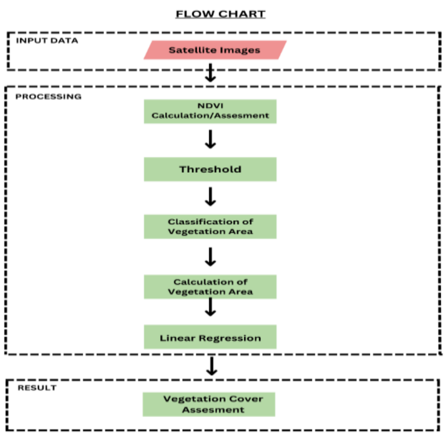

Figure 1: Overall Methodology Flowchart

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2.3.1 Gathering and Rendering of Satellite Images

These maps were rendered on the QGIS software for precise spatial analysis and to begin the assessment. This was achieved by accessing the browser panel and adding the collected satellite image. This initial phase was critical for establishing a baseline understanding of the terrain, allowing for a comparison examination between the three selected years. The project sought in capturing the initial status of the land area using Landsat images, which served as a critical reference point for subsequent rounds of analysis and assessments.

2.3.2 NDVI Assessment

In initiating the process in QGIS software, satellite images were imported for the computation of NDVI. The researchers utilized the raster calculator within the raster menu to compute values. The Normalized Difference Vegetation Index (NDVI), which relies on red and near-infrared bands, was employed in assessing vegetation health and density. Thus, the NDVI equation was applied across three distinct time periods: 2003, 2013, and 2023. Additionally, the use of Landsat 7, 8, and 9 involved different band numbers to accurately address each period. This computation produces NDVI values ranging from -1 to 1, with higher values indicating denser/higher vegetation cover. The NDVI equation was:

$$NDVI = \frac{NIR - RED}{NIR + RED}$$

Where:

NDVI = Normalized Difference Vegetation Index
NIR = Reflection in the near-infrared spectrum
RED = Reflection in the red range of the spectrum

2.3.2.1 Calculation of NDVI using Landsat 7

The NDVI calculation process utilized satellite data from Landsat 7 that captured the year 2003. Specifically, the red spectrum (BAND 3) and near infrared (NIR) spectrum (BAND 4) were employed for analyzing vegetation areas within the GIS program. Below was the equation used for this analysis:

$$Vegetation\ Cover = \frac{BAND_4 - BAND_3}{BAND_4 + BAND_3}$$

2.3.2.2 Calculation of NDVI using Landsat 8 and 9

The process of computing NDVI involved utilizing satellite data from Landsat 8 for the year 2013 and Landsat 9 for the year 2023. Both Landsat satellites utilized the red spectrum (BAND 4) and near infrared (NIR) spectrum (BAND 5) for analyzing vegetation areas within the GIS program. The equation employed for this analysis was:

$$Vegetation\ Cover = \frac{BAND_5 - BAND_4}{BAND_5 + BAND_4}$$

2.3.3 Threshold

After the calculation of NDVI, the images were outlined accurately using the clip raster by mask layer tool within the QGIS application. This refinement enhanced the overall reliability of the spatial data for it served as the boundary in determining the scope of the vegetation assessment.

