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Correlation Analysis Between Deforestation and Climate Change in Rwanda

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Abstract

The failure to maintain forests in this earth has raised the concerns of deforestation and climate change. It is in this context that this study was conducted in order to assess the extent to which deforestation contributed to climate change in Bugesera District, Eastern Rwanda. This study utilized secondary data on deforestation derived from the land use and land cover maps collected from the United States Geological Survey (USGS). Regarding climate change parameters, the authors considered both rainfall and temperature which were collected from the Rwanda Meteorology Agency (RMA). These datasets covered a period of thirty years ranging from 1990 to 2020. The Geographic Information System (GIS) and Statistical Package for Social Sciences (SPSS) were the mail tools for data collection and analysis. The results showed negative significant relationship between forest cover and maximum temperature with correlation r1=-0.279. However, the analysis indicated positive significant relationship between forest cover and minimum rainfall with r2=0.513; and between maximum temperature and minimum rainfall with r3=0.590 at 0.01 level of significance. This implies that forest cover has a negative effect on temperature and a positive effect on rainfall. The authors believe that the results of this study add more knowledge on the impact of deforestation in leading to climate change from which strategic measures for climate change adaptation can be addressed.

Keywords

Bugesera District, Climate Change, Rainfall, Temperature, Deforestation, and GIS

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1. Introduction

The world's forest cover grew by means of greater than 6 billion hectares, representing 45% of the whole vicinity of the earth in 10,000 years ago. However, wooded area cover has been declining due to the fact that then and solely 31% of the world's vicinity is covered with the assist of forests in 2010 [1, 2]. Agricultural enlargement as a crop in movement is one of the vital anthropogenic divers for deforestation in the tropics [3]. The annual charge of deforestation is 0.14%, which means that 5.2 million hectares are produced for 12 months of annual internet deforestation [1, 4], at some stage of the 21st century, deforestation was once gradual in temperate forests while deforestation used to be high in tropical forests [4].

The Intergovernmental Panel on Climate Change [2, 3] reported that the average worldwide temperature has been rising due to deforestation and consequently the fee of sea degree upward thrust used to be also excessive due to global warming. Smith and Smith [4] referred to that due to deforestation and industrialization, interest to carbon dioxide has expanded by extra than 25%, whilst the IPCC [3] stated

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that carbon dioxide has extended with the assist of 40% due to two anthropogenic techniques by means of which fossil gasoline emits allocation and deforestation to land use change. Severe consequences of nearby weather alternate in deforestation can lead to desertification, while, at the same time, deforestation is the important driver of local weather change; rising temperatures and droughts have negatively affected the variety of species, ecosystems and choices to humanity [5].

Numerous researchers [6, 7, 8] referred to the annual deforestation of Ghana's price at 2%, making it one of the excellent in Africa. The report of [7] stipulates that deforestation is created through the destruction of forest cover to use land intentionally for non-forest uses, such as agriculture in sub-Saharan African countries. Most sub-Saharan international locations exercise deforestation due to subsistence agriculture with an annual deforestation fee of 0.7% [7, 9].

In the district of Bugesera, deforestation is affected by agriculture, rapid urbanization and lack of planting cover [10, 11]. Meanwhile, rising demand for charcoal, building substances and agricultural land is contributing to the shortage of woody biomass. In 2009, 21% of Rwanda's biomass consumption was used to be attributed to unsustainable use of woody biomass and steady charcoal floating [10, 11]. Therefore, it implies that conducting research to verify the influence of deforestation on climate change would help to address alternative climate change mitigation and adaptation policies in Bugesera district, Rwanda.

2. Methodology

2.1. Study Area

This study was conducted in Bugesera District of Rwanda, inhabited by 361, 914 populations. The District borders with the Republic of Burundi (Kirundo Province) in the South, Ngoma District to the East, Kigali city and Rwamagana district to the North. It covers a total surface area of 1,337 Km² of which arable land is estimated at 91,930.34 ha. Bugesera's climate is dry with a temperature varying between 20°C and 30°C with an average temperature ranging between 26 and 29°C [11].

