ANALYSIS OF THE EFFECT OF LAND USE AND LAND COVER CHANGE ON SURFACE TEMPERATURE IN RWANDA DURING LAST THREE DECADES: CASE STUDY OF BUGESERA DISTRICT.

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Analysis of the effect of Land Use and Land Cover change on surface temperature in Rwanda during last three decades,

The case study: bugesera district.

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DECLARATION

I,MUKAZARUKUNDO Clarisse declare that this dissertation holds my own work except where specifically acknowledged.

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DEDICATION

The present work is dedicated to my family especially my husband NTAKIYIMANA Isaïe who was there for me in everything along this journey.

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ABSTRACT

Land Use and Land Caver has significant influence on climate elements such as temperature,

Precipitation, humidity etc, and it has great impact directly to the change of mentioned climate elements especially temperature which are measures of climate change.

The data utilized during this research are the recorded temperature (ENACTS) dataset from Rwanda Meteorology Agency (Meteo Rwanda) from 1991 to 2020, and Land Use and Land Cover images (Landsat images) generated by the US Geological Survey (USGS). To examine the trend in temperature variability, the study used graphical and statistical approaches.

The trend results from graphical method indicate that there is temperature variability and Statistical approaches indicate that there is enough evidence from statistics for deciding that there is a significant increase both maximum and minimum temperature trend over Bugesera excepting SOND season which indicate a non-significance decline.

The results indicated a coefficient of variation of 1.951% in maximum and 4.706% in minimum temperature of JJA season, a coefficient of variation of 2.742% in maximum and 4.807 in minimum temperature of JF season, a coefficient of variation of 2.143% in maximum and 4.092% in minimum temperature of MAM season, a coefficient of variation of 2.274% in maximum and 4.126% in minimum temperature of SOND season, a coefficient of variation of 1.387% in maximum and 3.959% in minimum annual temperature. Based on these result of coefficient of variation from different seasons, the minimum temperature varies more than maximum temperature.

LIST OF SYMBOLS AND ACRONYMS

ENACT: Enhancing National Climate Services

LULC: Land Use Land Caver

JJA: June, July, August

JF: January, February

MAM: March, April, May

SOND: September, October, November, December

IRI: International Research Institute

GEE: Google Earth Engine

SD: Standard Deviation

LST: Land Surface Temperature

PA: Producer Accuracy

UA: User Accuracy

OA: Overall Accuracy

KC: Kappa Coefficient

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CHAPTER ONE

I.1 INRODUCTION

Land Use and Land Cover is becoming more and gigantic challenges both at local and global Scales[1]. It is also a critical issue in Rwanda from the time when the yearly population growth rate is 2.4% in 2019, the population was 12 million and they are expected to be almost 22 million in 2050, with an assumed population growth rate of nearly 2%[2], according to this growth rate of population and the surface area of 26340 km^2 which is remained constant several years, Rwanda is rapidly urbanizing in comparison to the rest of regional countries which is considerably has great impact on land use by increasing residential, infrastructures and industrial uses in return increase temperature as well. Rwanda is composed by 5 provinces, those provinces are composed by 30 districts including Bugesera which is located in Eastern province, the surface area of Bugesera is dominated by vegetation of dry savannas, prolonged droughts are frequent in that area and they have been severe in the region, throughout drought period at the end of the year 2005, the vegetation stress was detected, the surface area of bugesera district is $1337km^2$ and its elevation belongs between 1300m and 1667m [3]. Because of increase human pressure on the natural vegetation, a huge part of Bugesera forests have been converted into cultivated domains and settlements, the climate of Bugesera varies from hottest to driest of the country, it have mean temperature of 21^OC [4].In general, the surface area of Rwanda is covered by the forests, buildings, Lakes, Rivers and crops. Between 1958 and 1978, the surface area of Nyungwe mountain forests was reduced from 19114,125 ha to 97,138 ha due to clearing of the forest, approximately 17,000 ha in 22 years, in other words it was reduced by 15% of the forests surface area and Akagera National Park's surface was reduced from 331,000 ha in 1956 to 255,000 ha in 1992 the park now has a surface of 90,000 ha [5].If population is keeping growing, it will contribute to the reduction of forest cover which in turn will reduce rainfall and contribute to the rise of greenhouse gases by removing the CO2 sink. Forest destruction restricts the normal recycling of moisture from soils, through vegetation, and into the atmosphere, where it returns as rainfall, and cutting forests increase emission of CO2 into the atmosphere, which contributing to increasing temperatures worldwide [6].

LULC is similarly considered as the sources of detected global warming in different region especially in Rwanda [7] and it has been recognized that the earth's increase of temperature is not only caused by the increase of greenhouse gases but also to urbanization and other climatic factors [8].The urbanization rate is expected to increase about from 16.5% in 2012 to 30% in 2030 so the urban population will increase faster than rural population [9] this will cause the change of temperature in urban places. The change of climate and worldwide warming are the most serious problem the world is facing in our day. According to current research, the world's surface air temperature increased by 0.6 ^{0}C to 0.8 ^{0}C throughout the twentieth century, along with changes in the hydrological cycle. This has alerted the global population and attracted the interest of climate experts, resulting in many studies on climate variability at various scales [7], and the temperature extreme occurrences, both hot and cold, have gotten a lot of attention in the literature because of the negative effects they have on society. [10].It has also been demonstrated that changes in mean temperatures may be associated to changes in severe events, which are more directly related to the effects of climate on human society and the environment, and one of the cause of the raising global mean temperature is human activities [11].The Intergovernmental Panel on Climate Change came to the conclusion that anthropogenic effects have undoubtedly impacted the world's climate, with one effect being a 0.7°C rise in global mean temperature since the second half of the nineteenth century, and a rise in mean surface temperature certainly leads to a raise in extreme events. [12]. It is observed that most regions of Africa experienced a significant increase in temperature with the northern and Southern parts exhibiting higher temperatures in the months of June and August from 1995 to 2010 compared to 1979 to 1994 while December to February the increase was indicated over the northern part with high increase observed especially during the decade of 2001 to 2010[13]. A further research on monitoring land surface temperature in Bahir Dar in Ethiopia and its surrounding areas by using Landsat images found that land surface temperature is a huge issue caused by urbanization and the significant changes in land use and land cover that it entailed[14]. An analysis of the pattern of land use land cover change and its impact on land surface temperature, conducted in Dhaka, has revealed that rapid urbanization has a significant impact on urban land use land cover and increases land surface temperature [15]. The research done on how will Rwandan Land Use and Land Cover Change under High Population Pressure and Changing Climate has shown that the existing trend of LULC change will continue for the next 30 years, and the future LULC pattern will exhibit a trend in which cropland area will increase in the west and grassland area will decrease, whereas grassland area will increase in the east and cropland area will decrease[16].There is another research on Modeling Rainfall-Runoff Response to Land Use and Land Cover Change in Rwanda (1990–2016) which has shown that Natural grassland and forests in Rwanda experienced an important conversion to agricultural land and built- up areas[17]. A research done on Assessment of Land Cover Change using Landsat Data in the satellite city Area of Runda in Southern province of Rwanda showed that Runda satellite city has experienced a rapid increase of settlement between 1990 and 2017 which is the result of some population migrated from Kigali to Runda and this is the key drivers of the detected changes on Land Cover Land Use patterns in the study area[18].Other study on assessing spatial-temporal changes of land use in Runda reveal the increase of built up area caused by population growth especially in Ruyenzi cell within 16 years only[19].According to a study conducted in different districts of western province in Rwanda namely Ngoma, Rwamagana, Kayonza, Bugesera, on Employing Remote Sensing Tools for Assessment of Land Use and Land Cover (LULC) Changes, has shown that there is Land use and Land cover (LULC) changes that were detected in that area in 15 years from 2005 to 2020[20]. Further research that has been conducted on Spatial Assessment of Urban Growth on Green Spaces in Kicukiro, Kigali, Rwanda indicated that significant decrease in green space with an increase in the built-up areas in the period of 2000 – 2021[21].

Recent studies on land use and land cover change have focused on different party of Rwanda (**16 - 20**) and Kigali[21]. However, none of these studies investigated the effect of land use and land cover change on surface temperature in the Bugesera District. Therefore, it is very important to analyze the effect of Land Use and Land Caver change on surface temperature in Bugesera district which will inform on land use planning, environmental protection and implementation of sustainable mitigating measures [14].

I.2 STATEMENT PROBLEM

Land Use and Land Caver influencing change in surface temperature like urbanization in which rises the temperature in cities and in recurrence affect rainfall and winds patterns, deforestation causes the raising of temperature and reduction of rainfall while afforestation may be one of the solution of global warming, particularly in previous years, the Bugesera District experienced many changes in the use of the land [22]. This urbanization is caused by people looking for inexpensive land for residential buildings places, the districts bordering Kigali City and those hosting secondary cities are particularly impacted. Similarly, the conversion of agricultural land into residential purposes is the outcome of overpopulation of Muyumbu in Rwamagana, Nyamata in Bugesera, and Shyorongi in Rulindo district [23], As a result of this condition, Bugesera is subject to climate change, as seen by the unpredictability of surface temperature.

The majority of Rwandan studies on the impact of Land Use Land Cover on local climate have been limited to Kigali, but none of these studies have evaluated the impact of Land Use Land Cover on climate change in Bugesera District, which is similarly affected by climate change. The present research will look into the effect of land use land cover on temperature at the surface in Bugesera District of Rwanda's eastern province.

I.3 OBJECTIVES

The major objective of this research was the analysis of the effect of Land Use and Land Cover change on surface temperature in Bugesera.

The following three specific objectives have been achieved in order to accomplish this major objective:

1. To assess the variability in temperature over Bugesera in last three decades.
2. To investigate the changes in Land Use and Land Cover in the study period over Bugesera District.
3. To analyze fundamental relationship between Land Use and Land Cover and surface temperature changes in Bugesera.

I.4 HYPOTHESIS OF THE STUDY

Temperature over Bugesera, Rwanda has experienced the variability, caused by Land Use and Land Caver change. That variability is to be expected to continue even in the future.

I.5 JUSTIFICATION OF THE PROBLEM

The impact of change in climate and worldwide warming are two most serious issues confronting the globe today. Temperature variation is a crucial indicator of climate change. Rwanda has highly density of population and they are still increasing day to day, the residential place is also increasing, the urbanization in cities are unavoidable, the sector of industry is keep growing which will lead to the deforestation followed by the increase of temperature.

This research will identify the possible contribution of Land Use Land Cover change on surface temperature, and give recommendations to the possible strategies of mitigation and adaptation of change in temperature in Bugesera.

I.6 STUDY AREA

Bugesera district is located in the south-east of Rwanda's Eastern province, between 2°01'55" S and 2°24'45" S of latitude, and 29°56'50" E and 30°23'19" E of longitude. The whole area of this District is 1,303 Km^2. This territory is limited in the north by the River of Nyabarongo, in the west by the River of Akanyaru, and in the south by the Republic of Burundi from which is separated in the south-east by Lake of Rweru and the south-west by Lake of Cyohoha. It is also bounded by Ngoma, Rwamagana, Kicukiro, Nyarugenge, Ruhango, and Nyanza districts.

I.6.1 Topography

The Bugesera region is a huge plateau with elevations ranging from 1,300 to 1,667 meters. It is bounded by the Nyabarongo's fluvial depositions. The topography is not very broken, with half of the area having extremely mild slopes and the sharpest ranging from 25 to 55%. The minimum elevation is 1,321 m and the maximum elevation is 1,744 m [4].

I.6.2 Temperature climatology of Bugesera.

Because of its rainfall limitations, the climate of Bugesera District ranges from the hottest to the driest in the country, with an average temperature of 21°C.[4]

CHAPTER TWO

II.0 LITERATURE REVIEW

II.1 Climate variability

Significant rising temperature trends were detected in all of Africa, the Northern Hemisphere Africa, the Southern Hemisphere Africa, tropical Africa, and subtropical Africa. In the months of June and August, locations in both North and South Africa experienced significantly warmer temperatures in the 1995-2010 periods than in the 1979-1994 periods. However, significant warmth was centered in northern Africa from December to February. When the two most recent decades are compared to the period 1979-1990, warming is evident over these same regions, with the most recent decade, from 2001 to 2010, being the most intense [13].

Climate change has become a social, economic, environmental, and political challenge for humanity at the local, regional, and global levels in recent years. The various effects of climate change, exacerbated by rising average global temperatures, endanger people's lives in practically all sectors of the EAC region's economies [24].

The research on minimum and maximum temperature in Congo-Brazzaville from 1932 to 2010 revealed an increase of roughly 1 °C in Brazzaville over the period 1960-1990, with values ranging from 0.6 °C to 1.6 °C across the remaining part of the entire country. It has been established that climate fluctuations and shifts occurred throughout West and Eastern Africa during the twentieth century.[25].

Global climate change has been recognized to be one of the most important environmental problems. The greatest immediate and direct impact of variability in the climate and change on public health is the stable increases in global surface temperature, which is accompanied by an increase in the frequency, severity, and duration of heat waves.[26].

A further research on monitoring land surface temperature in Bahir Dar and its surrounding areas using Landsat images found that land surface temperature is a huge issue in the world since it influences climate and the environment at the local, regional, and global levels. It was primarily caused by urbanization and the significant changes in land use and land cover that it entailed. As a result, land use monitoring is essential. Land cover change is an important factor in understanding Land Surface Temperature variation and implementing sustainable mitigating methods [14].

Global atmospheric temperature is expected to increase around 4 degrees Celsius by 2080, in line with a doubling of atmospheric CO2 concentration. The efficiency of photosynthesis increases to a maximum and then falls as temperature rises, while the rate of respiration increases more or less until a plant dies. In response to global warming, the hydrological cycle is expected to accelerate as rising temperatures increase the rate of evaporation from land and sea. Temperature estimates in Rwanda indicate that the country's temperature will rise by 1 to 2.5°C between 2000 and 2050, and another 1 to 6°C by 2100. The rise is predicted to remain steady across the country and across seasons, with the exception of the protracted dry season may be marginally higher than in other seasons. Aside from impacting crop yields, this will make previously malaria-free highlands increasingly sensitive, if not highly appropriate, for malaria over the next several decades12, with populations at risk increasing by 150% by 2050.[27].

II.2 LULC change

Rapid population increase in West Africa has put growing strain on natural resources, resulting in visible changes in land cover and land usage. However, quantitative evaluations of land cover change over extended time periods and at the regional scale that are spatially explicit and thematically detailed have been sparse. Change intensities quickened and increased from dry to sub-humid sub-regions through time, as did population densities. The area inhabited by human-dominated land cover categories has more than doubled from 493,000 km^2 in 1975 to 1.1 million km^2 now. 1,121,000 km^2 in 2013 [28].

A study on Assessment of land use/land cover changes and their impacts on land surface temperature in Bangui (the capital of Central African Republic) observed a considerable change in Land Use land cover in 1986 and 2017, particularly extended in vegetation and built-up areas while declining in bare soil. The mean Land Surface Temperature of built-up regions increased from 26.21 °C in 1986 to 27.59 °C in 2017. Furthermore, the mean Land Surface Temperature of bare soil increased from 26.51 °C to 27.33 °C between 1986 and 2017. These indicate that built-up and bare land has higher LST than vegetation and water bodies. [14].

