Impact Assessment of Land Use and Land Cover Change of Agusan River Basin to Climate Using Geospatial Techniques And Regression Analysis

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Impact Assessment of Land Use and Land Cover Change of Agusan River Basin to Climate Using Geospatial Techniques And Regression Analysis

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Abstract: *This study utilizes Geospatial Techniques and Regression Analysis to examine the impact of Land Use and Land Cover changes on the climate dynamics of the Agusan River Basin. It analyzes the correlation between Land Surface Temperature (LST) and Normalized Difference Vegetation Index (NDVI) over a 20-year period from 2000 to 2020 with four (4) years interval. The study reveals a gradual negative trend in the LST-NDVI correlation, with notable spikes in 2004 and 2008, influenced by extreme temperature conditions linked to drought and El Niño. However, the trend increased in the years following 2012. The dominant land cover types in the basin are vegetation, barren land, built-up areas, and water bodies. This study contributes to a better understanding of the relationship between land use and land cover, and climate dynamics, aiding informed decision-making for sustainable land management and climate change adaptation strategies in the Agusan River Basin.*

Keywords: Land Surface Temperature; Geospatial Techniques; Regression Analysis; Agusan River Basin

1. INTRODUCTION

Lands (flood plains) adjacent to the Agusan River is very fertile that it attracted people to cultivate it as an agricultural area. However, human actions have altered the environment for countless decades. Local, regional, and global trends in modern atmospheric temperature records and other pertinent climatic indicators reveals the climate effects of these changes [1]. According to Chithra et. al., the changes from past to impervious land use patterns has provide numerous social and economic benefits. However, changes in the Land Use and Land Cover have shown significant effect on climate through various ways that modulate the land surface temperature (LST) and precipitation [2]. LST patterns provide useful information regarding the climate and can hence aid in understanding urban climate [3] [4]. Changes in atmospheric composition have been the main focus of human climate influences. By altering the physical properties of the land surface, land-cover change serves as a major forcing of climate, based on a considerable amount of research [5] [6]. In addition, the complex impact of land use and land cover change (LULC) on climate and weather is considered as a global environmental problem. [7].

2. MATERIALS AND METHODS

This chapter focuses on the determination of Land Use and Land Cover (LULC) and Land Surface Temperature (LST). It delves into the methods and techniques used to accurately identify and map LULC patterns and assess variations in LST across different areas.

2.1 RASTERIZED LULC DATASETS

This study incorporated the Land Use and Land over (LULC) maps as the secondary data source, which was obtained from the Center for Resource Assessment, Analytics, and Emerging Technologies (CReATe) in Caraga State University. The LULC data used Landsat 7 (2001-2012) and Landsat 8 (2013-2020) images to extract the spectral bands needed for our analysis. These maps represent the spatial distribution of different land cover classes in the study area for each specific year. LULC maps provide valuable information for various applications, including urban planning, environmental monitoring, natural resource management, and land use change analysis.

2.2 ACQUISATION OF LST

The source of our Metadata (Landsat 7 and 8) was downloaded from USGS website www.earthexplorer.usgs.gov from years 2000-2020. The data downloaded undergo several processes to determine its LST per year, including the following:

2.2.1 Cloud Masking

Cloud cover presents a notable challenge when it comes to obtaining precise LST estimates from optical remote sensing data, especially in conditions with cloudy skies. To enhance the accuracy of LST estimates, the researcher employed the used of cloud masks in conjunction with LST generation. This approach was adopted based on empirical evidence from a study referenced as [8]. The study's findings showcased promising results in reducing the Root Mean Square Error (RMSE) in an area known for its extensive cloud cover, by incorporating a cloud mask.