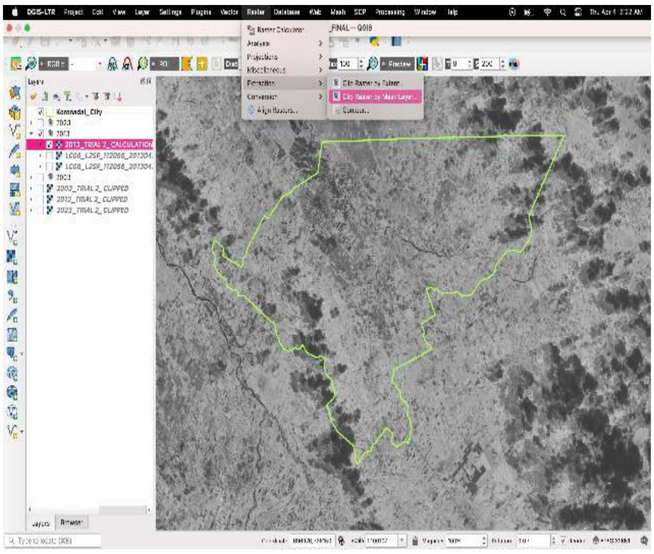

Figure 2: Mask Clipping the Boundary of Koronadal City

2.3.4 Classification of Vegetation Area

Since the threshold was already set, results from the NDVI assessment were categorized. The NDVI classification range was inputted into the layer properties under symbology. This was followed by assigning colors to delineate non-vegetation areas (-0.28-0.18), low vegetation areas (0.18-0.36), and high vegetation areas (0.36-0.74).

2.3.5 Calculation of Vegetation Area

After classifying the vegetation area, the researchers utilized the raster calculator to separate the values of each range of data – non-vegetation areas, and low and high vegetation areas. The equations were:

All Vegetation area: Initial Raster Data ≥ 0.18
High Vegetation Area: Initial Raster Data ≥ 0.36
Low Vegetation Area: [Final Raster Data of Vegetation] – [Final Raster Data of High Vegetation]

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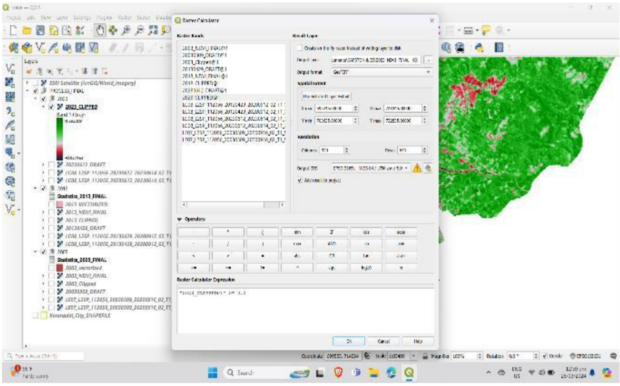

Figure 3: Calculating All Vegetation Area

Next, the raster data was converted to vector data using QGIS polygonized feature. In the field calculator, the researchers accessed the attribute table and used coding to assign values for vegetation and non-vegetation areas based on defined criteria. The coding used was:

CASE
WHEN “DN” =1 THEN to_string (‘vegetation’)
WHEN “DN” =0 THEN to_string (‘non-vegetation’)
ELSE 0
END
adopted from (QGIS User Guide — QGIS Documentation Documentation, n.d.) [15]

Consequently, the user opens the attribute table of the vector data and calculates the area of each pixel count using the feature “$area” under Geometry. Next, they access the statistics by categories feature of QGIS to solve for the sum of the different pixel counts per category. Finally, they input the data under sum using Microsoft Excel.

2.4. Statistical Analysis

Vegetation cover analysis in Koronadal City was performed individually for each time period to enable a thorough examination. The necessary data for assessing the vegetation cover included: (a) total area, (b) vegetation cover area in 2003, (c) vegetation cover area in 2013, and (d) vegetation cover area in 2023. Once all the data was collected, it was presented in table form, ranked from the highest vegetation cover to the lowest for the year 2013. The vegetation cover percentage for the given period was computed using MS Excel. This involved applying a formula that utilized frequency and percentage distribution:

$$\%\,Vegetation = \frac{F}{N} x100$$

Where:

% Vegetation = Percentage of Vegetation

F = Vegetation Area

N = Total Area

Furthermore, after computing all numerical values, the values were entered into MS Excel to conduct linear regression. The user inserts a scatter plot figure and inputs the data. Subsequently, they access the "Add Trendline" feature to incorporate the slope-intercept formula and R^2 value. Following this, they transform the existing figure into a line chart.