Another study, Impact of urbanization and land-use change on climate, conducted by Cai, Eugenia Kalnay, and Ming from the University of Maryland, found that the most significant human activities caused impacts on climate are greenhouse gas emissions and changes in land use, such as urbanization and agriculture. Both greenhouse emissions and land use change tend to elevate the daily average temperature at the surface [29].

It was established in the mid-1970 that land-cover change impacts surface albedo and consequently surface-atmosphere energy exchanges, which affect regional climate. Terrestrial ecosystems were highlighted as carbon sources and sinks in the early 1980, emphasizing the impact of land-use/cover change on global climate through the carbon cycle [30].

Population growth and economic development have had a significant impact on Rwanda's land use/land cover (LULC) pattern in recent decades. In accordance with analyses conducted in Rwanda in 1990, 2000, 2010, and 2015, it was revealed that LULC change in Rwanda predominantly consisted of an overall decrease in forest area and a growth of agricultural area, with a slight increase in grassland area and a yearly increase in urban land area [16].

CHAPTER THREE

III.1 DATA

III.1.1. Station data

The temperature data used to conduct this research were obtained from the Rwanda Meteorology Agency (Meteo Rwanda). Meteo Rwanda generated the dataset in collaboration with the International Research Institute for Climate and Society (IRI), and it is recognized as Enhancing National Climate Services (ENACTS) data set. ENACTS has a spatial resolution of 0.05 degrees (5km) for temperature [31]. It should be noted that the ENACTS gridded data includes the entire country [32]. Mean of seventy-nine grid point was considered and presented in the Figure 3.

III.1.2 Land Use and Land Cover data

The data of Land Use Land Cover (Landsat images) was generated by US Geological Survey

(USGS) and was used to analyze the possible change in land use land cover.

III.2 METHODOLOGY

Temperature behavior over Bugesera was evaluated using statistical methods. The Mann Kendal and Sen's slope estimators have been used in this study. Remote sensing technics through Google Earth Engine (GEE) platform was used to classify and analyze Landsat images using Python tool, the change detection and calculation of gain and loose methodology was also used.

III.2.1 Temporal Trend Analysis

A trend represents a time series' long-term movement. There are numerous approaches for defining trends in climatological data. These approaches are classified into several categories, including graphical, polynomial, and statistical methods. The trend analysis in this work was conducted using a graphical plot, and statistical methods were utilized to examine the statistical significance of the observed patterns in a time series [33].

This approach was used to examine the seasonal and annual temperature variations in Bugesera, Rwanda. The seasonal to annual temperature analysis involved determining the seasonal and annual temperature climatology.

III.2.1.1 Graphical Method

The data of different seasons from June to August (JJA), January to February(JF), March to May (MAM), September to December (SOND) and annual temperature are presented versus time in the graphical approach. The positive aspect of this approach is the way it facilitates rapid visual evaluation of an existing trend in a specific time series. Furthermore, the graphical method for trend analysis is straightforward to apply. Moreover, graphic approaches have limitations such as subjectivity because it relies on each person's opinions and some data sets disappear because of the smoothing procedures [32].

III.2.1.2 Statistical Method

To examine the statistical significance of observed trends in a time series, statistical methods had been applied. Time series of temperature were pre-whitened before the Mann-Kendall trend and Sen's slope estimator analysis were applied. A similar method has been applied in different research [34].

These methods are categorized as parametric or non-parametric tests. The Mann-Kendall (MK) test was used in the present research to evaluate the nature of the trend of a given time series [24], [5]. The MK test has been applied to several studies in different areas, including Rwanda. Positive numbers indicate an upward trend, while negative numbers indicate a declining slope [27], [5] [28]. Theil-Sen's slope estimator has been applied for estimating the magnitude of temperature change [28].

The test computes the Kendall Z and S statistics values, which show an increasing trend when positive and a declining trend when negative [28]. We can evaluate the level of significance of the trend using the significance level (α), observing that if the p-value (probability value) of the data is greater than the significance level, we can claim that the null hypothesis H0 is satisfied and there is "no trend." The alternative hypothesis H1 will demonstrate a trend in the series, with findings indicating that the p-value is less than the significance level (α).

III.2.1.3 The Non-Parametric Mann-Kendall Test [35],[36]

The following formula is used to compute the Mann-Kendall statistic test S:

$$S = \sum_{i=1}^{n-1} \sum_{j=i+1}^{n} sgn(xj - xi)$$

Where n is the number of data points, xi and xj are the data values in the time series i and j, in which (j >i) and (xj - xi) respectively are the sign functions as:

$$sgn(x_j - x_i) = \begin{cases} 1 \; if \; xj - xi > 0 \\ 0 \; if \; xj - xi = 0 \\ -1 \; if \; xj - xi < 0 \end{cases}$$

The next equation was applied for determining the variance

$$VAR(S) = \frac{1}{18}\left[n(n-1)(2n+5) - \sum_{p=1}^{q} ti(ti-1)(2ti+5)\right]$$

The number of related groups is presented by q, and the number of data values in the pth group is presented by p.

The numbers of S and VAR(S) were utilized for computing the test statistic Z as follows:

$$Z = \begin{cases} \frac{S-1}{\sqrt{VAR(S)}} & if \; S > 0 \\ 0 & if \; S = 0 \\ \frac{S+1}{\sqrt{VAR(S)}} & if \; S < 0 \end{cases}$$

The Z value is used to determine the existence of a significant statistical trend. A Z number that is positive or negative implies an increasing or decreasing trend. The distribution of the statistic Z is normal. To test both an upward and downward monotone trend (a two-tailed test) at α level of significance, H0 is rejected if the absolute value of Z is greater than Z1- α/2, where Z1- α/2 is obtained from the standard normal cumulative distribution tables.

The statistical significance was identified on level of significance α = 0.05 in JJA, JF, MAM and annual maximum temperature while the trend of SOND indicate a decline but not significant. For minimum temperature the annual and all seasons trends are significantly increase at 0.05 significant levels.

III.2.1.4 Sen's method [35][36]

Sen developed this test for the purpose of evaluating statistical linear relationships, it has been utilized for determining the magnitude of trends in long-term historical information. Sen's slope is considered to be stronger for detecting linear relationships because it is unaffected by outliers in the data.

Sen's slope Estimator has the following equation:

$$Q_i = \frac{Xj - Xj}{j-1}$$

where i =1 to n + 1, j = 2 t n, x_j and x_i are data values at time j and i (j > i), respectively. If in the time series, there are n values of x_j, estimations of the slope will be N = n (n - 2)/2. The slope of the Sen estimator is the mean slope of such slopes' N values.

The Sen's slope is: $Q_{ij} = \begin{cases} \frac{Xj-Xi}{j-1} & if\ n\ is\ odd \\ \frac{1}{2}\left(Q\,\frac{N}{2} + Q\left[\frac{N+2}{2}\right]\right) & if\ n\ is\ even \end{cases}$

Positive (Qi) values imply a trend that was increased, and negative Qi values show a decreasing trend in the temporal data. The slope magnitude per year is the unit of Sen's slope (Qi).

In this research it shows that there are negative and positive Qi in different season at different timescale which means that in the study present there are negative and positive trends in which present increase and decrease of maximum and minimum temperatures.

III.2.1.5 Mean

A variable's mean is defined as the total of its observations divided by the number of observations. If the variable has n values x1, x2 ,... x_n, the mean is given by:

$$\text{Mean} = \frac{x1+x2+x3+\cdots xn}{n} = \frac{1}{n}\sum_{i=1}^{n} xi \text{ [37]}$$

III.2.1.6 Standard Deviation [37]

The standard deviation (SD) is a statistics that measures the variability of a dataset compared to its mean, a SD that is low means that the values tend to be very close to the mean of the set, whereas a high SD shows that the values are dispersed out over an extended range, it is the square root of the variance and is given by:

standard deviation SD = $\sqrt{\frac{\sum_{i=1}^{n}(Xi-\bar{x})^3}{n}}$ this is population Standard Deviation

sample standard deviation s is given by

$$s = \sqrt{\frac{\sum_{i=1}^{n}(Xi-\bar{x})^3}{n-1}}$$

III.2.1.6 Coefficient of Variation [38]

The coefficient of variation (CV) evaluates the variation of a series of values regardless of the measuring unit used; it is indicated by CV and provided by:

CV = $\frac{S}{M}$ where S represents the standard deviation and M represents the mean.

The coefficient of variation is frequently represented in percentage, which corresponds to the equation below:

Coefficient of Variation = $\frac{S\times100}{M}$

III.2.1.7 Remote sensing technics

Remote sensing technology and method have progressed considerably over the last three decades to encompass a suite of sensors working at an extensive range of image sizes of possible interest and value to planners and land managers. When combined with the readily accessible nature of historical remote sensing data, data cost reductions, and higher resolution from satellite platforms, remote sensing technology seems ready to have a bigger effect on planning agencies and land management initiatives responsible for monitoring land cover and land use change at various spatial scales. Recently, remote sensing technology allows data collection and analysis of ground-based, atmospheric, and Earth-orbiting platforms, as well as connections to GPS data, GIS data layers and functions, and developing modeling capabilities. As a result, remote sensing has become a useful source of land cover and land use information [39].

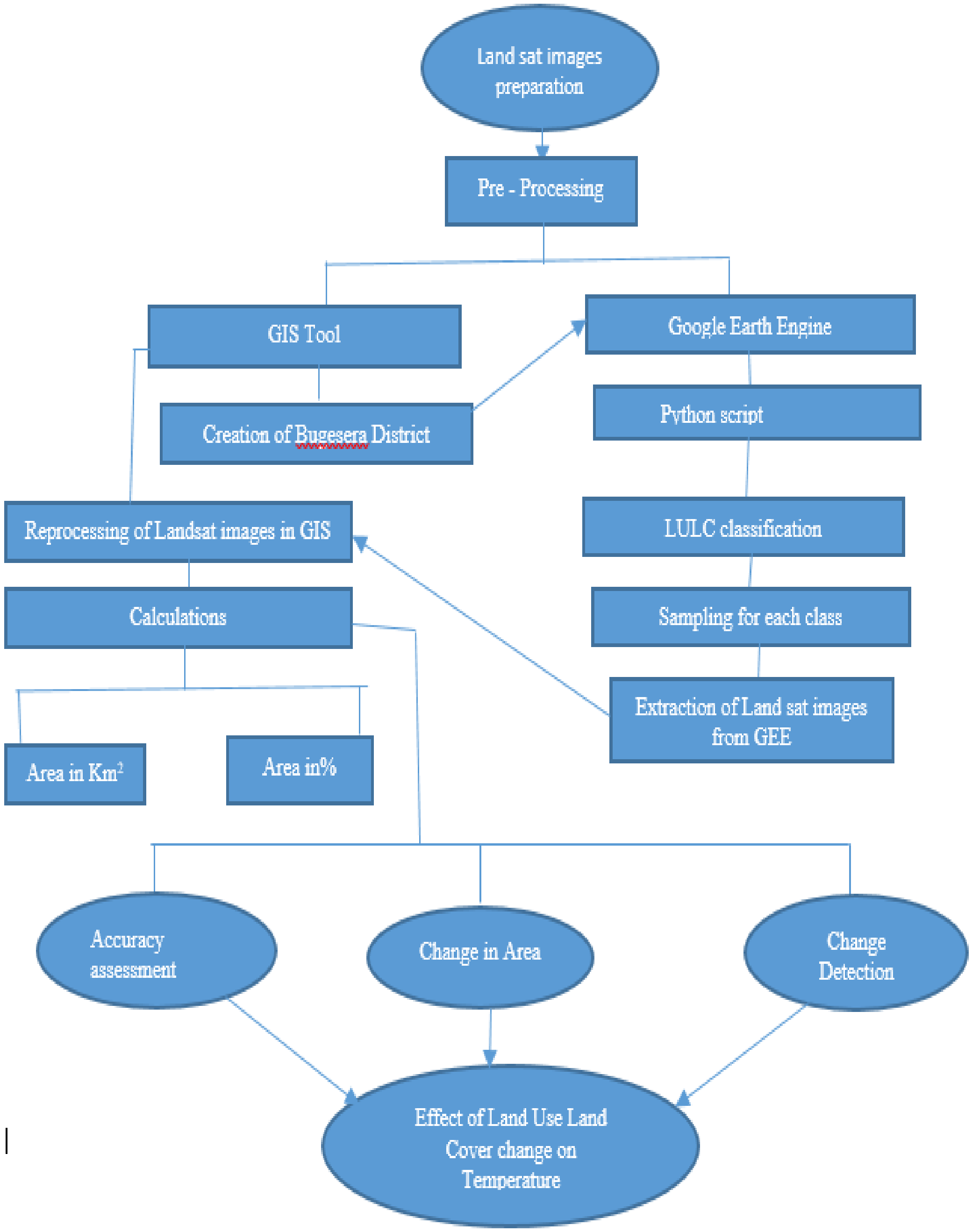

Figure 1: LULC methodology

CHAPTER FOUR

VI.0 RESULTS AND DISCUSSION

VI.1 CHARACTERISTICS OF TEMPERATURE IN BUSGESERA

This chapter highlights the findings from the various strategies applied for achieving the study's objectives. The outcomes include the observed annual mean temperature, June to July season's mean temperature, January to February season's mean temperature, March to May season's mean temperature and September to December's mean temperature. Several statistical measures were performed for assessing the behaviors of temperature in Bugesera distrist such as mean, Standard Deviation, coefficient of variation and time series. Another result from analysis of different land sat images from GEE, and different calculations for LULC changes.

VI.1.1 Mean temperatures

The result for annual mean temperature indicates that the average yearly maximum temperature is 27.663 degrees Celsius, while the average yearly minimum temperature is 15.537 degrees Celsius. JJA mean temperature are 28.052˚C and 15.192˚C, JF mean temperatures are 27.838˚C and 15.378˚C, MAM mean temperature is 27.102˚C and 15.846˚C and SOND mean temperature is 27.707˚C and 15.641˚C for maximum and minimum temperature, respectively.

The maximum temperature's highest mean is 28.052 C found in JJA while the lowest is 27.102˚C found in JJA. is the MAM which has an elevated mean of minimum temperature around 15.846 Celsius degrees and lowest Mean temperature is 15.192˚C found in JJA in minimum temperature. This means that the JJA season has the smallest minimum and biggest maximum mean temperatures in Bugesera.

VI.1.2 Standard Deviation

On average of very year's maximum and minimum temperatures deviate from long term mean by 0.384˚C and 0.615˚C, while JJA deviates by 0.547˚C and 0.715˚C, JF Standard Deviation is 0.763˚C and 0.739˚C, MAM Standard Deviation is 0.581˚C and 0.649˚C, SOND Standard Deviation is 0.63˚C and 0.645˚C, respectively.

The maximum SD is 0.763 ˚C found in JF and minimum SD is 0.384˚C found in annual in maximum temperature while the maximum SD is 0.739 ˚C found in JF and minimum SD is 0.615˚C found in annual in minimum temperature.

VI.1.3 Coefficient of Variation

The JJA season shows a coefficient of variation (CV) of 1.951% and 4.706% for maximum and minimum, the CV of JF is 2.742% and 4.807% for maximum and minimum respectively, the CV of MAM is 2.143% and 4.092% for maximum and minimum temperature, SOND coefficients of variation are 2.274% and 4.126% for maximum and minimum temperatures, respectively. Finally, the CV of yearly temperature is 1.387% for maximum and 3.959% for minimum temperatures.