2.2.2 Preprocessing Satellite Data (SCP Plugin In QGIS)

The SCP plugin method used in this study was adopted from previous studies by [9] [10] and [11] to estimate land surface temperature in the study area. The SCP plugin is a Python-based plugin developed by Van Rossum in 2007, which integrates pre-processing features suitable for different kinds of satellite images, including Landsat 5 TM and Sentinel 2A [12]. The SCP plugin utilizes QGIS as remote sensing software to generate temperature maps from raw remote sensing images captured by Landsat-7 and Landsat-8 satellite sensors.

2.2.3 Gap Fill for Landsat 7 (Bands 3, 4, 6 (1&2))

The Landsat 7 Enhanced Thematic Mapper Plus (ETM+) instrument's Scan Line Corrector (SLC) posed a challenge in obtaining reliable data for studying Land Use and Land Cover (LULC) changes. Despite this, there has been ways to address the issue and use Landsat 7 data effectively. One such approach is the scan line correction technique, which fills gaps caused by hardware failure [13].

2.2.4 ArcGIS Cell Statistics (Mean Value of Thermal Bands)

This process involves calculating statistical measures such as mean, minimum, maximum, standard deviation, and sum of pixel values within a specified neighborhood of cells. The mean value of thermal bands obtained through the cell statistics process is a critical parameter for estimating land surface temperature. It helps to remove noise from the data and minimize the impact of atmospheric interference, thereby improving the accuracy of land surface temperature estimation

2.2.5 NDVI (Bands3&4)

NDVI (Normalized Difference Vegetation Index) is a commonly used index in studying vegetation status and health as well as the presence of green cover. This index is based on the principle that vegetation reacts to the absorption and reflection of red and near-infrared light. NDVI values range from -1 to 1, where a value of zero indicates the presence of urban areas, while a negative value is an indication of a water body. To measure the Normalized Difference Vegetation Index NDVI values of the data, method followed by [14] & [15] which uses the equation.

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

Where NIR is Near-infrared band (Bands 4 for Landsat7 and Band 5 for Landsat 8) and R means Red (Bands 3 for Landsat7 and Band 4 for Landsat 8)

2.2.6 Mosaic Upper and Lower Datasets

Mosaic Upper and Lower Datasets are created by merging multiple satellite images into a single image, which include thermal bands and NDVI data.

2.2.7 Proportion of Vegetation (PV)

Large fig PV was employed to differentiate between non-vegetated, partially vegetated, and heavily vegetated land surfaces, [16]. The degree of coverage of vegetation is calculated by the equation by [17]:

$$PV = \left(\frac{NDVI - NDVImin}{NDVImax + NDVImin}\right)^2 \quad (2)$$

Where PV is Proportion of vegetation, NDVImax is the Maximum values, NDVImin is the Minimum values and Square is the Squaring the formula.

2.2.8 Emissivity (E)

Land surface emissivity (ε) is a scaling factor that adjusts the blackbody radiance based on Planck's law to estimate the emitted radiance, [18] [19]. In order to accurately estimate LST, it is necessary to take into account the emissivity of the land surface. This is done through a process called emissivity correction, where the emissivity value obtained with the raster calculator of ArcGIS software and the following equation by [19]:

$$e = m\,Pv + n \quad (3)$$

Where e is Land Surface Emissivity, m is the value of emissivity of vegetation, (0.004), PV is the Proportion of vegetation, N is Soil emissivity value, (0.986) and E is 0.004 * PV + 0.986

2.2.9 LST Computation

The settling time formula, as applied to land surface temperature mapping using satellite information and ArcGIS software, was used in the study by [20].

$$\mathrm{LST} = \frac{\mathrm{BT}}{\left(1 + \left(\lambda * \frac{\mathrm{BT}}{\mathrm{C2}}\right) * \mathrm{Ln}\,(e)\right)} \quad (4)$$

Where BT is Brightness Temperature (°C), λ is Wavelength of emitted radiance, E is Land Surface Emissivity, C2 is given h * c/s = 1.4388*10-2 m, K is 14,388 mK, h is the Planck 's constant (6.626*10-34Js), s is Boltzmann constant (1.38*10-23 JK) and c is the velocity of light (2.998*108m/s)

2.3 ZONAL STATISTICS

Zonal statistics were used to calculate the average land surface temperature within different land use and land cover classes. We used the same process of overlaying our land use and land cover map with our land surface temperature map and employed the zonal statistics tool to compute the average temperature values within each land cover class. This approach allowed us to detect any patterns or trends that could be attributed to changes in land cover.