2.5 Ethical Consideration

The researchers conducted this study in complete adherence to established research protocols. Initially, they obtained permits from the administration to conduct the study, including processing letters for the conduct of the study to the principal and letters of permission for various environmental organizations for the collection of data. Implementation of data security measures was a priority to ensure the integrity of information and aimed to maintain scientific integrity throughout the research process. Further, researchers diligently ensured all authors were cited for the ideas they contributed to avoid plagiarism.

III. RESULTS AND DISCUSSIONS

This section provides the gathered numerical data illustrating the comprehensive scope of vegetation cover and its percentage distribution, along with an analysis of its implications for the overall condition of vegetation in Koronadal City.

3.1 Gathering and Rendering Satellite Images

The figures illustrate the collection and processing procedures applied to the satellite images.

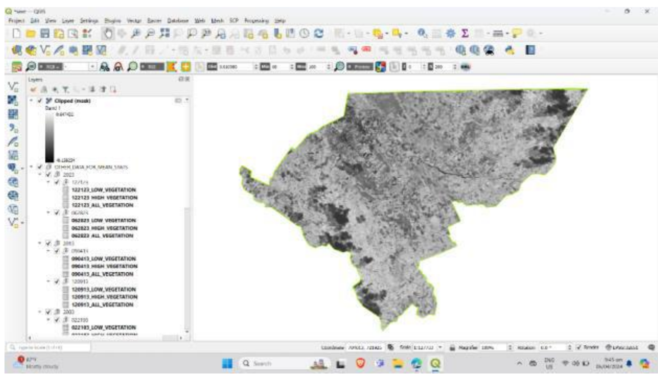

Figure 4: Rendered Satellite Image

These figures depict the gathered and rendered satellite images taken from Landsat 7, 8, and 9. The utilization of these images for research purposes represents a significant aspect of environmental and urban studies. The selection of appropriate

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satellite platforms and images with the right resolution must be tailored to the research objectives, with the study of Price (1997) [16] indicating that reduced spectral resolution coupled with heightened spatial resolution is favored in visible-near infrared remote sensing due to its capacity to offer richer data and enhanced measurement accuracy. Furthermore, it has the efficiency in determining land cover classification and change detection as illustrated by Sheffield and Morse-McNabb (2015) [17]. Satellite imagery can aid in evaluating patterns of vegetation cover change at a landscape scale and enhance comprehension of production variability across the landscape. Consequently, Landsat 8 provides worldwide moderate-resolution data, which is instrumental in identifying land cover, condition, disturbances, and alterations, thereby assisting in resource management and research on climate change (Roy *et al.*, 2014) [18].

3.2 Visual Comparison of Satellite Images

The figures depict the mapping of vegetation coverage over the period from 2003 to 2023.