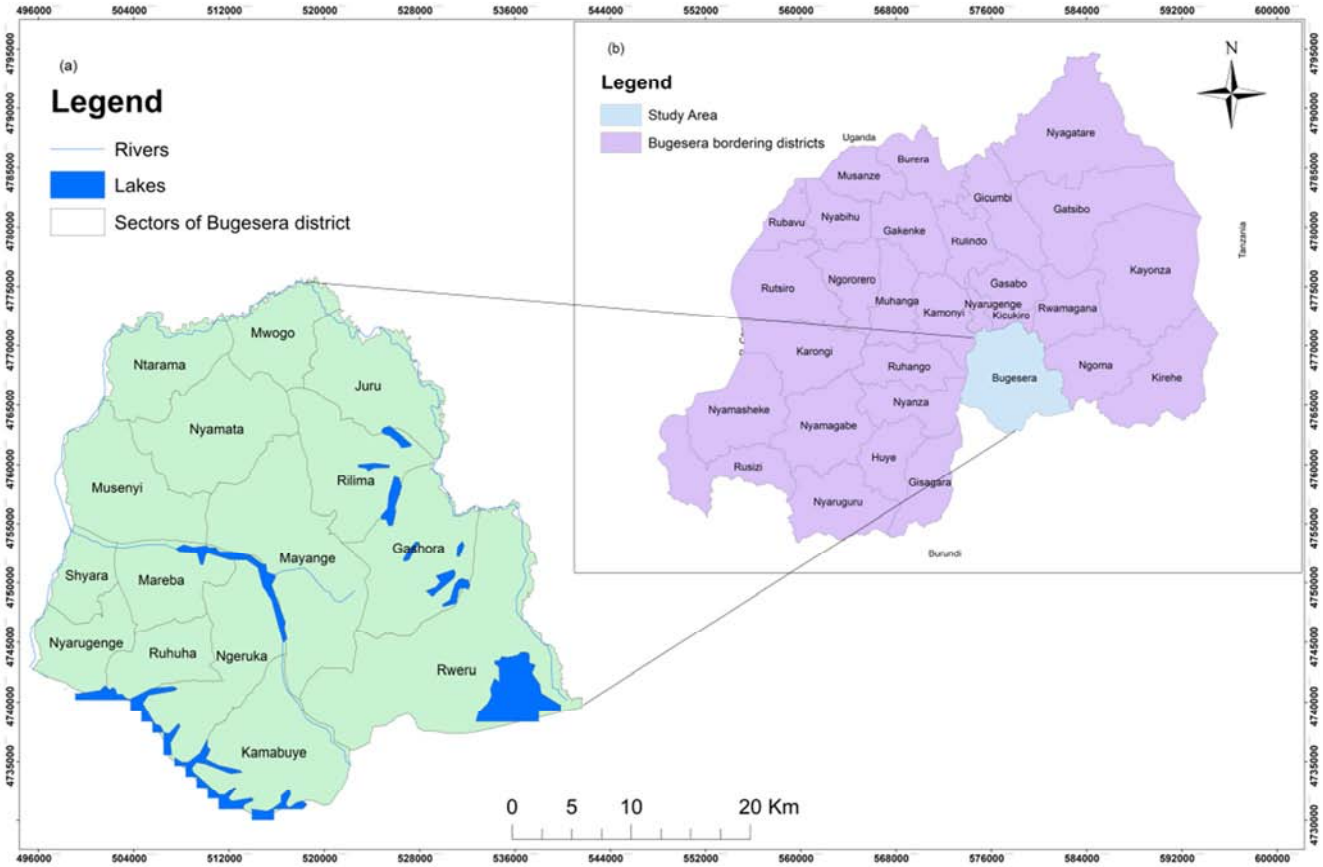


Figure 1. Map indicating the sectors of Bugesera district and its bordering districts of Rwanda.

2.2. Data Collection and Analysis

The data on deforestation was analysed from the land use and land cover maps collected from the United States Geological Survey (USGS). The data on climate change were mainly of temperature and rainfall which were collected from the Rwanda Meteorological Agency. The above datasets ranged from 1990 to 2020 respectively.

The author employed the Remote Sensing and Geographic Information System (GIS) for collecting, analyzing and presenting the trend and patterns of deforestation in Bugesera district from 1990 to 2020. This procedure of data collection involved the process of capturing, automation, converting, transferring, translation and digitizing data. The Microsoft Excel also helped the researcher to gather and analyze the trend of climate variables (rainfall, temperature) and then the GIS was employed to present the distribution of climate change over Bugesera district.

Furthermore, the Statistical Package for Social Sciences (SPSS) through its Pearson correlation and levels of significance facilitated the analysis indicating the extent to which deforestation contributed to climate change in Bugesera District.

3. Results

3.1. Deforestation Patterns in Bugesera District of Rwanda

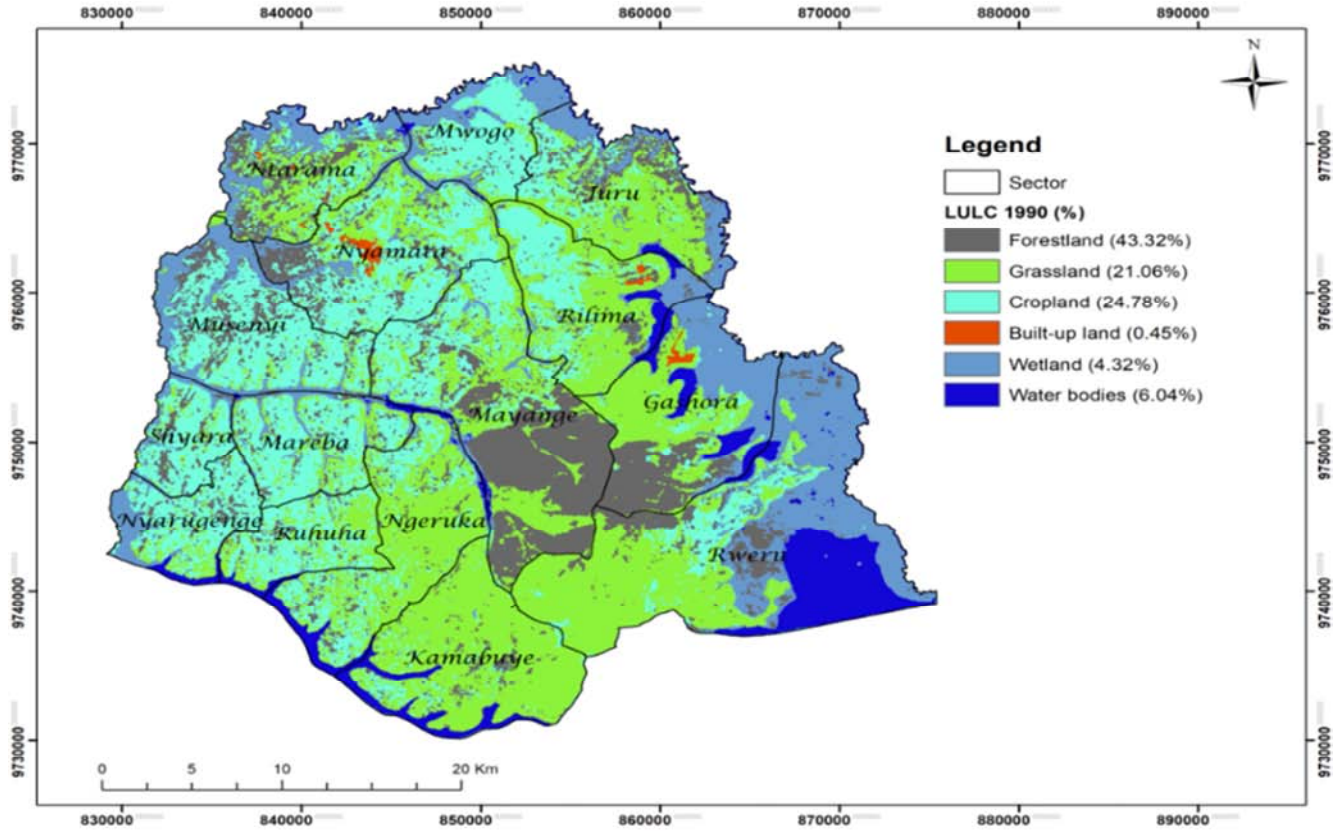


Figure 2. Forest Cover Change in Bugesera District in 1990.