2.4 REGRESSION ANALYSIS

Regression analysis is a statistical technique used to investigate the relationship between a dependent variable and one or more independent variables, aiming to comprehend the impact of independent variable changes on the dependent variable. Regression analysis allowed us to determine the relationship between LST and NDVI, with LST being the dependent variable and NDVI being the independent variable.

3. RESULTS AND DISCUSSION

This chapter present the results and discussion, which are organized into three main sections: (1) Land Use Land Cover (LULC) of Agusan River Basin, (2) Acquisition of Land Surface Temperature in Agusan River Basin, (3) Linear Regression Model, and (4) Influence of LULC change to Temperature.

The researcher conducted an impact assessment of LULC in the Agusan River Basin, analyzing data from six intervals: 2000, 2004, 2008, 2012, 2016, and 2020. The focus was on four main land cover categories: Barren Land, Built-Up Areas, Vegetation, and Water.

3.1 LAND USE LAND COVER MAPS

These maps cover a 20-year period with 4-year intervals and provide a visual overview of LULC changes and associated temperature patterns. Each map has a Support Vector Machine (SVM) overall accuracy value, ranging from 95.00 to 98.75. The color scheme represents different land cover types: green for vegetation, brown for barren land, red for built-up areas, and blue for water bodies. The maps depict land cover changes in the Agusan River Basin from 2000-2020.

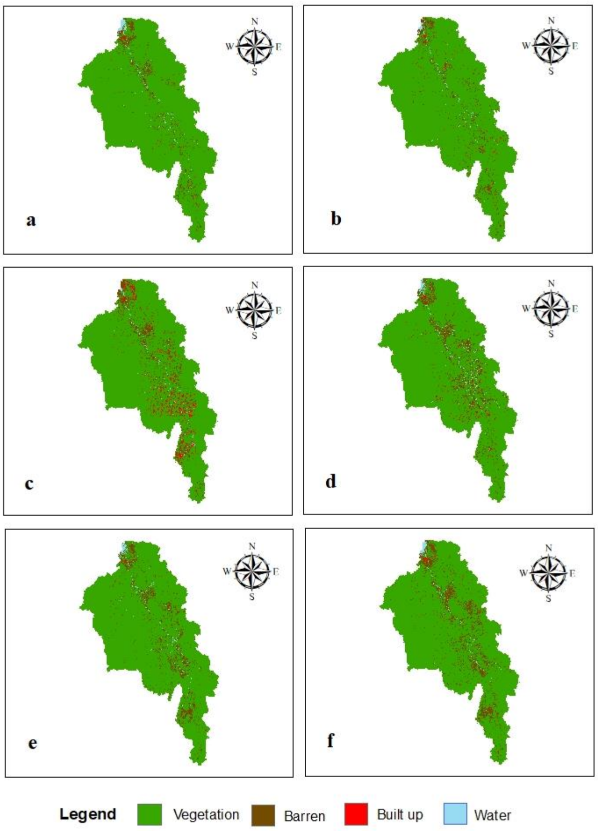

Figure 1. Land Use Land Cover
(a. 2000 b. 2004, c. 2008, d. 2012, e. 2016 f. 2020)

3.1.1. Area Distribution

Shown in the figure below is an overview of the distribution of areas for each land cover types in the ARB over the specified time period.