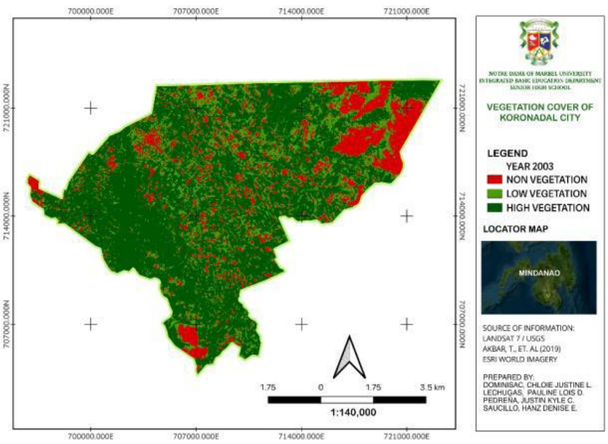

Figure 5: Vegetation Cover of 2003

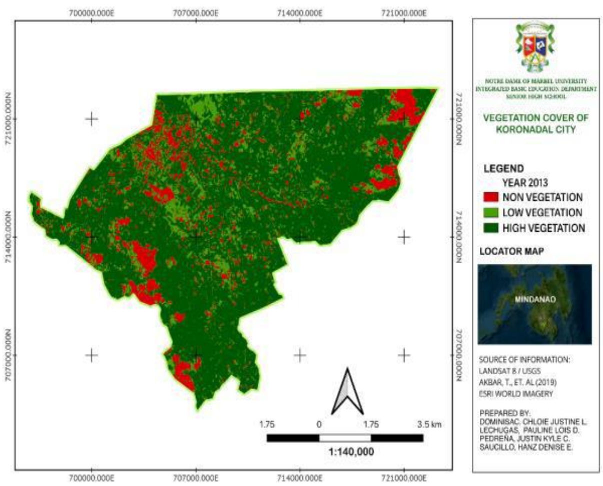

Figure 6: Vegetation Cover of 2013

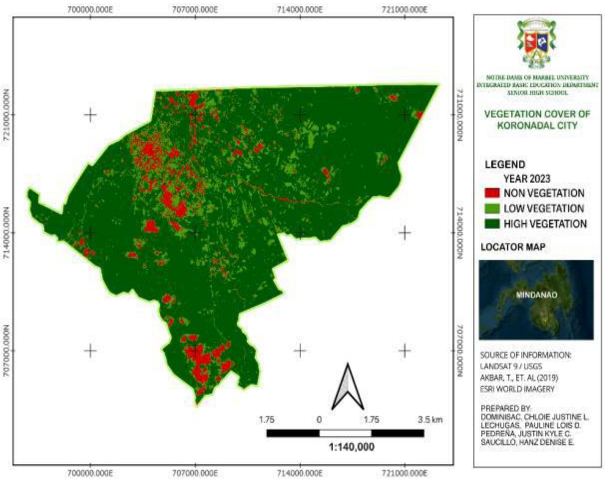

Figure 7: Vegetation Cover of 2023

In Koronadal City, there have been significant changes in some areas while others have remained the same over the decades. For example, in Barangay San Isidro, there has been a noticeable shift from having abundant vegetation to becoming non-vegetated. Similarly, in Barangay Cacub, there has been a marked transition from being predominantly non-vegetated with sparse vegetation to becoming a highly vegetated barangay. On the other hand, the Poblacion area (Zone I, II, III, and IV) has maintained its status as a non-vegetated area, evolving further into an urbanized hub from 2003 to 2023. Lastly, in Barangay Mambucal, the landscape has remained consistent, with a mix of low and high vegetation persisting until 2023.

The figures offer a visual representation of the variations in non-vegetated, low vegetation, and high vegetation areas across different years in Koronadal City, revealing a notable increase in vegetation cover alongside a decrease in non-vegetated areas. A study by J. Wang., *et al.* (2015) [19] found a substantial increase in plant life across the mountains of southern China. This rise in vegetation is likely due to a combination of factors, including changes in climate and human actions in the region. Moreover, research indicates that the expansion of vegetation areas in landscapes often results from local mitigation efforts, as evidenced by studies such as Li *et al.* (2016) [20], which underscore the important role of major ecological restoration initiatives like the Natural Forest Conservation and Grain for Green projects in fostering vegetation growth and reducing runoff coefficient. Similarly, events such as the Tree Growing Festival, initiated in 2011, is now in its 13th year and counting, with over 2000 volunteers and a total of 16,277 bamboo, and fruit seedlings including nato, tamagong, durian, mangosteen, and others in Koronadal City. This exemplifies the government's commitment to environmental preservation, thus exerting a significant impact on the current vegetation cover (Manato, 2020) [21].

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However, there is still a notable change in an area in Koronadal City. The figures illustrate the continuous growth of non-vegetation cover, particularly in the northwestern part of the city, where the urbanized area of Koronadal City is located. These findings validate the observed changes in vegetation cover depicted in the visual comparisons.

3.2.1 NDVI Assessment of Satellite Images

The tables provide data regarding the total vegetation cover and its change over the years.