The lowest CV is 1.387% founded in annual temperature while the highest CV is 2.274% founded in SOND season for maximum temperature.The annual maximum temperature indicates a CV of 3.959% while highest CV is 4.807% during JF for minimum temperature. The result of CV indicate that minimum temperature have higher variation than maximum temperature. All those result are summarized in the table 1.

VI.1.4 Trends analysis

VI.1.4.1 Trends analysis for Maximum Temperature

The present research used Mann Kendal non-parametric method to analyse the trends but Sen's slope estimator was used to determine the amplitude of the trends and test their significance at 95%. Many researchers have previously employed the 95% confidence level, which proved to provide sufficient statistical evidence for concluding that there has been an important increase or decrease in temperature.

Based on a research that have done on Trend Analysis of the Mean Annual Temperature in Rwanda that have showed that annual mean temperature indicated non-significant cooling trend during the period from 1958 to 1977-1979 while a significant warming trend was observed for the period after the 1977- 1979 where Kigali, the Capital of Rwanda, presented the highest values of the slope (0.0455/year)[7].

The result of this research reveal that once a year maximum temperature has significantly augmented by 0.011^{o}C, while JJA, MAM, and JF seasons has significantly increased by 0.027^{o}C, 0.014^{o}C, and 0.03^{o}C, respectively. On contrary, SOND season indicate a non-significant decline in maximum temperature of 0.004^{o}C per season. The decadal trend analysis shows that the last two decades experienced a high increase in Maximum Temperature than the first decade of the study period as shown in the figure 1.

VI.1.4.2 Trends analysis for Minimum Temperature

A recent research on Trends and Variability in Temperature and Related Extreme Indices in Rwanda has showed that the positive trend of 0.170C/decade and 0.20^{0}C/decade in minimum temperature, respectively, for the JJA season and SOND season, In general, maximum temperature represents higher variability compared to the minimum temperature [41].The present research has found that the annual minimum temperature has significantly amplified by 0.03^{o}C, however the JJA, MAM, JF and SOND seasons has significantly increased by 0.04^{o}C, 0.03^{o}C, 0.05^{o}C, and 0.03^{o}C, respectively.The result indicates that the minimum temperature has high increase trend than maximum, generally all seasons has positive trend and the 3^{rd} decade has high increase in trend than others.

VI.2 LAND USE LAND COVER CHANGE ANALYSIS

VI.2.1 LULC change in %

The result form LULC changes analysis through Land sat images from Google Earth Engine indicate that in 1990 there was a very small built up area, followed by the forests and water bodies, the area for other land in which grouped the area of agriculture, the arid area and wet land was very huge, in 2000 the built-up area was small increased by 0.29%, the forest area was increased by 1.51%, other land was decreased by 1.55% and the water bodies was decreased by 0.257%, in 2010 the urbanized area was enlarged by 1.18%, the forest area was increased by 5.72%, other land was decreased 6.21% and the water bodies was decreased by 0.68%, in 2020 the built- up was more increase than previous year by 2.594%, the forest area was decreased by 2.37%, other area was decreased by 2.59% and the water bodies was increv nnnased by 2.36%. Consequently, from 1991 to 2020 there are more changes in LULC as it is shown in the table 6.

VI.2.2 Accuracy assessment

Accuracy assessments, generally evaluate the quality of information obtained from data collected via satellite. These evaluations can be qualitative or quantitative. A qualitative evaluation is often a quick way to verify if the remote sensed data or map "looks right" and correlates with what is on the ground. Accuracy evaluation is the last stage in the processing of remote sensing data that allows us to confirm the accuracy of our results. It is typically done after the interpretation and classification is accomplished [42].

The result from accuracy assessment specify that overall exactness is belongs between 82.7% and 92.3%, the producer accuracy is belonging between 64.1% and 99.2% at water bodies, but water bodies has the highest producer accuracy, the Kappa coefficient is belongs between 74.5% and 87.1%, the detailed information is in the table 3 and 4.

VI.2.3 Change in area

Changes in land use is the manner in which human interventions alter the landscape's natural characteristics, relating to the way land has been used, with an emphasis on the functional use of land for economic activity. Significant variations in area like the settlements, forests, agriculture land, affect rural-urban migration and land price value[43],a research that have been conducted in Eastern province of Rwanda in the period of 2005 to 2020 and comes to the result of decrease of Built Up area from 290. 1159 km^2 to 191.5146 km^2 and an increase in: agricultural land from 391.464 km^2 to 475.335 km^2, Water surface from 106.2549 km^2 to 156.0465 km^2, wetland from 91.5552 km^2 to 199.7406 km^2 [20]. While the present research has shown an increase in Built Up area from 0.92km^2 to 53.57km^2, forests from 102.49 $km^2$to 165.38 km^2, water from 127.87km^2 to 146.28 km^2 and a decrease in other land from 1063.05 km^2 to 929.09 km^2, table 5.

VI.2.4 Change detection

The detection of a modification in LULC classification is a method of establishing a change from one type of LULC classification to another. Change detection in land use and land cover (LULC) based on data from satellite imagery is an essential source of information for many systems that support decisions. Changes in LULC detection information is crucial for land conservation, sustainable development, and water resource management [43]. Other research that have been conducted in Eastern province of Rwanda in the period of 2005 to 2020 have proved that there are different changes that were detected like built up areas of 31.077 km^2, 42.3774 km^2, and 30.177 km^2 were converted into bare land, agriculture, and forest, respectively. Agriculture area of 130.6908 km^2, 43.8525 km^2, and 63 km^2 were converted into built-up area, bare land, and forest, respectively. Wetlands area of 26.6742 km^2, 47.5893 km^2, 37.0332 km^2, and 51.2406 km^2 were converted into built-up area, agriculture, forest, and vegetation respectively[20]. While the present study in the period of 1990 to 2020 has showed that the surface area of other land of 48.80 km^2, 119.16km^2, and 55.43km^2 has been converted into built up, forests and water respectively. Forest surface area of 3.08 km^2, 54.92 km^2 and 2.33 km^2 are converted into built up, other land and water respectively. The surface area of water of 1.37 km^2, 3.99 km^2 and 33.97 km^2 has been converted into built up, forests and other land respectively. The surface area of built up of 0.057km^2, 0.54km^2 and 0.0077km^2 has been converted into forests, other land and water respectively as it is shown in the Table 8.

VI.2.5 Impact of LULC change on temperature

Land use land cover changes are characterized by a shift in different LULC classifications, such as vegetative cover to built-up land, Forest area to built-Up, and agriculture land to habitation place. These changes have an impact on the temperature of the land surface. The intensity of rainfall is affected by changes in land surface temperature. When the vegetation index falls, the built-up index rises, and the land surface temperature rises with it. The intensity of rainfall will increase as the land surface temperature rises. For assessing vegetation index, built-up index, and land surface temperature, satellite remote sensing images is useful and efficient [44]. Thermal properties, conductivity, albedo, surface roughness, and heat capacity are some of the main elements that influence the overall amount of LST for various land uses. The mixed value of LST for each pixel is further affected by the spatial organization, area, nearby land uses, and connection of diverse land uses [45].

In this research, it is showed that from the year of 1990 – to 2020 the built up has been increased by 52.65km^2, the class of other land which combine the total area of Bugesera unless the surface area occupied by built up, forests and water was decreased by 133.97km^2, the class of forests was increased 62.89km^2 and the class of water was increased by 18.43km^2 more detail are in the table5.

It has shown that there is various change in LULC especially built Up which have been increased more in the last ten years of the study than the previous decades, which is an indicator of urbanization in area of study, also there are a decrease of other land, this class is the one occupied a huge part of Bugesera district at the initial time of the study, followed by water and forests, lastly the built up. At the end, the study showed that the class of built up has been improved than others after Forest, which explain the increase of temperature caused by growing in settlements area which implicate the raising of Thermal properties, conductivity, albedo, surface roughness and heat capacity also the reduction of land surface cover, in other word forest cleaning.

CHAPTER 5
V.1 CONCLUSION AND RECOMMENDATION

The primary goal of the research was to analyze the effect of land use and land cover change on surface temperature in the Bugesera District of Rwanda. This study used graphical and statistical methods to assess the trend in temperature variability. The Remote sensing technics through Google Earth Engine (GEE) platform was used to classify and analyze Landsat images to assess the variation of Land Use Land Cover using Python tool, The GIS tool was used as well for change detection and calculation of gain and loose methods.

The results show that there is a noticeable increase within both minimum and maximum temperatures at the annual and Seasons unless the season of SOND for maximum Temperature in which indicate non-significant decrease, In the last decade of the study period, the minimum temperature is significantly highly increased than the maximum temperature.

Generally, increase of temperature is harmful on crops as when they are on the stage of pollination and reproduction phonological stage and this affect more the production, excessive heat caused reduction in grain number and reduced duration of the grain filling period[46].

As Rwanda's main economic activity is agriculture, and the country's population is growing and there is an increase of temperature in short and long agriculture season, it is highly recommended to the government of Rwanda and Bugesera District's authority to: Elaborate good adaptation strategy in agriculture for example selecting crops which shed pollen in the cooler times of the day or are indeterminate so flowering occurs over a longer period of the growing season. Make a plan for reforestation where it is possible, plant trees that are recommended to be mixed with the crops and Protection of environment in this region of country.

It is very important to recommend the decision maker of Bugesera district to make a plan for urbanization, habitation area, and industrial area and recommend people to have trees around their home, elaborate mitigation strategy of green infrastructure, greenery buildings and greenery on the round for reducing peak surface temperature.

ADDENDUM 1: LIST OF TABLES

Table 1: Statistical analysis for Maximum and Minimum Temperature

Attribute	Mean(˚C)		SD(˚C)		CV(%)		P-Value		Sen's Slope	
SEASON	Tmax	Tmin	Tmax	Tmin	Tmax	Tmin	Tmax	Tmin	Tmax	Tmin
SOND	27.71	15.64	0.63	0.65	2.27	4.13	0.79	0.03	0.00	0.03
JF	27.84	15.38	0.76	0.74	2.74	4.81	0.02	0.00	0.03	0.05
MAM	27.10	15.85	0.58	0.65	2.14	4.09	0.25	0.04	0.01	0.03
JJA	28.05	15.19	0.55	0.72	1.95	4.71	0.02	0.01	0.03	0.04
ANNUAL	27.66	15.54	0.38	0.62	1.39	3.96	0.02	0.01	0.01	0.03

Table 2:Statistical analysis from Mann-Kendal and Sen's slop estimate.

	SEASON/TEMP	**JJA**			**JF**			**MAM**			**SOND**			**ANNUAL**		
		Test Z	**Sig.**	**Q**	**Test Z**	**Sig.**	**Q**	**Test Z**	**Sig.**	**Q**	**Test Z**	**Sig.**	**Q**	**Test Z**	**Sig.**	**Q**
Tmax	Annual	2.1	*	0.0	2.7	**	0.1	1.4		0.0	0.2		0.0	1.7	+	0.0
	1991-2000	-0.5		0.1	0.4		0.1	-0.4		0.1	0.0		0.2	0.0		0.1
	2001-2010	2.5	*	0.3	1.8	+	0.4	0.0		0.1	0.4		0.3	1.6		0.2
	2011-2020	0.9		0.2	-0.2		0.2	1.1		0.2	1.8	+	0.2	0.9		0.2
Tmin	Annual	1.9	+	0.1	2.6	**	0.1	1.5		0.0	1.7	+	0.1	1.9	+	0.0
	1991-2000	2.0	*	0.1	0.0		0.1	0.0		0.1	0.9		0.2	0.5		0.1
	2001-2010	1.3		0.2	0.7		0.2	-0.2		0.1	-0.5		0.1	0.7		0.1
	2011-2020	3.0	**	0.4	2.5	*	0.5	2.9	**	0.4	3.6	***	0.4	3.6	***	0.4

Table 3: Accuracy assessment of the year 1990 - 2000

Year	1990				2000			
	PA	UA	OA	KC	PA	UA	OA	KC
Water	0.96	0.97	0.92	0.87	0.93	0.90	0.83	0.74
Forest	0.67	0.74			0.72	0.75		
Other Land	0.93	0.90			0.85	0.82		
Built-Up	0.92	0.85			0.64	0.92		

Table 4: Accuracy assessment of the year 2010 - 2020

Year	2010				2020		
PA	UA	OA	KC	PA	UA	OA	KC
0.97	0.94	0.83	0.76	0.97	0.99	0.82	0.75
0.67	0.64			0.64	0.67		
0.79	0.79			0.78	0.75		
0.8	0.87			0.85	0.79		

Table 5: Change in area in square Kilometers

					Change in area in kilometer square			
Years	1990	2000	2010	2020	1990-2000	2000-2010	2010-2020	1990-2020
Water	127.85	124.59	115.72	146.28	-3.26	-8.87	30.56	18.43
Forest	102.49	122.01	196.01	165.38	19.51	74.01	-30.63	62.89
Other Land	1063.05	1043.07	962.59	929.09	-19.98	-80.48	-33.50	-133.97
Built-Up	0.92	4.68	20.00	53.57	3.77	15.31	33.57	52.65

Table 6 Area in Percentages in different LULC classifications

Years	1990	2000	2010	2020
	Percentage Area		Percentage Area	Percentage Area
Water	9.87	9.62	8.94	11.30
Forests	7.91	9.42	15.14	12.77
Other land	82.73	80.58	74.37	71.78
Built-up	0.07	0.36	1.54	4.13

Table 7: The change in Percentages area at different time scale

Years	1990-2000	2000-2010	2010-2020	1990-2020
	Changes in %	Changes in %	Changes in %	Changes in %
Water	-0.252338	-0.684921	2.36101	1.423751
Forests	1.507321	5.718073	-2.366804	4.85859
Other land	-2.145987	-6.216206	-2.588078	-10.950271
Built-up	0.290974	1.183053	2.593869	4.067896

Table 8: Change detection in different timescale

Changes	1990-2000	2000-2010	2010-2020	1990 - 2020
Built-Up - Built-up	0.071	0.36561513	4.43805984	0.30304826
Built-Up - Forests	0.100	0.43133287	1.9214978	0.05755338
Built-Up - OtherLand	0.744	3.81626049	13.56614723	0.54932876
Built-Up - Water	0.003	0.06832873	0.0666612	0.00779881
forests - Built-up	0.252	2.04842566	3.97952037	3.08021477
forests - Forests	34.294	32.68783579	53.91014805	42.14705343
forests - OtherLand	66.805	85.55902101	131.7130461	54.92544406
forests - Water	1.137	1.70927398	6.40045979	2.33776965
OtherLand - Built-up	4.217	17.47184312	44.43246857	48.80598744
OtherLand - Forests	84.678	157.315743	106.8125995	119.1674088
OtherLand - OtherLand	931.423	836.0504795	763.1587632	839.590135
OtherLand - Water	42.697	32.12101844	48.15081272	55.43588576
Water - Built-up	0.142	0.10516418	0.71548132	1.37519568
Water - Forests	2.933	5.56703764	2.72226186	3.99153262
Water - OtherLand	44.004	37.12456076	20.59555781	33.97182587
Water - Water	80.384	81.44789333	91.35762582	88.11940725