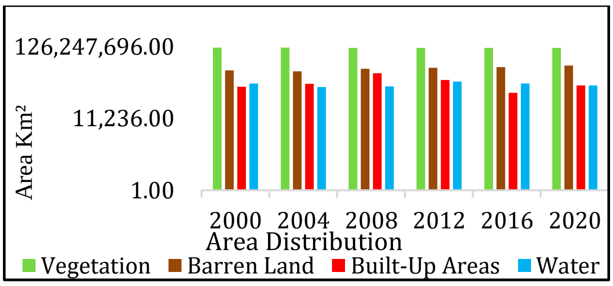

Figure 2. Area Distribution
(2000,2004,2008,2012,2016,2020)

Over the years, the land cover types in the Agusan River Basin have undergone changes over time. As shown in the figure 2, the vegetation covered a large area, primarily driven by agricultural activities, starting from 112,015,904.00 km² in 2000 and steadily increasing each year. However, there was a noticeable decrease in 2020, with an area of 108,582,750 km². Primarily, due to factors such ongoing environmental changes across the basin [21].

Barren land, representing areas with limited vegetation, had a smaller distribution compared to vegetation. It covered 5,824,416.00 km² in 2000 and reached its highest value of 10,955,376 km² in 2020, due to urbanization, land degradation, or desertification processes [22].

Built-up areas, associated with urban development, started at 711,152.00 km² in 2000 and increased to 813,110 km² in 2020. This growth attributed to urban expansion, infrastructure development, and population growth [23].

The water area experienced fluctuations over time. It had an area of 1,070,784.00 km² in 2000, decreased to 684,112.00 km² in 2004, due to drought or increased water usage. However, it showed an increase in 2008, reaching 736,893 km², which is a result of improved water management or precipitation levels. By 2020, it had further increased to 821,079 km², reflecting ongoing water-related challenges or changes in water resource management [24].

3.2 LAND SURFACE TEMPERATURE OF AGUSAN RIVER BASIN

Figure 3 shows maps of Land Surface Temperature (LST) using a color spectrum. Warmer temperatures are represented by red shades transitioning to yellow (42 to 22 °C), while cooler temperatures are depicted by yellow to green colors (21 to 0.99 °C). The LST changes reflect alterations in local climate conditions and highlight the diversity within the Agusan River Basin. The temperature variations indicate spatial heterogeneity influenced by factors like land cover, vegetation density, and land management practices.

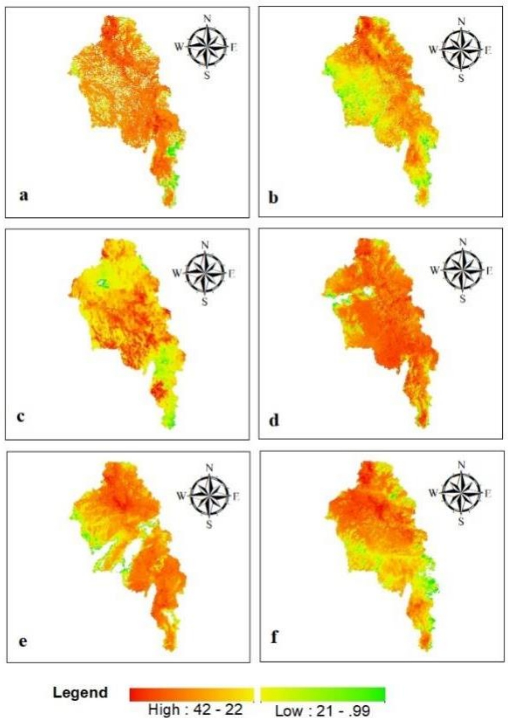

Figure 3. LST

(a. 2000, b. 2004, c. 2008, d. 2012, e. 2016 & f. 2020)

3.2.1 Minimum Temperature

Figure 4 illustrates the minimum temperatures for different land cover categories in the Agusan River Basin from 2000 to 2020. In terms of vegetation, the minimum temperature fluctuated from 0.99°C in 2000 to 2.20°C in 2016. Barren land exhibited variations from 1.48°C in 2000 to 5.40°C in 2012. Built-up areas experienced a range of minimum temperatures, starting at 1.96°C in 2000 and reaching 10.19°C in 2020. Water bodies displayed minimum temperatures between 1.96°C in 2000 and 11.13°C in 2020. These fluctuations highlight the dynamic thermal conditions within each land cover category.