Table 1: NDVI Classification Range

Class	NDVI Range
Non-Vegetation Area	-0.28-0.18
Low Vegetation Area	0.18-0.36
High Vegetation Area	0.36-0.74

Table 1 presents the classification ranges for Normalized Difference Vegetation Index (NDVI), specifying values from -0.28 to 0.18 as non-vegetation areas, 0.18 to 0.36 as low vegetation areas, and 0.36 to 0.74 as high vegetation areas. As elaborated by Alex et al. (2017) [22], NDVI values span from -1 to 1, with higher values approaching 1 signifying dense vegetation cover. Moderate vegetation typically falls within the range of 0.2 to 0.4, while NDVI values ranging from 0.4 to 0.6 indicate moderate vegetation density and values between 0.6 and 1 represent dense vegetation. Additionally, Kwan et al. (2020) affirm that values below 0 characterize non-vegetated areas. This classification framework aids in accurately assessing vegetation cover and distribution across the landscape, providing valuable insights for environmental monitoring and land management strategies.

3.2.2 Total Vegetation Area

Table 2: Changes in Total Vegetated Area

Year	Non-Vegetation Area (km^2)	Low Vegetation Area (km^2)	High Vegetation Area (km^2)	Total Vegetation Cover (km^2)
2003	79.35 ± 43.09	141.62 ± 26.42	47.12 ± 31.93	183.41 ± 46.53
2013	48.69 ± 17.79	100.30 ± 4.05	119.10 ± 16.16	214.07 ± 21.45
2023	32.03 ± 12.53	99.05 ± 11.96	137.01 ± 11.44	230.73 ± 16.82

The examination of total vegetated area across the specified timeframes reveals significant shifts in vegetation dynamics within the city. Between 2003 and 2013, Koronadal City experienced a notable decrease in non-vegetated land area, indicating possible efforts towards land reclamation or afforestation projects. However, both low vegetation and high vegetation experienced reductions, indicating potential challenges such as deforestation, urban expansion, or agricultural intensification impacting vegetated areas. According to the study of Baniya *et al.* (2019) [23], NDVI significantly increased in Nepal with an average trend of 0.0018 yr− 1 from 2000 to 2017, indicating a 27.88% greening in the country. Moreover, Dong *et al.* (2014) [24] reported improvements in vegetation coverage in Beijing in 2013 compared to 2000, indicating the effectiveness of conservation efforts. Remarkably, by 2023, non-vegetated areas further decreased to 32.03±12.53 km², suggesting ongoing land restoration efforts. Simultaneously, high vegetation experienced substantial growth, expanding to 137.01±11.44 km², potentially reflecting successful reforestation efforts or land-use policies promoting forest conservation and ecosystem restoration, as highlighted by Yu and Dida (2023) [25] in the Mts. Palay-Palay Mataas-Na-Gulod Protected Landscape in the Philippines. Despite these changes, forests remain the predominant land cover class.

Table 3: Percentage Alterations in Vegetation Cover

Year	Non-Vegetation Area	Low Vegetation Area	High Vegetation Area	Total
2003	29.60%	52.83%	17.58%	100%
2013	18.16%	37.41%	44.43%	100%
2023	11.95%	36.95%	51.11%	100%

The changes in vegetation cover percentages provide deeper insights into the evolving landscape of Koronadal City. In 2003, non-vegetated areas comprised 29.60% of the landscape, with low vegetation covering 52.83% and high vegetation making up 17.58%. Subsequent years witnessed notable shifts in vegetation distribution. The decrease in non-vegetated areas to 11.95% suggests successful interventions aimed at combatting land degradation and promoting land restoration practices. However, the decline in low vegetation to 36.95% raises concerns about agricultural expansion or urban invasion. Conversely, the significant increase in high vegetation to 51.11% indicates positive trends in vegetation recovery and ecosystem resilience within the city. Initiatives like the Tree Growing Festival, initiated in 2011, underscore the government's commitment to environmental conservation and have bolstered the city's resilience (Manato, 2020) [26]. Additionally, the said initiative involves collaborative efforts among various stakeholders to organize tree planting events, collect baseline data through satellite imagery analysis, field surveys, and community mapping, and carefully record the number, species, and location of trees planted to quantify its impact on increasing vegetation cover and biodiversity.