ADDENDUM 2: LIST OF FIGURES

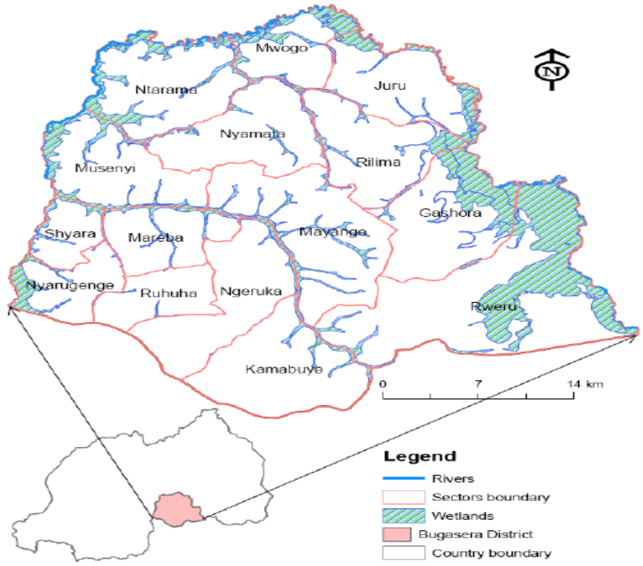

Figure 2:Map of Bugesera District

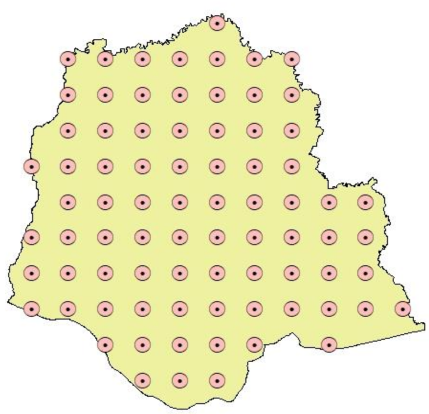

Figure 3: Map of Gridded point used

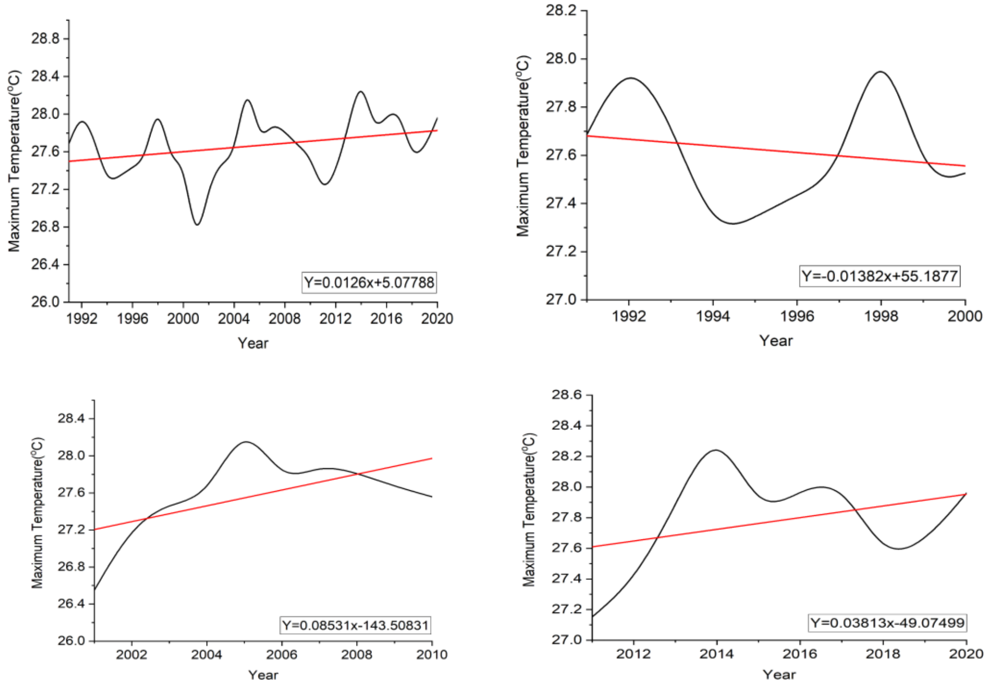

Figure 4: Trends for annual Maximum Temperature

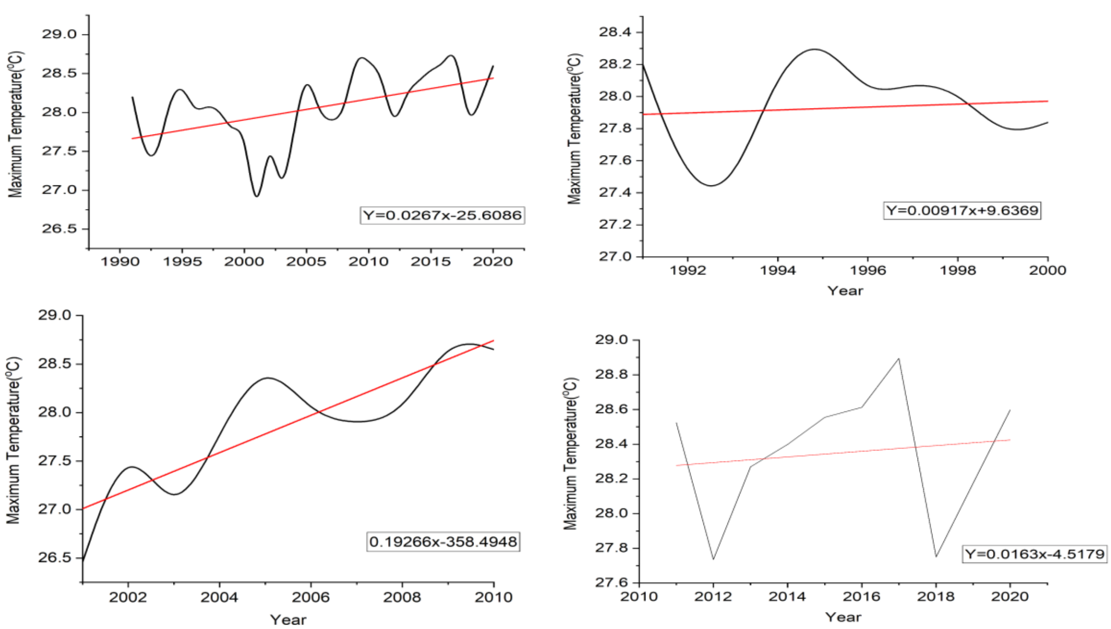

Figure4: Trends of JJA for Maximum Temperature

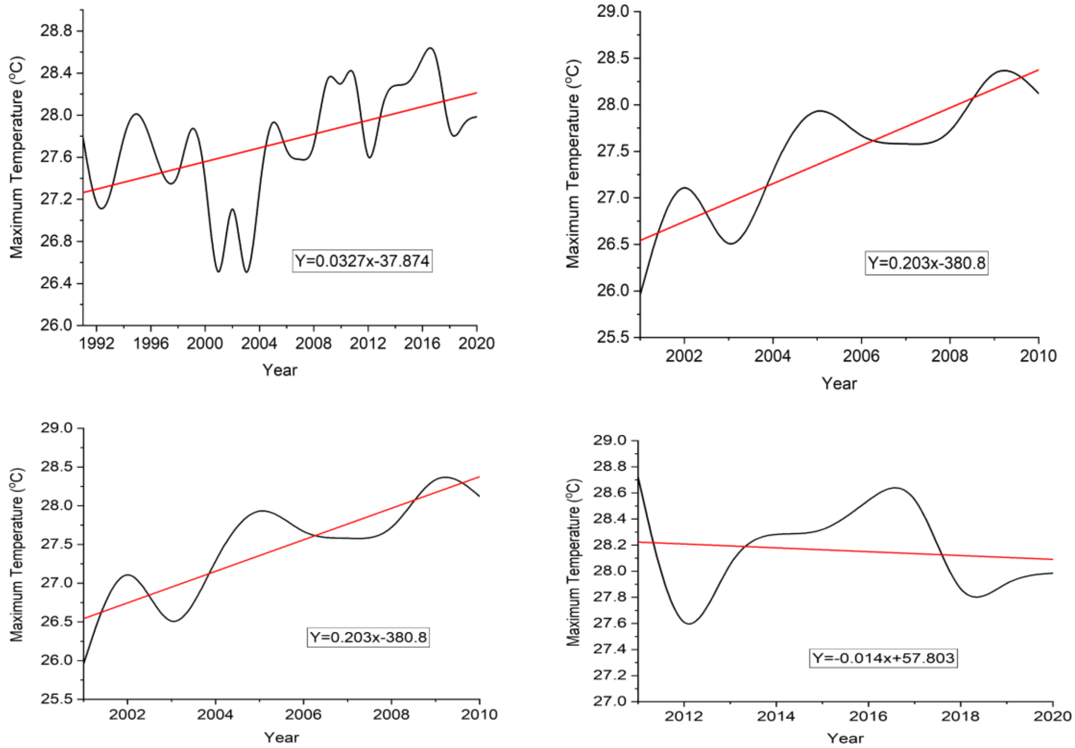

Figure 5: Trends of JF for Maximum Temperature