The results in Figure 2 indicated that forestland occupied the majority 43.32% of land in Bugesera District in 1990, while cropland occupied only 24.78% of land in Bugesera District and the built- up land was under low percentage of 0.45% among other land use classes in the Bugesera district in 1990.

The results in Figure 3 indicated that cropland occupied the majority 44.48% of land in Bugesera District in 2000, while forestland has reduced and occupied only 29.75% and the built- up land was under low percentage 0.45% among other land use classes in the Bugesera district in 2000.

The results in Figure 4 indicated that cropland occupied the majority 44.05% of land in Bugesera District over 2000, while forestland has reduced and occupied only 29.13% and the built-up land was under low percentage 0.82% among other land use classes in the Bugesera district in 2000.

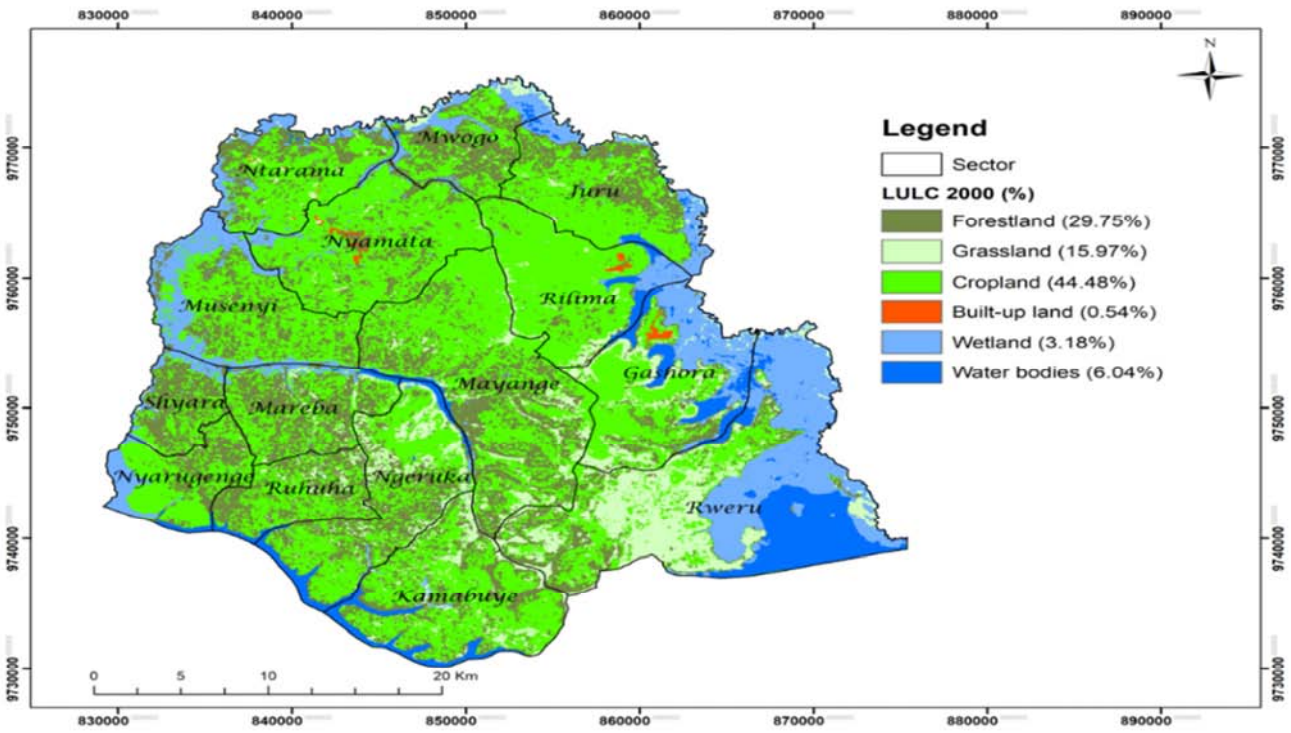


Figure 3. Forest change over Bugesera district in 2000.