3.3 Model of Vegetation Area

The figure illustrates the vegetation area model constructed using linear regression.

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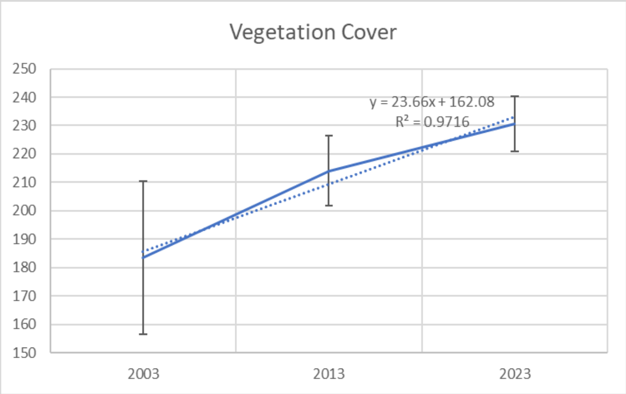

Figure 8: Model of Vegetation Area

Figure 8 shows the vegetation area model for Koronadal City in 2003, 2013, and 2023, showing a progression from (183.41 ± 46.53) km² in 2003 to (214.07 ± 21.45) km² in 2013, and further expanding to (230.73 ± 16.82) km² by 2023. The data shows a very strong positive correlation with an R-coefficient of 0.97 that showcases a positive trend in green cover expansion over the years, suggesting environmental resilience and effective management strategies. This aligns with research such as that conducted by Strohbach *et al.* (2013) [27], which emphasizes the potential benefits of minor green initiatives in urban areas, such as Boston, in enhancing biodiversity and improving the quality of life for residents. The observed increase in vegetation area underscores the potential effectiveness of such measures in promoting environmental sustainability and ecological balance.

IV. CONCLUSION

Satellite images from platforms like Landsat 7, 8, and 9 are essential tools in environmental and urban studies due to their ability to provide valuable data for research purposes. Additionally, the analysis of gathered and rendered satellite images from Landsat 7, 8, and 9 provides valuable insights into the changing landscape of Koronadal City. The visual representations reveal a significant increase in vegetation cover alongside a decrease in non-vegetated areas over the years, indicating shifts in vegetation dynamics due to ongoing land restoration efforts and successful reforestation initiatives. Moreover, the observed changes underscore the effectiveness of environmental conservation measures such as the Tree Growing Festival, emphasizing the Koronadal City government's commitment to preserving the environment and enhancing urban resilience. Lastly, the regression model, with an R coefficient of 0.97, suggests a very strong correlation, indicating that as the years increase, vegetation would also increase. Further, this model demonstrates a significant and consistent expansion of vegetation cover in Koronadal City from 2003 to 2023, highlighting the effectiveness of environmental management strategies.

V. RECOMMENDATIONS

In the course of the research, the researchers (1) suggest that site verification is essential to guarantee the accuracy and reliability of the captured satellite images. Additionally, (2) integrating Unmanned Aerial Vehicle (UAV) technology could enhance the innovation of the study. It is also recommended to (3) conduct tests on a minimum of five (5) satellite images or additional monthly images to verify the accuracy of the reported values for both non-vegetation and vegetation areas. Consequently, (4) exploring alternative satellite image providers with fewer cloud cover is advised to improve the assessment of Normalized Difference Vegetation Index (NDVI) within the QGIS application. Furthermore, the researchers (5) propose employing the linear regression model to forecast vegetation growth over the next decade.

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