A study by [25] emphasizes the impacts of deforestation on vegetation loss, affecting temperature dynamics in the watershed area. Another study [26] suggests that urbanized areas, with increased built-up cover, experience greater temperature increases. Implementing sustainable land management practices is crucial for maintaining a balanced ecosystem and regulating temperatures in the Agusan River Basin.

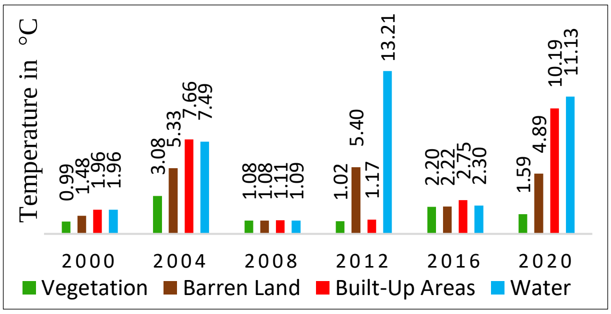

Figure 4. Minimum Temperature

3.2.2 Maximum Temperature

The Figure 5 depicts maximum temperatures for different land cover categories in the Agusan River Basin from 2000 to 2020. Vegetation exhibited an overall increasing trend, reaching a peak of 42.33°C in 2004 and slightly decreasing to 26.04°C in 2020. Barren land temperatures remained relatively stable, ranging from 30.28°C in 2000 to 26.10°C in 2020. Built-up areas experienced minor fluctuations, with temperatures ranging from 31.79°C in 2000 to 26.25°C in 2020. Water bodies showed fluctuations, peaking at 35.00°C in 2004 and decreasing to 24.88°C in 2020. These findings emphasize the significance of land cover changes in shaping temperature dynamics in the Agusan River Basin, with vegetation potentially moderating temperature and built-up areas exhibiting higher temperatures [27]. Proper land management practices and land cover choices play a vital role in shaping temperature patterns and local climate conditions in the region [2].

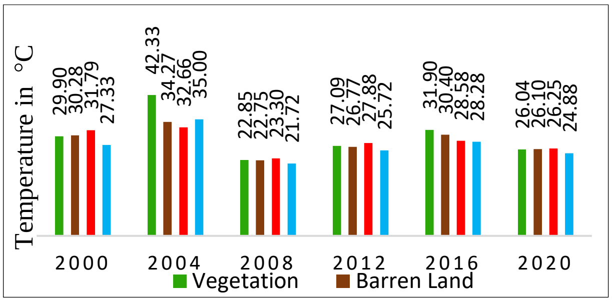

Figure 5. Maximum Temperature

3.2.3 Mean Temperature

In Figure 6, mean temperatures for four land cover categories (Vegetation, Barren Land, Built-Up Areas, and Water) from 2000 to 2020 are analyzed. Vegetation showed fluctuations, ranging from 14.89°C (2008) to 19.85°C (2016) These fluctuations suggest the complex interaction between vegetation cover and temperature regulation in the Agusan River Basin [28].

Barren land varied between 15.19°C (2008) and 22.09°C (2016). These fluctuations in barren land temperatures may be attributed to changes in land use and surface characteristics [26]. Built-up areas experienced changes from 15.34°C (2008) to 22.14°C (2016). These temperature changes in built-up areas can be attributed to urbanization, land development, and anthropogenic influences [26]. Water bodies demonstrated stability, ranging from 15.19°C (2008) to 21.13°C (2016). These findings suggest the buffering effect of water bodies, with their high heat capacity and ability to absorb and release heat gradually.