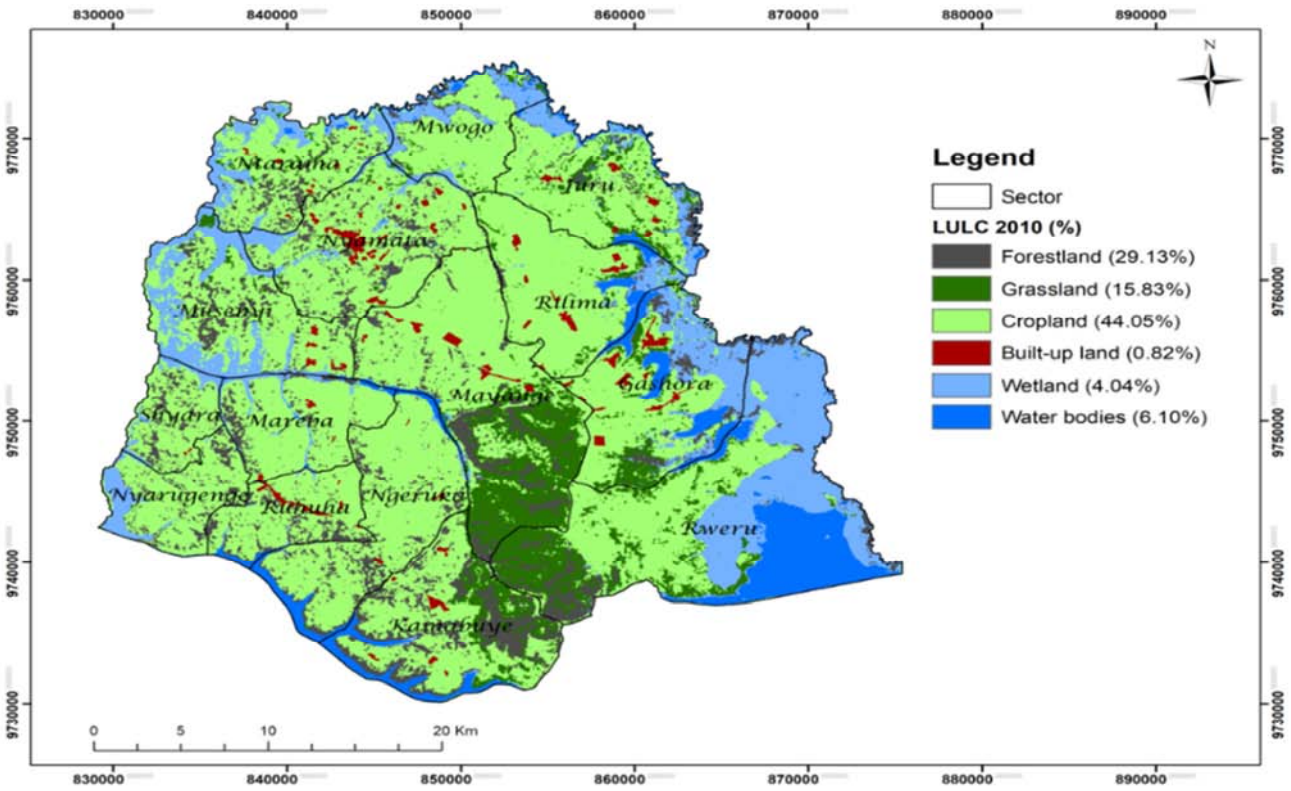


Figure 4. Forest change over Bugesera district in 2010

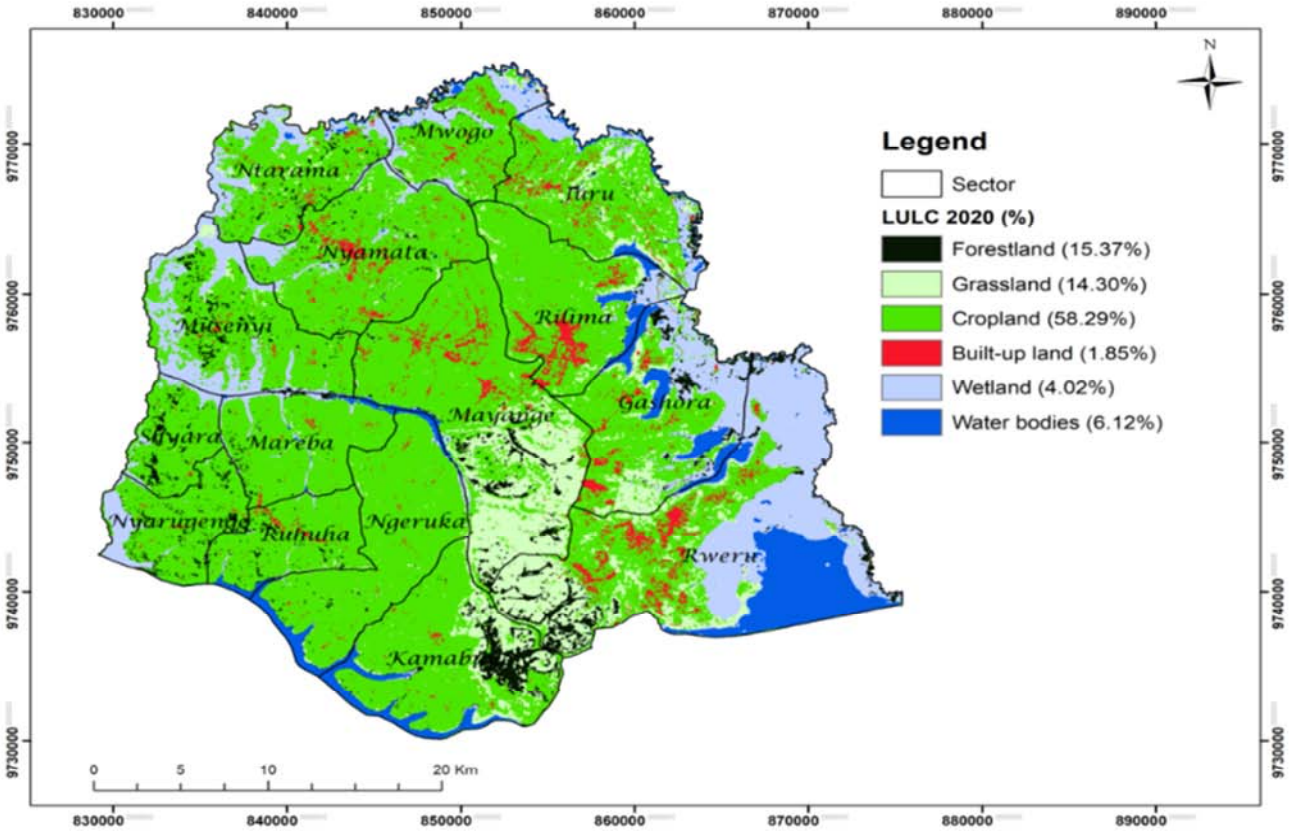
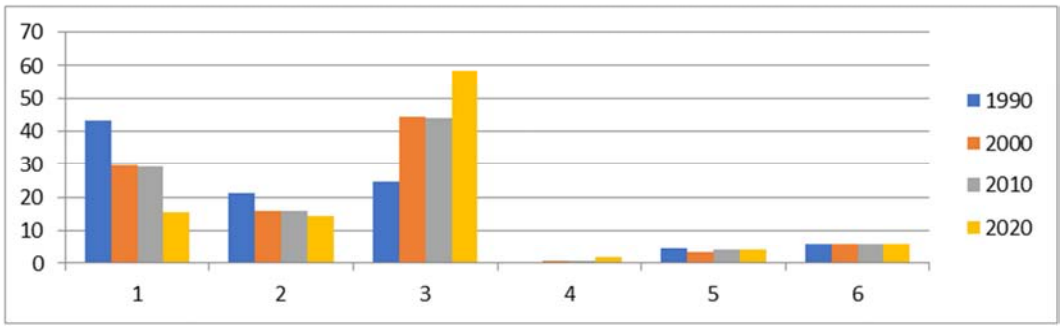


Figure 5. Forest Change over Bugesera District in 2020.