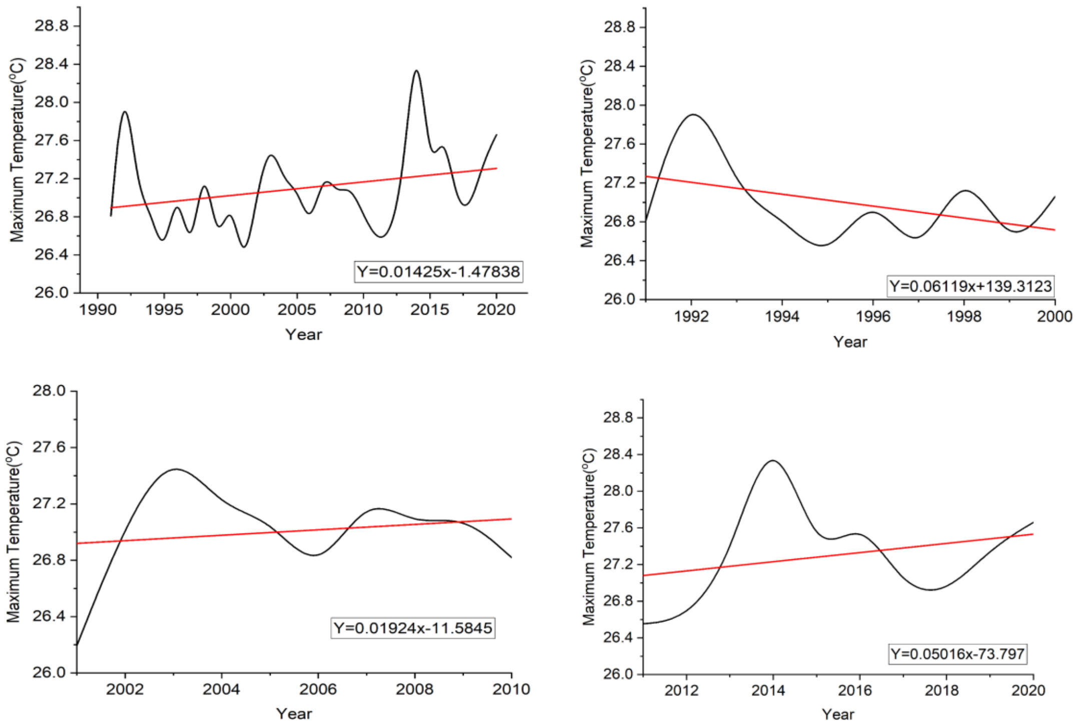

Figure 6: Trends of MAM for Maximum Temperature

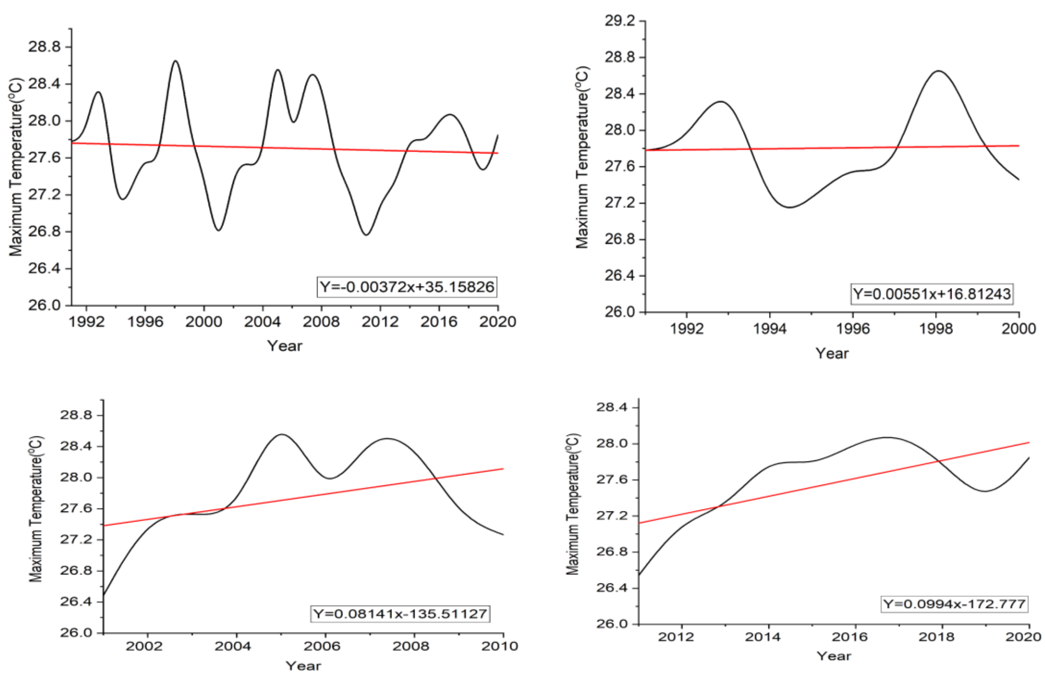

Figure 7: Trends of SOND for Maximum Temperature

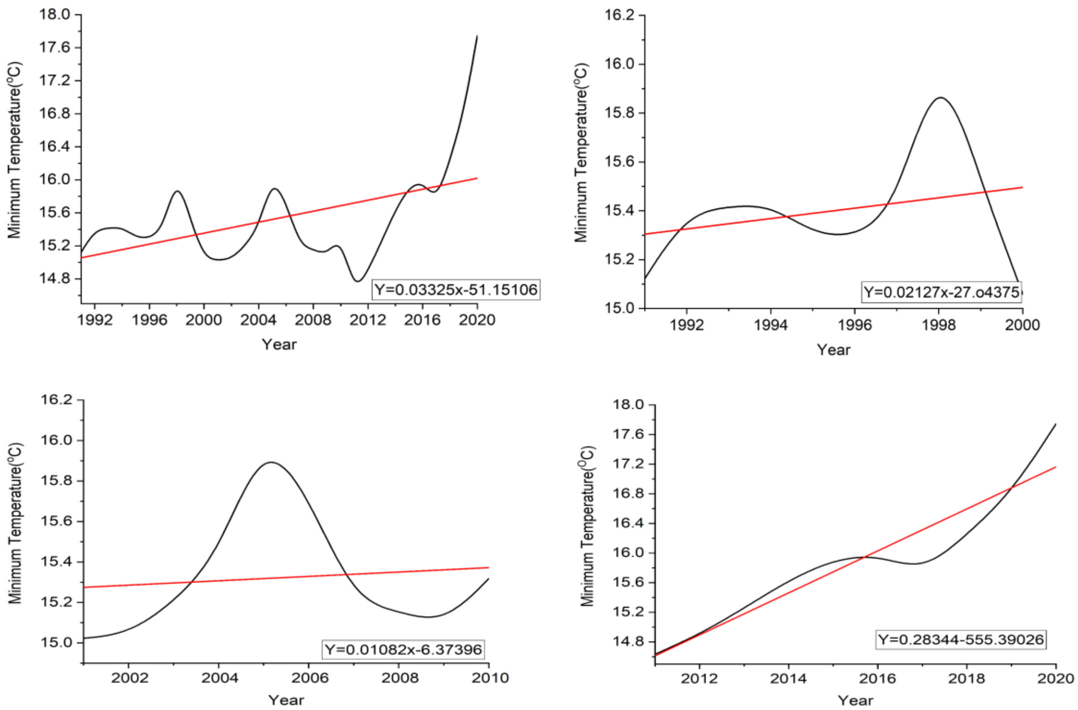

Figure 8: Trends of Annual Minimum Temperature

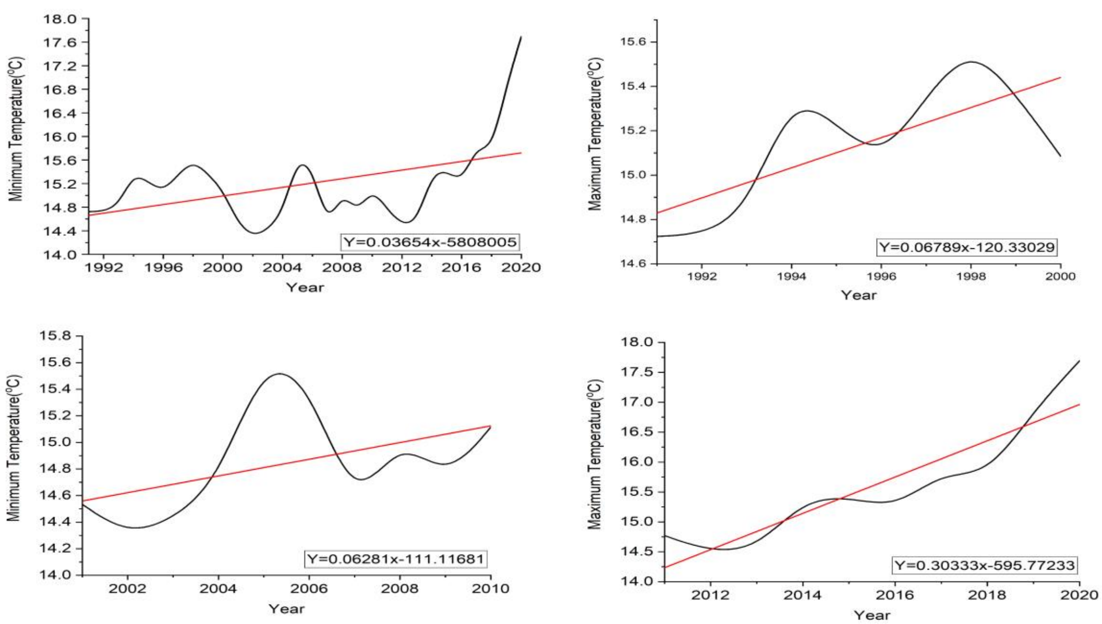

Figure 9: Trends of JJA Minimum Temperature

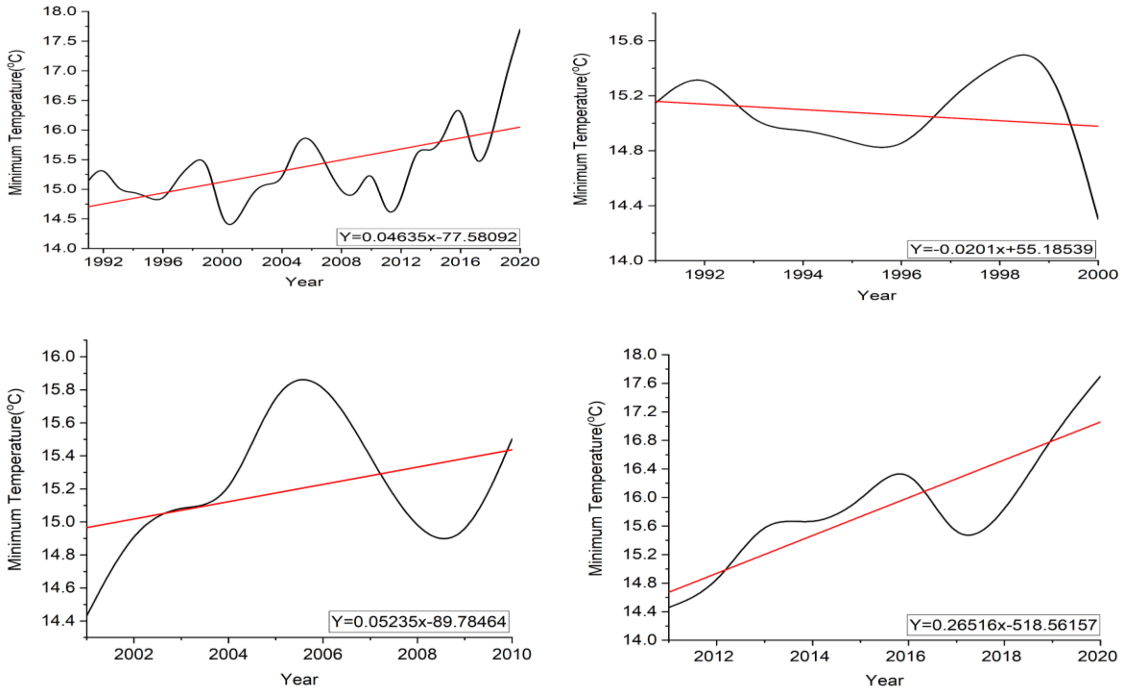

Figure 10: Trends of JF for Minimum Temperature

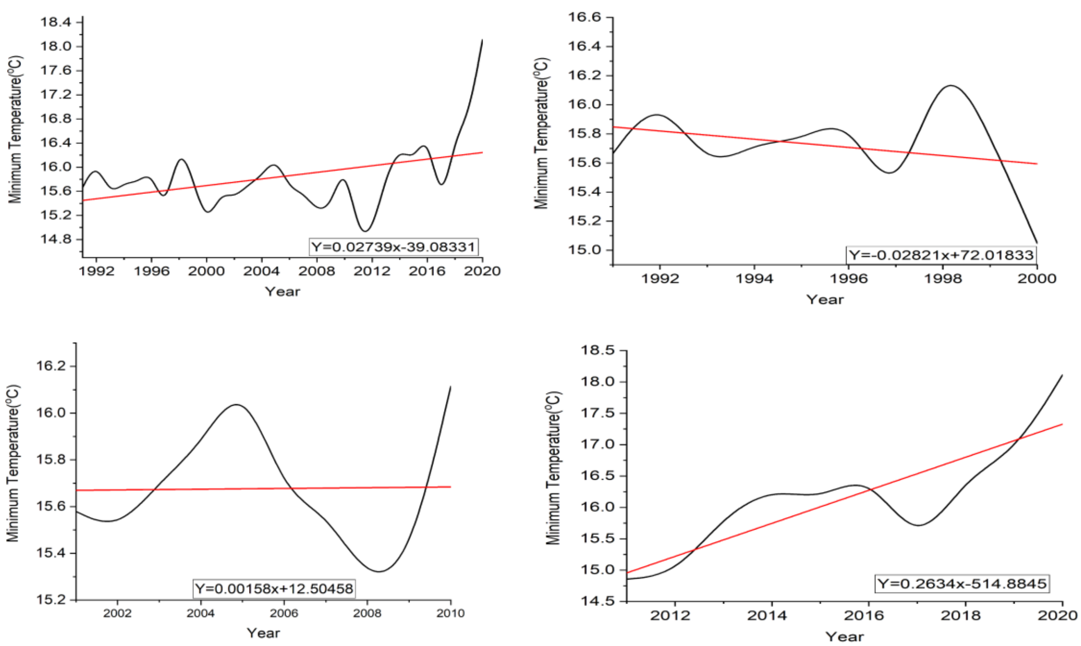