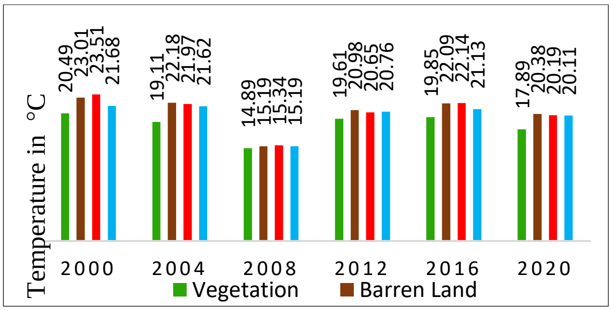

Figure 6. Mean Temperature

3.3 LINEAR REGRESSION MODEL

Linear Regression Analysis was utilized to model the relationship between NDVI and LST. NDVI assesses the amount and health of plant cover, whereas the LST measures land surface temperature.

The relationship between land surface temperature (LST) and the Normalized Difference Vegetation Index (NDVI) was examined for different years. Strong negative correlations were observed in the years 2000, 2012, and 2016, indicating that as NDVI increased, LST decreased. Moderate negative relationships were found in 2004 and 2008. The coefficient of determination (R^2) values ranged from 0.7828 to 0.9567, indicating that a significant portion of the LST variability could be explained by NDVI in each year. Overall, NDVI proved to be a significant predictor of LST variability in the study area. Moreover, our results are in line with previous studies of [29], which also reported a strong negative correlation between land surface temperature (LST) and vegetation surface. This indicates that surface characteristics play a significant role in controlling LST, further supporting the validity and relevance of our findings.

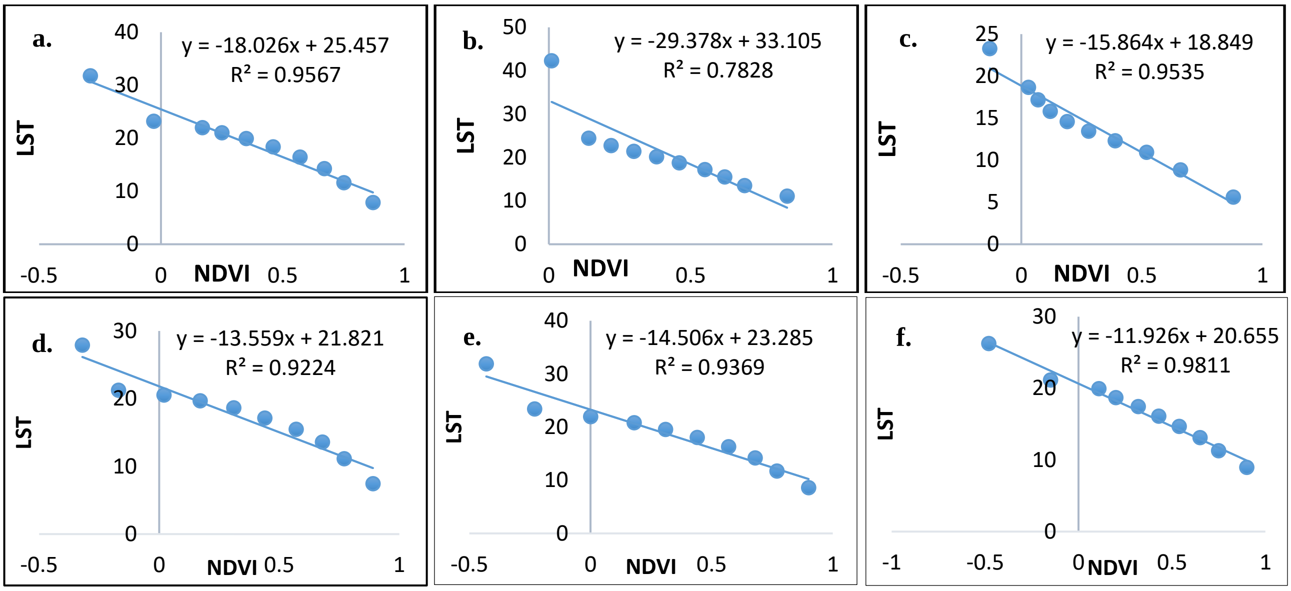

Figure 6. Linear Regression Model (a. 2000, b. 2004, c.2008, d. 2012, e. 2016, & f. 2020)