The results in Figure 5 indicated that cropland occupied the majority 58.29% of land in Bugesera District in 2020, while forestland has reduced and occupied only 15.37% and the built- up land was under high percentage of 1.85% among other land use classes in the Bugesera district in 2020.



Source: Primary data, 1990-2020.

Figure 6. Average of Forest Cover Change in Bugesera District between 1990 and 2020.

The data presented in Figure 6 showed that forestland have reduced from 43.32% in 1990 to 15.37% in 2020 while the built-up land increased from 0.45% in 1990 to 1.85% in 2020. The cropland has also increased from 24.78% in 1990 to 58.29% in 2020. Hence, it can be noted that, the primary agent of deforestation is the expansion of cropland which is expanded while looking for land to cultivate and built up land. This is likely influenced by high rate of migration of people from Kigali and other parts of the country looking for plots due to the expected development in Bugesera near Kigali City.

The findings of this study are supported by the study of [12, 13] who revealed that intensification of agriculture production through firm land and higher livestock farming and the use of chemical inputs which has the potential to increase greenhouse gases can contribute to climate change which affects agricultural production only because deforestation was increased by creating firm land. The findings are also supported by [14, 15] who stated that the

control of climate change requires policymakers to regulate human activities while the results of the current study showed that human activities such as building and expanding land for crop have increased in 2020 compared to 1990.

The migration of people from Kigali and other Districts of Rwanda to Bugesera District due to infrastructure development and overpopulation of Bugesera District accelerate the rate of built up land, cropland and decrease of water bodies as indicated in Figure 6. These factors affect the decrease of air quality, destabilize climate and influence soil erosion which significantly affect the economic impact of ecosystems services in Bugesera.

3.2. Climate Change in Bugesera District

The findings of the study presented in this subsection are based on the map extracted from GIS data indicating the spatial rainfall and temperature distribution between 1990 and 2020 which were considered as factors of climate change in this study.

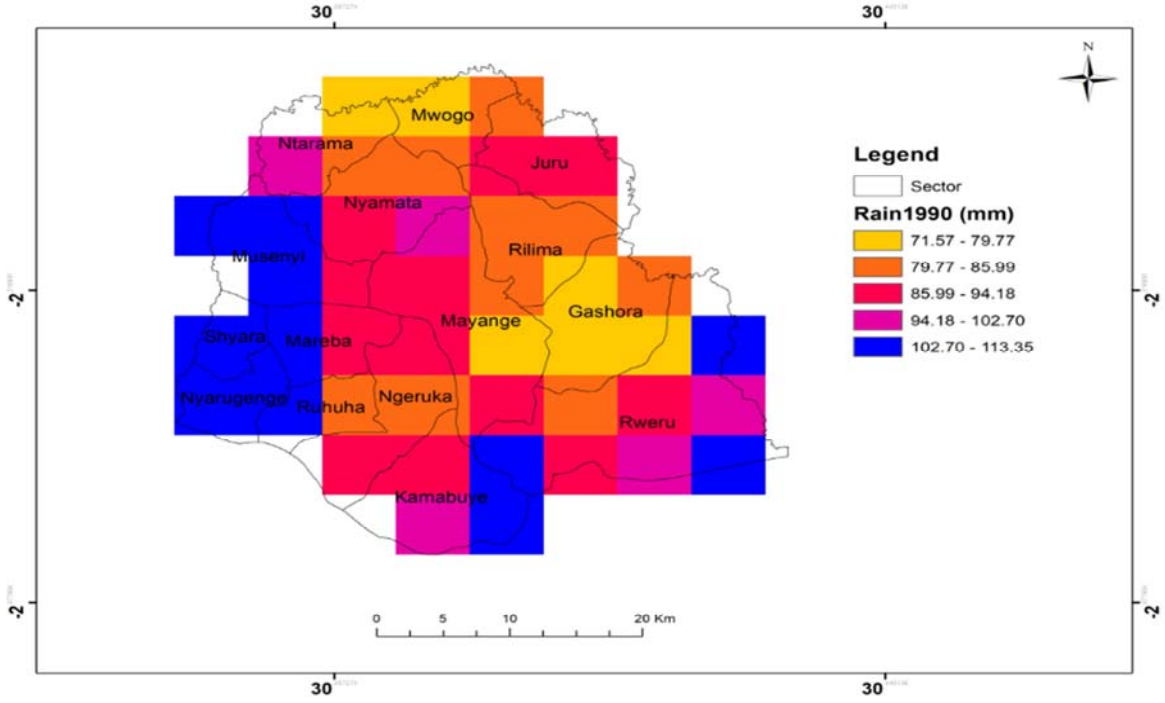


Figure 7. Rainfall distribution in Bugesera district in 1990.