Figure 11: Trends of MAM for Minimum Temperature

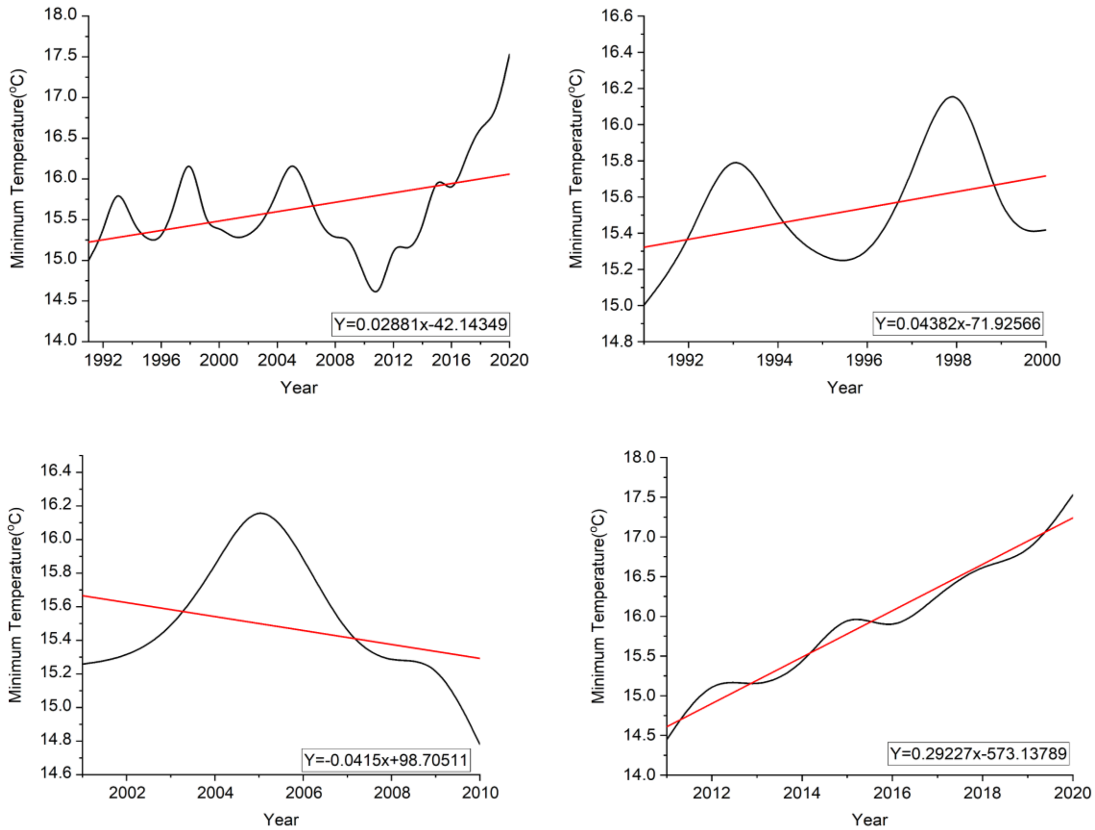

Figure 12: Trends of SOND for Minimum Temperature

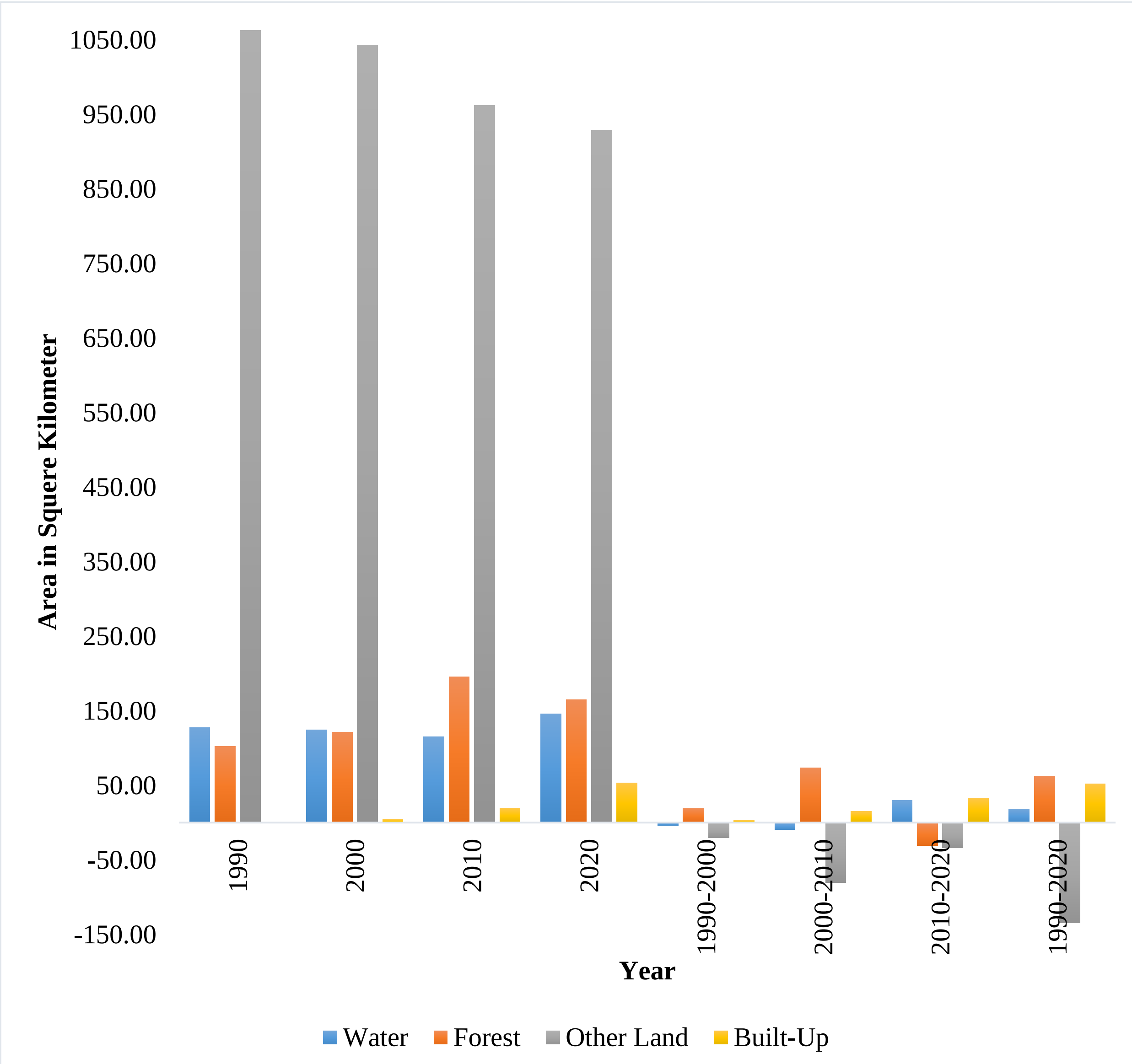

Figure 13: Change in Area in Square Kilometer

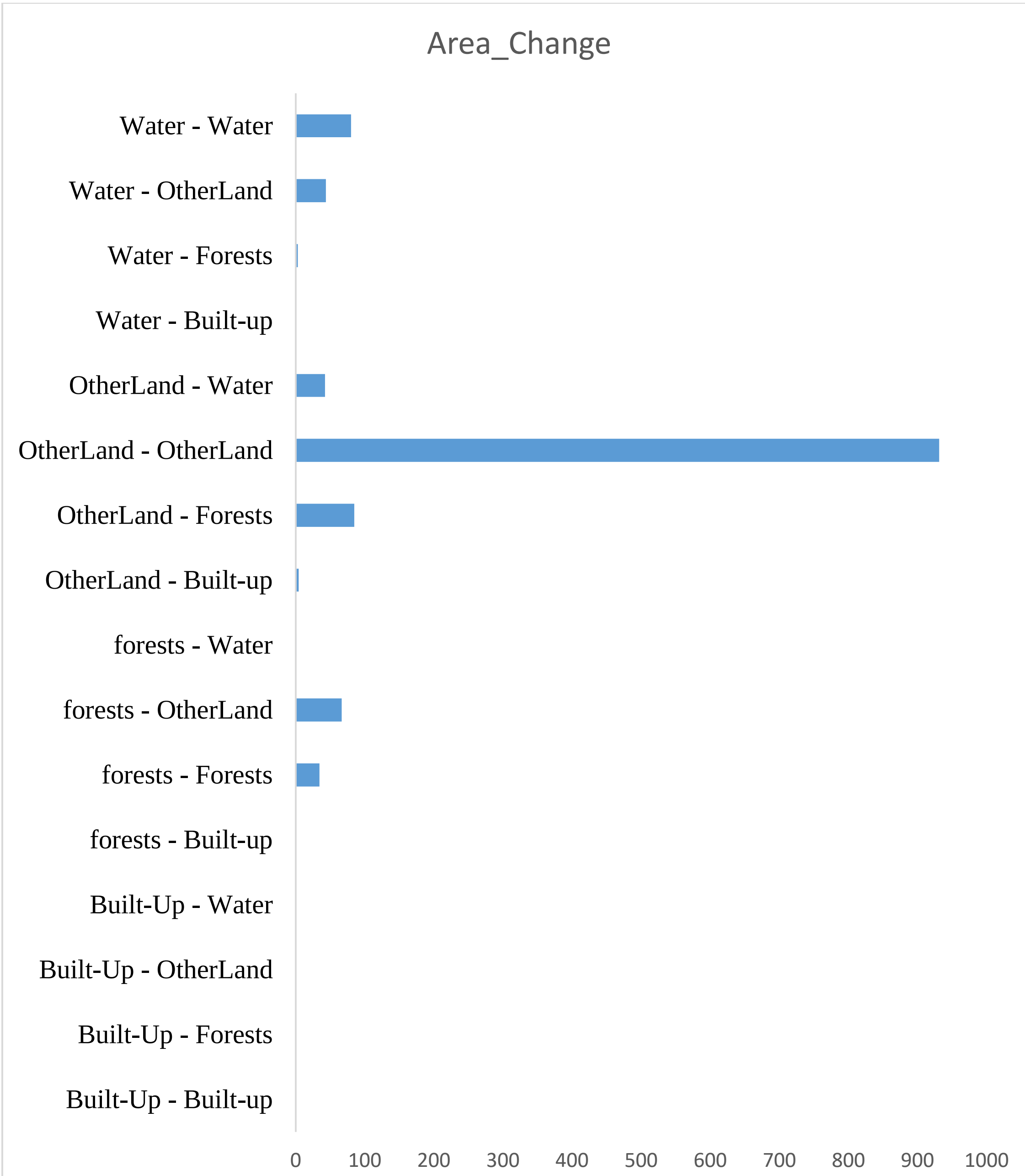

Figure 14: Change Detection of the year 1990 to 2000

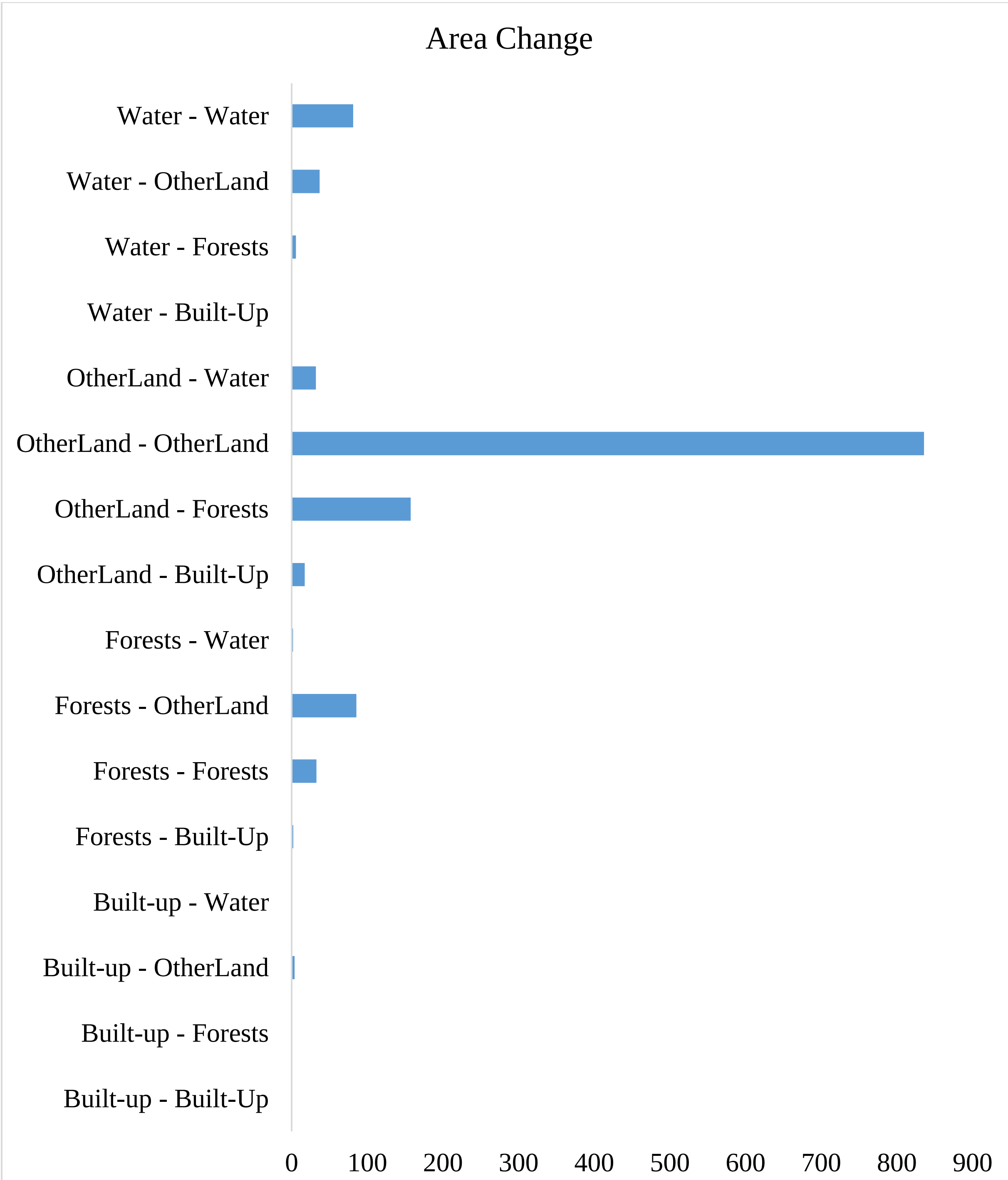

Figure 15: Change Detection of the year 2000 to 2010

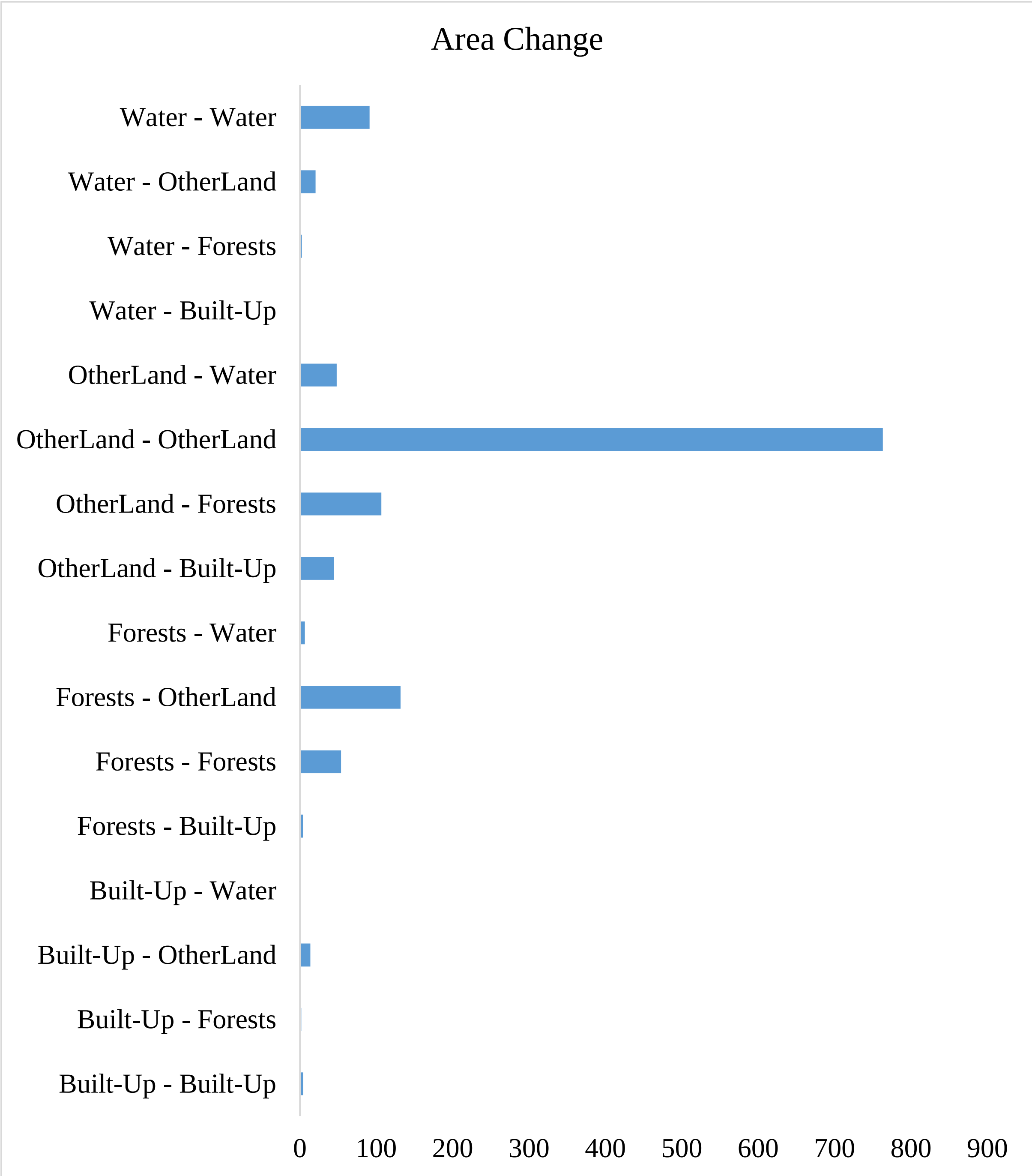