3.4 INFLUENCE OF LULC CHANGE TO TEMPERATURE

Land Cover Type	Influence of Land Use and Land Cover Change to Temperature
Vegetation	The mean temperature in vegetation-covered areas is 18.81°C. Over the span of 20 years (2000-2020), there has been a slight increase in temperature by 0.6°C, indicating a gradual warming trend. Additionally, there has been a decrease in the area covered by vegetation by approximately 3,433,154 km². This suggests that as the temperature increases, there has been a reduction in the extent of vegetated areas, indicating changes in vegetation distribution or land use practices that have led to a decrease in vegetation-covered regions.
Barren Land	The mean temperature in barren land areas is 20.79°C. Over the 20-year period, there has been pronounced temperature increase of 3.41°C. In line with this temperature rise, the area covered by barren land has increased by approximately 5,130,960 km².This indicates that as the temperature increases, there has been an expansion of non-vegetated areas, due to changes in land use practices such as urbanization or the conversion of vegetated areas to barren land.
Built-up Areas	The mean temperature in built-up areas is 20.63°C. Over the specified period, there has been a substantial increase in temperature by 8.23°C. Concurrently, the area covered by built-up areas has expanded by approximately 101,958 km². This suggests that as the temperature rises, there has been an intensification of urban development, resulting in an increase in built-up areas.
Water	The mean temperature in water bodies is 20.08°C. Over the 20-year period, there has been a significant increase in temperature by 9.17°C. However, area covered by water decreases of abou249,705 km². This suggests that as the temperature increases, there has been a reduction in the extent of water bodies, influenced by land use changes or water management practices.

4. CONCLUSION

In conclusion, the analysis of the correlation between Land Surface Temperature (LST) and Normalized Difference Vegetation Index (NDVI) in the Agusan River Basin reveals important trends and dynamics over the 20-year period from 2000 to 2020. The findings indicate a gradual negative trend in the correlation between LST and NDVI, suggesting a strong relationship between land cover and surface temperature. However, the analysis also highlights notable variations in the trends, particularly during the years 2004 and 2008, where an exponential negative growth is observed. The negative correlation is dependent on the time the data was captured, on the region and the season [28]. In some regions, the negative correlation may be more evident during certain seasons, such as summer, when vegetation is actively growing and temperatures are higher. However, during dry seasons, the correlation may weaken or even reverse due to different factors influencing temperature and vegetation patterns. And on other studies, the negativity between LST and NDVI is stronger in wet seasons [29]. Overall, the negative correlation between LST and NDVI is not consistent across different regions or time periods and can vary depending on the season and time of day [30]. These reports further validate the influence of weather patterns on the relationship between variables and highlight the importance of considering specific climatic conditions, but the overall 20-year trend indicates a negative correlation. The result in this study also shows that different land cover exerts distinct influences on temperature patterns as land cover areas change. Vegetation exhibits a cooling effect, with extensive coverage and lower average minimum temperatures, indicating its potential for temperature regulation and ecosystem services. In contrast, barren land areas experience relatively higher temperatures due to the absence of vegetation, while built-up areas display slightly elevated temperatures, potentially influenced by the urban heat island effect. Water bodies contribute to milder temperatures owing to their high heat capacity and acting as heat sinks. These insights into the spatial distribution of land cover types contribute to a better understanding of the impact of land use and land cover changes on the basin's climate and ecosystem dynamics.

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