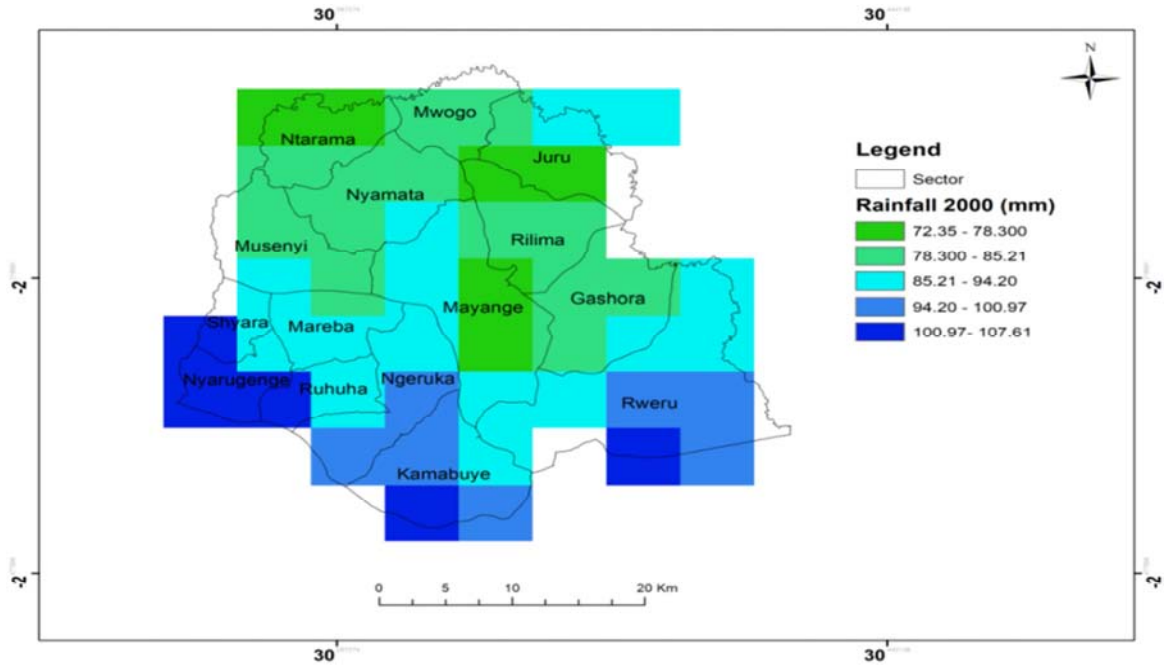


Figure 8. Rainfall distribution in Bugesera district in 2000.

The results in Figure 7 revealed that the minimum average annual rainfall recorded in 1990 ranged between 71.55mm and 79.77 mm while the maximum rainfall was ranging between 102.70 and 113.35 mm. The same Figure 7 indicated that Shyara, Nyarugenge and Musenyi sectors registered low maximum rainfall compared to Mwogo and Gashora sectors.

The results in Figure 8 revealed that the minimum average annual rainfall recorded in 2000 ranged between 72.35 and 78.300 mm while the maximum rainfall was ranging between 100.97 and 107.61 mm.

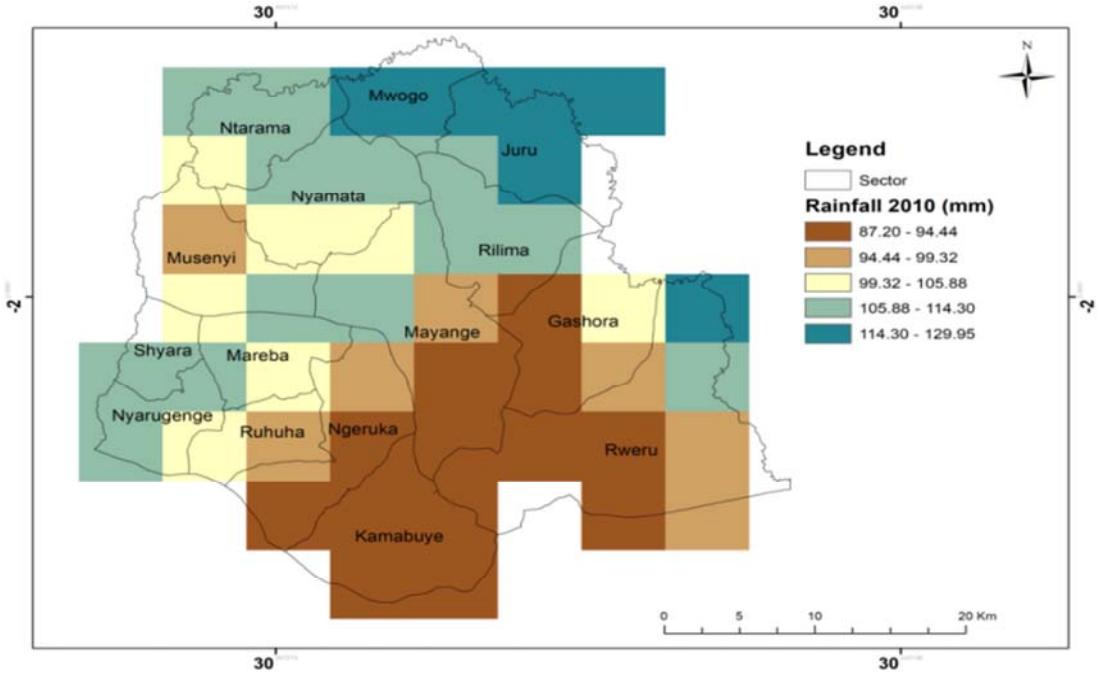


Figure 9. Rainfall distribution in Bugesera district in 2010.

The results in Figure 9 revealed that the minimum average annual rainfall recorded in 2010 ranged between 87.20 and 94.44 mm while the maximum