Figure 16: Change Detection of the Year 2010 to 2020

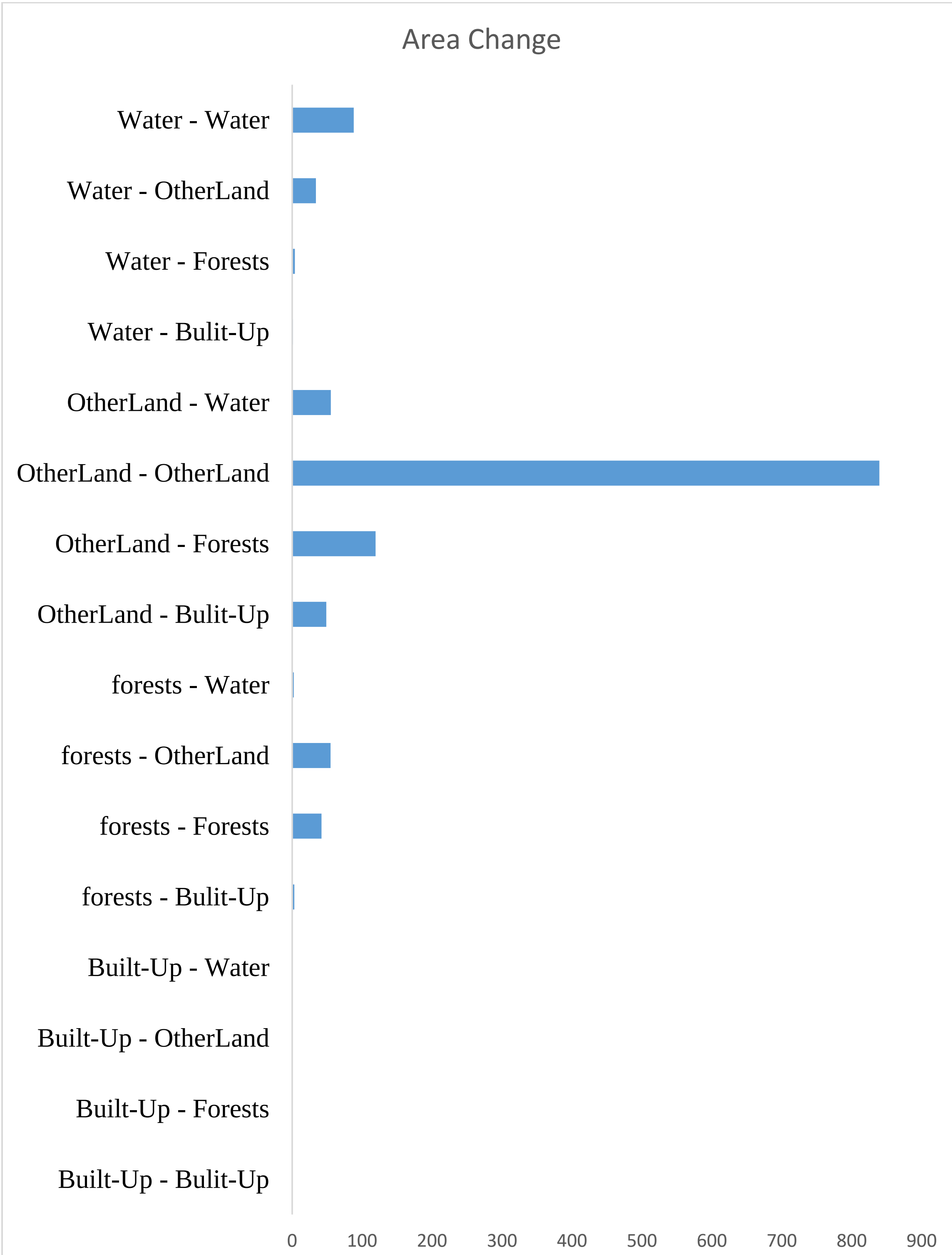

Figure 17: Change Detection of the year 1990 to 2020

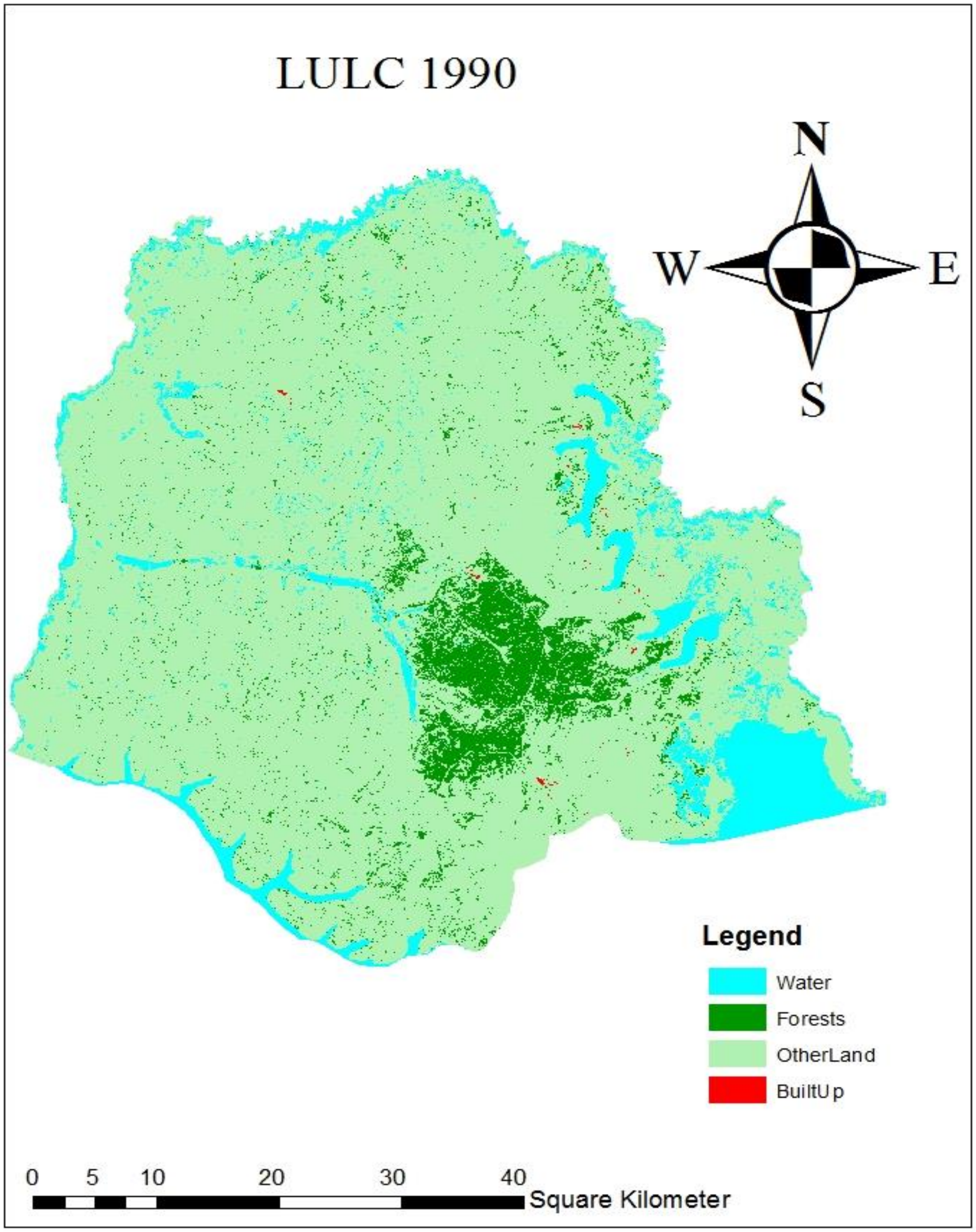

Figure 18: LULC of the year 1990

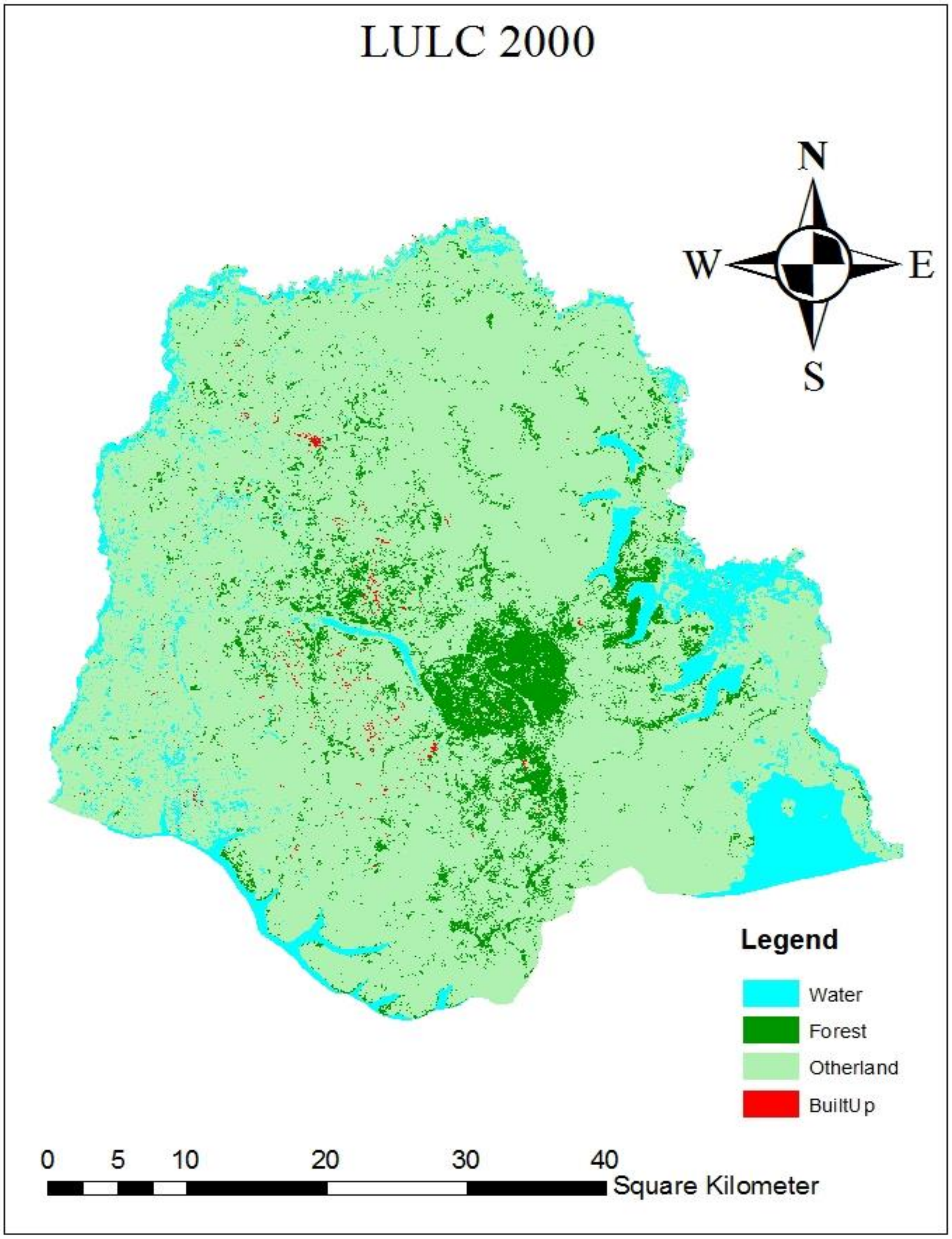

Figure 19: LULC image of the year 2000

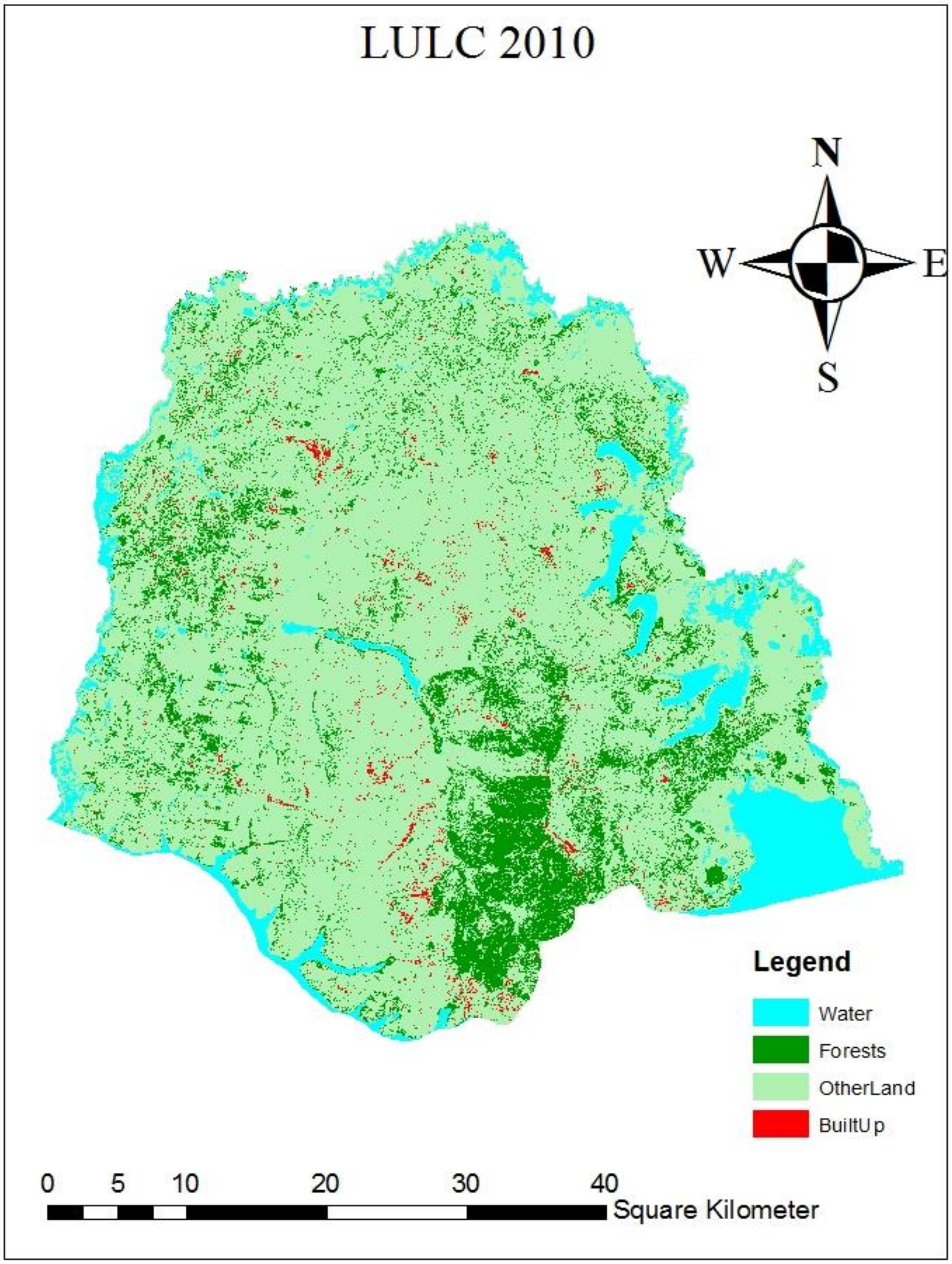

Figure 20: LULC image of the year 2010

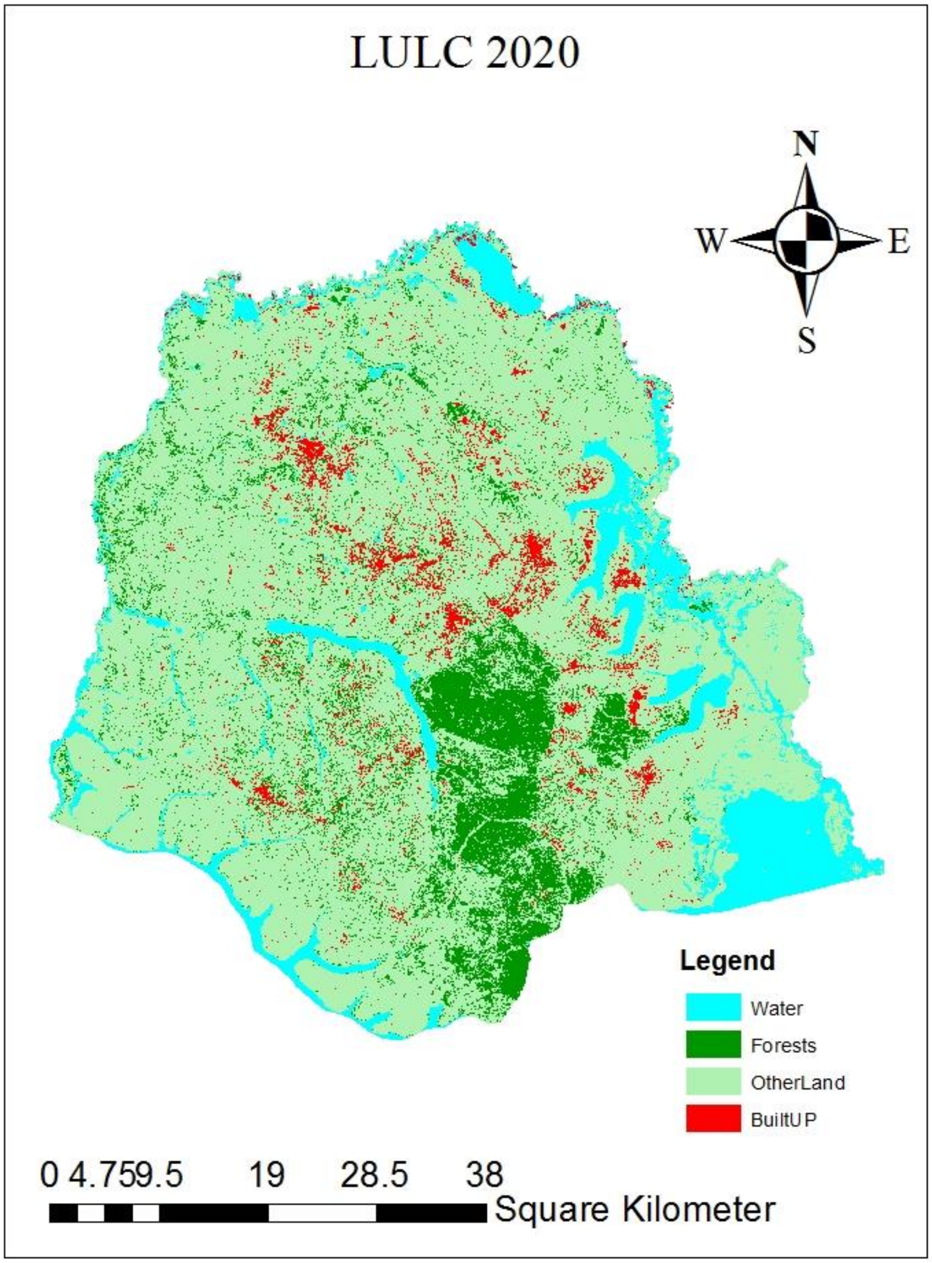