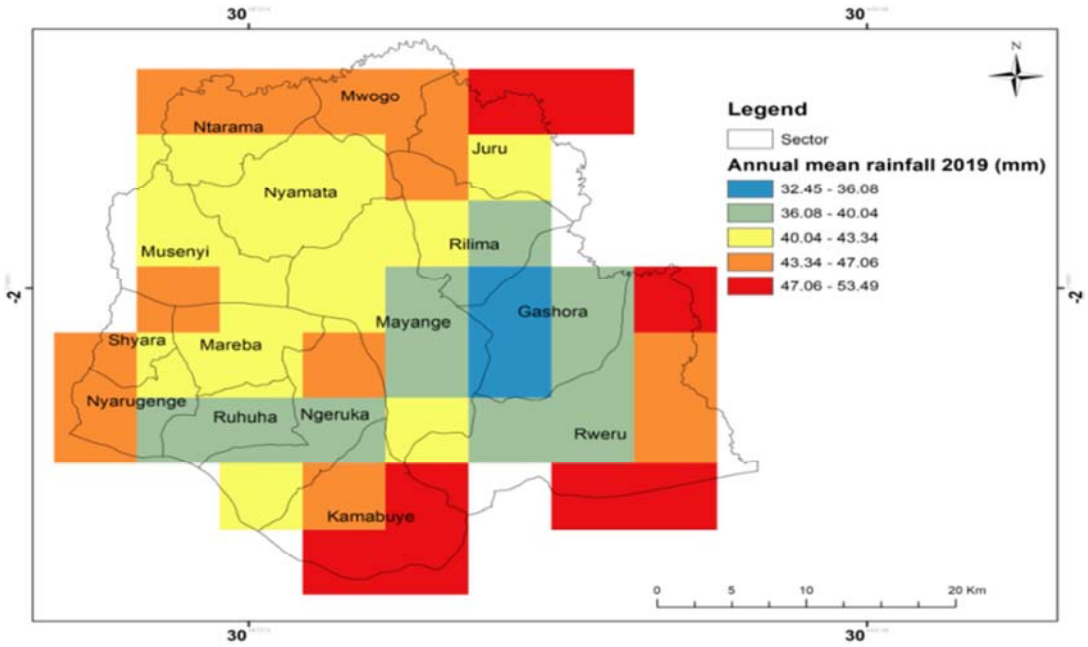


Figure 10. Annual mean rainfall in Bugesera district in 2019 (mm).

The results in Figure 10 reveal that the minimum average annual rainfall recorded in 2019 ranged between 32.45 and 36.08 mm while the maximum rainfall was ranging between 47.06 and 53.49mm.

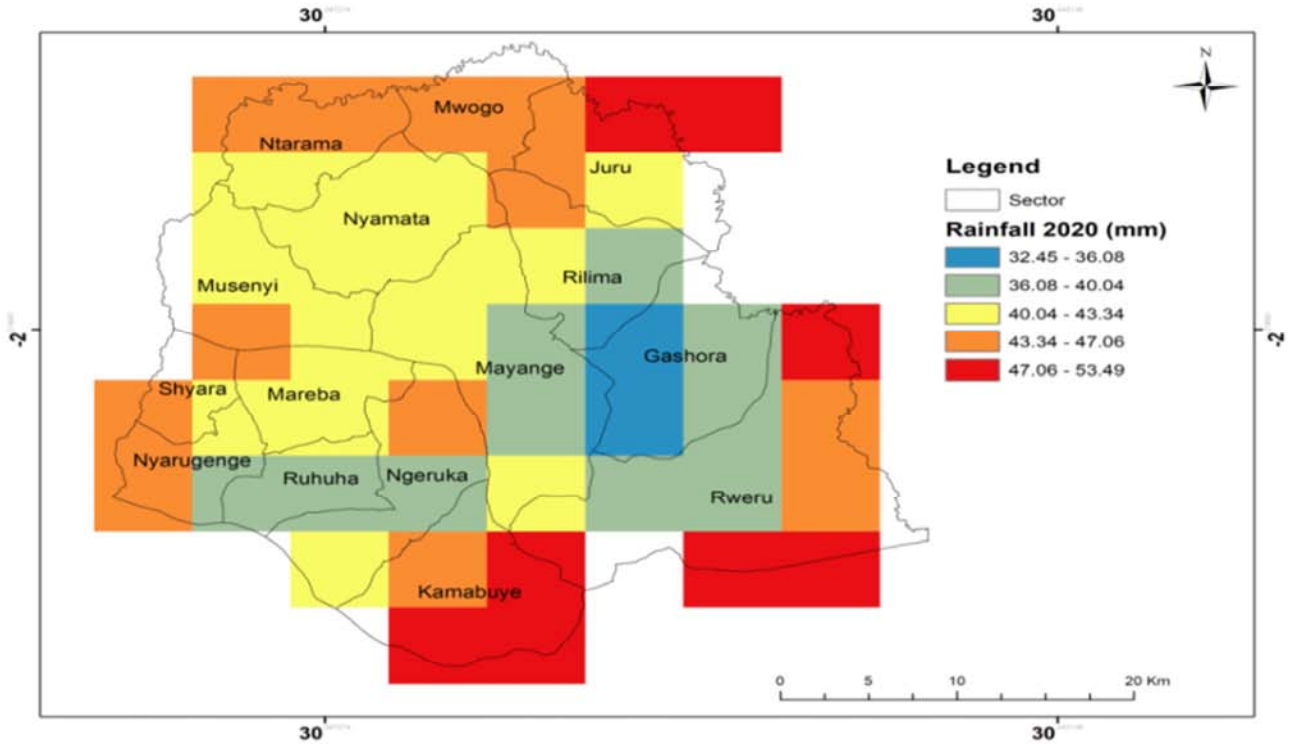


Figure 11. Rainfall distribution in Bugesera district in 2020.

The results in Figure 11 reveal that the minimum average annual rainfall recorded in 2020 ranged between 32.45 and 36.08 mm while the maximum rainfall was ranging between 47.06 and 53.49 mm.