Figure 21: LULC image for the year 2020

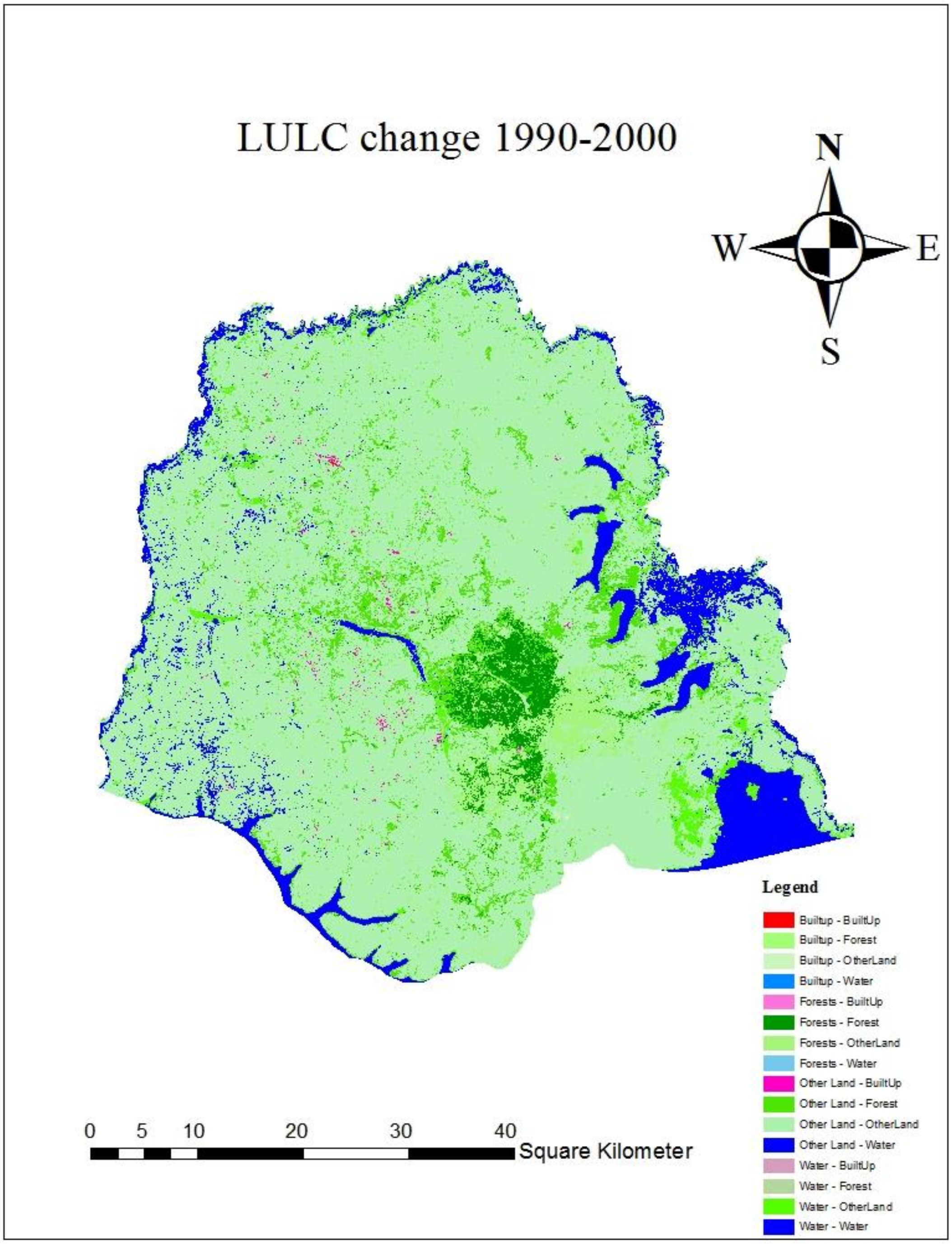

Figure 22: Area change from the year 1990 to 2000

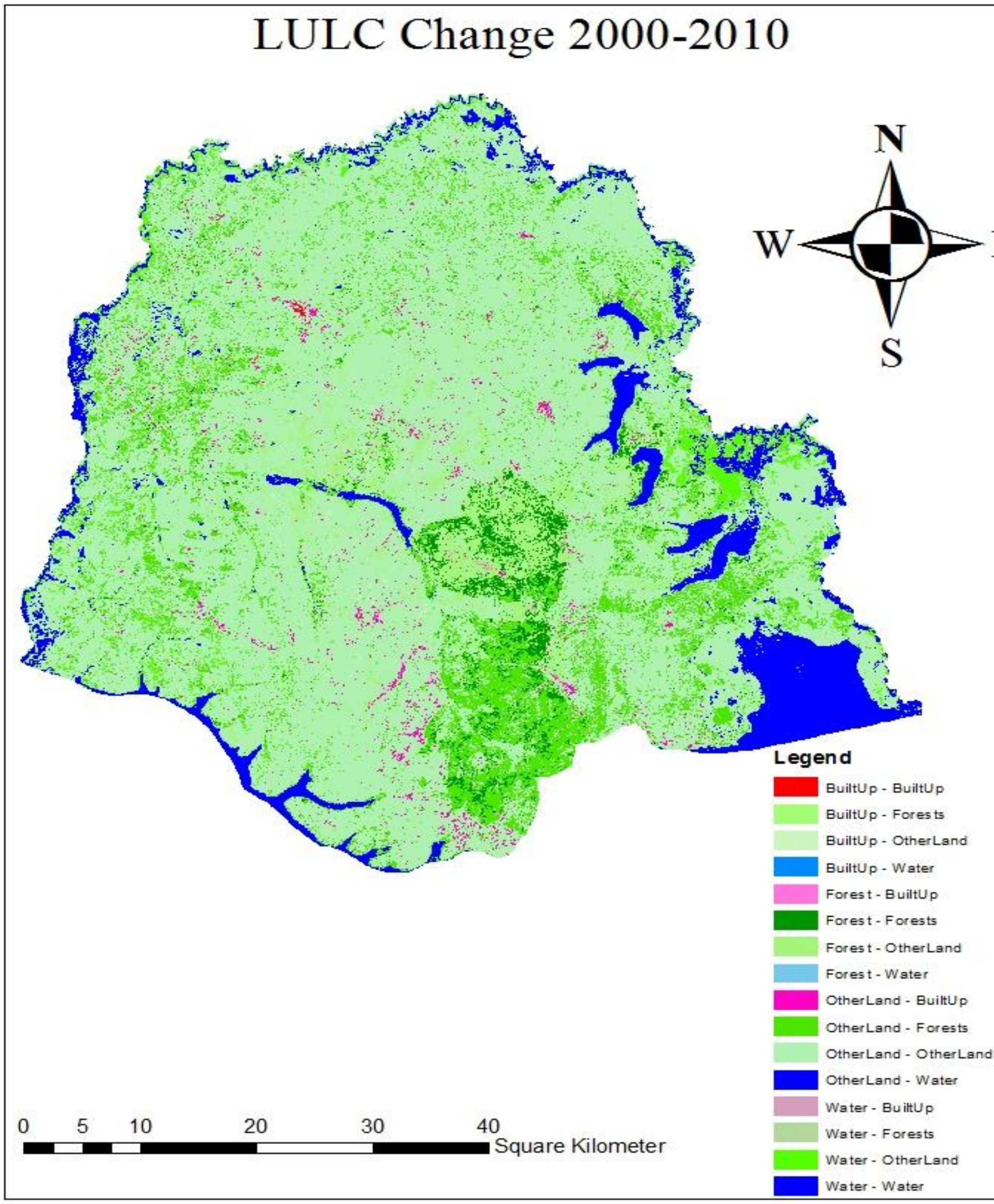

Figure 23: Area change from the year 2000 to 2010

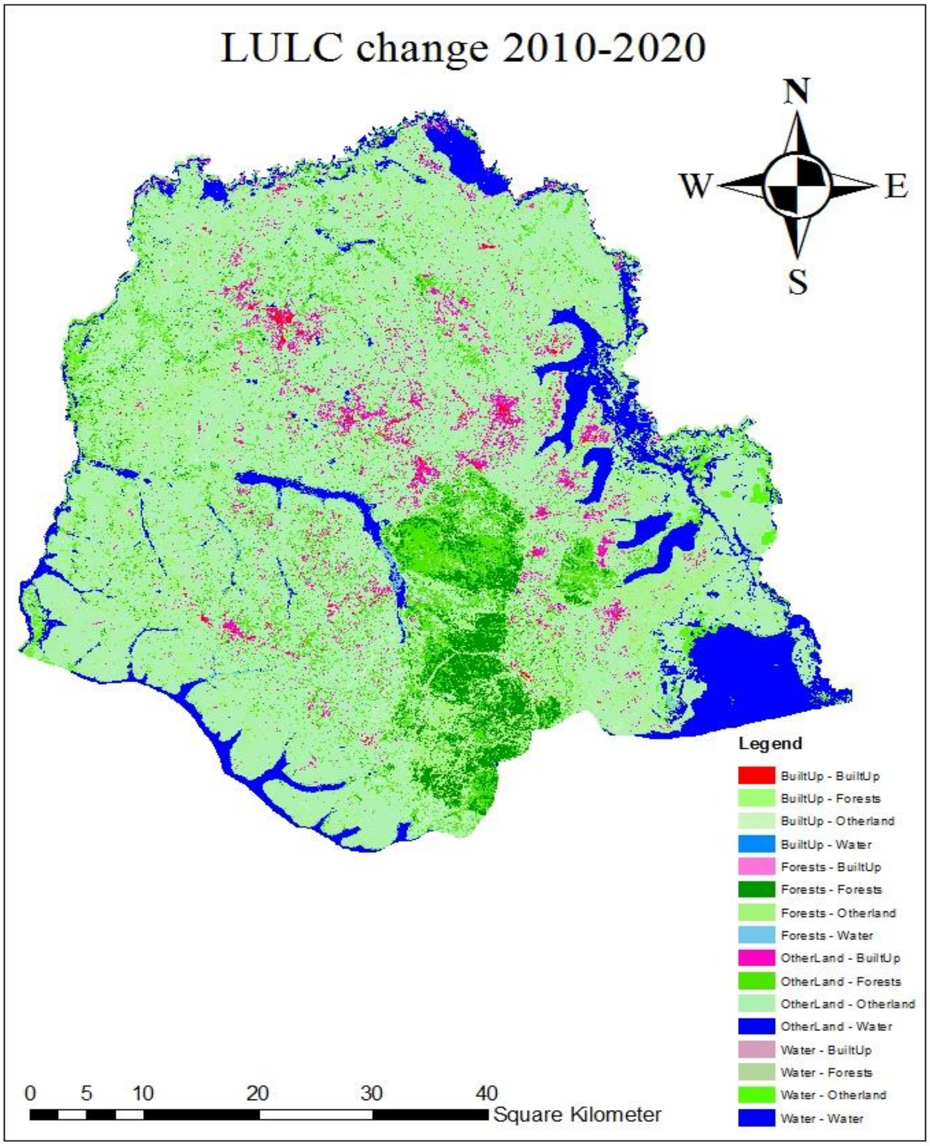

Figure 24: Area change from the year 2010 to 2020

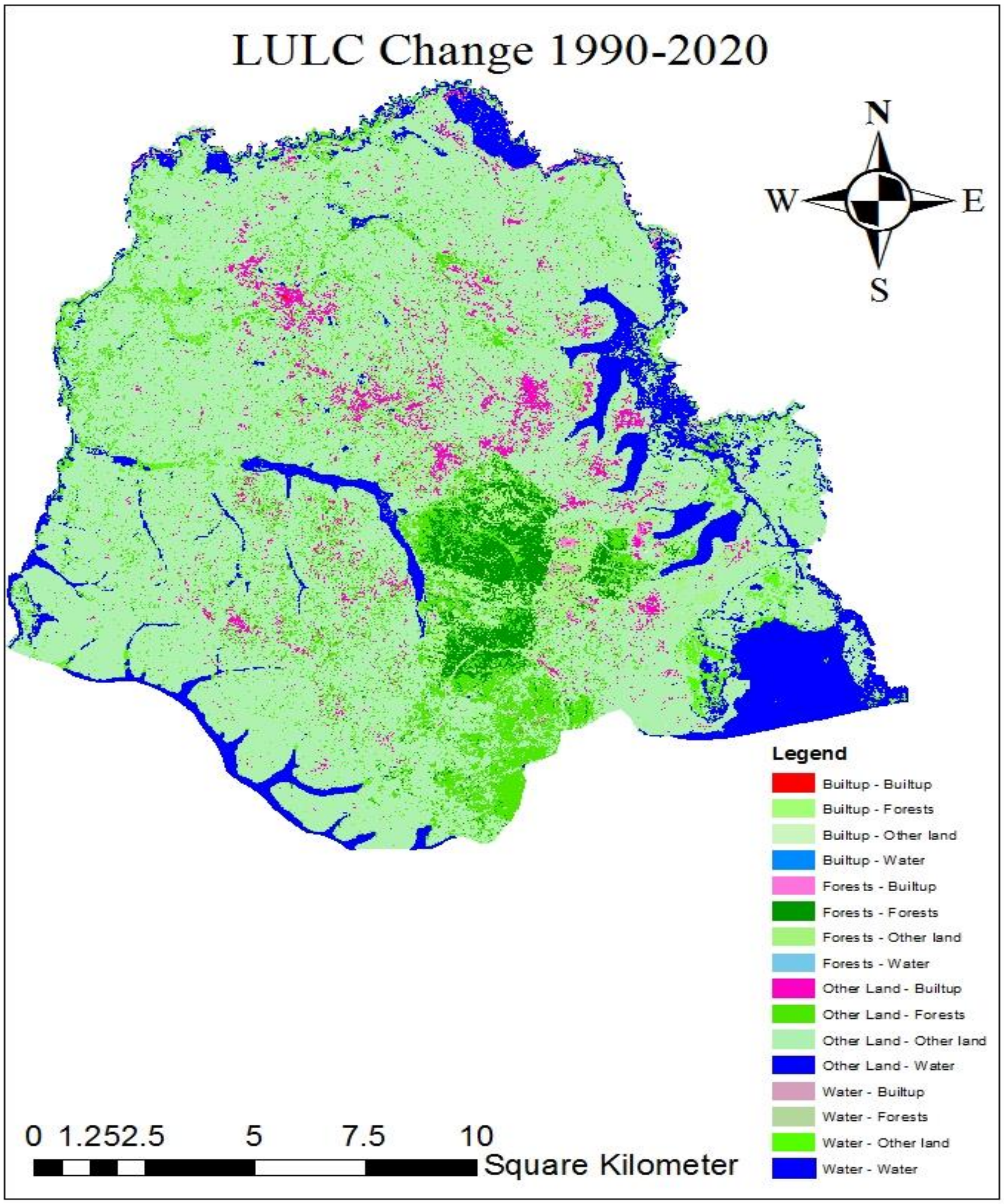

Figure 25: Area change from the year 1990 to 2020

Reference

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