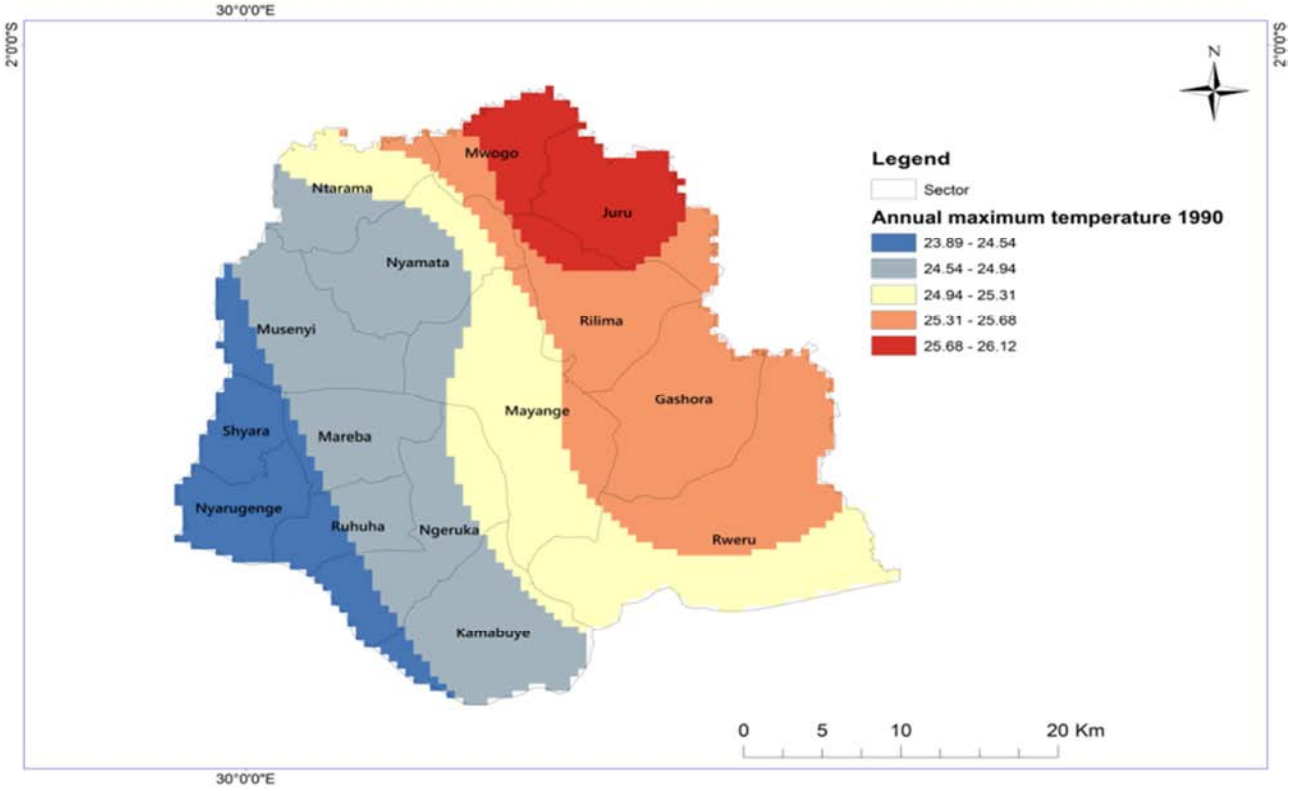


Figure 12. Annual maximum temperature in Bugesera district in 1990.

The results in Figure 12 reveal that the highest annual maximum temperature recorded in 1990 ranged between 25.66°C and 26.12°C while the minimum temperature was ranging between 23.09°C and 24.54°C.

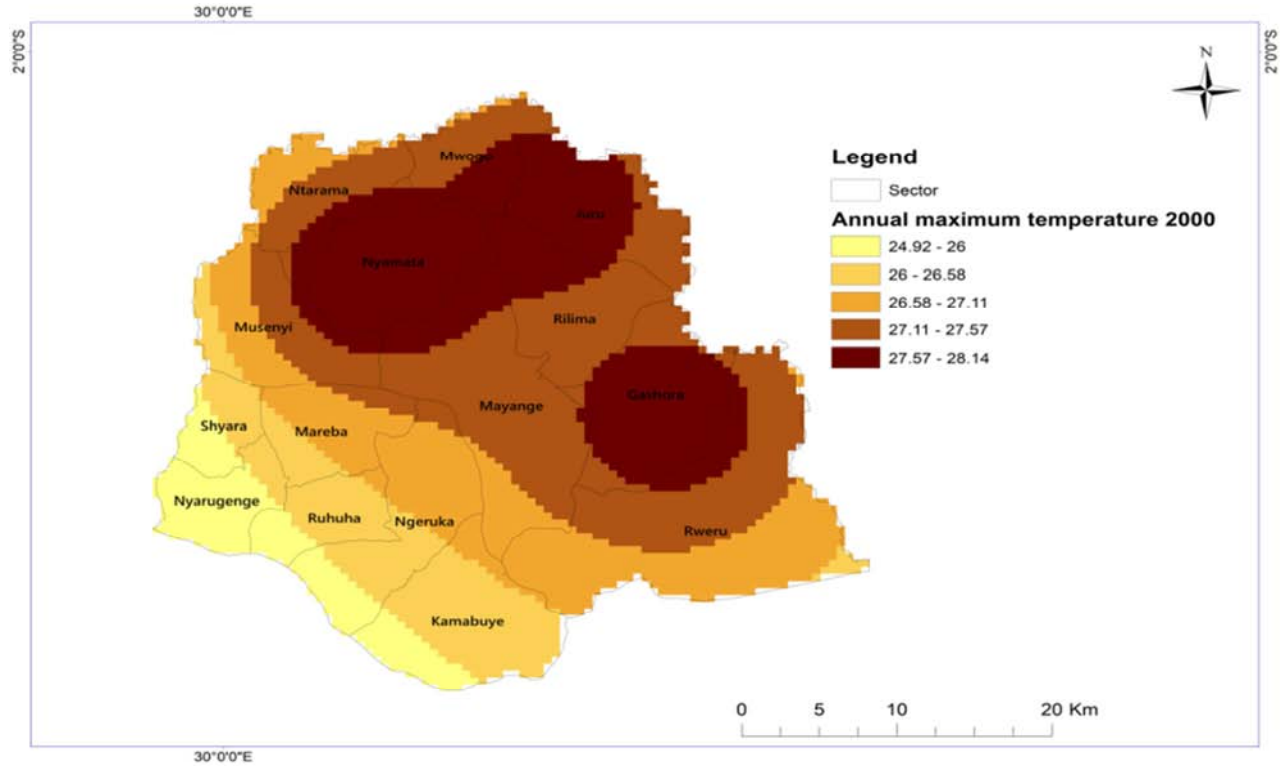


Figure 13. Annual maximum temperature in Bugesera district in 2000.

The results in Figure 13 reveal that the highest annual maximum temperature recorded in 2000 ranged between 27.57°C and 28.34°C while the minimum temperature was ranging between 24.92°C and 26°C.

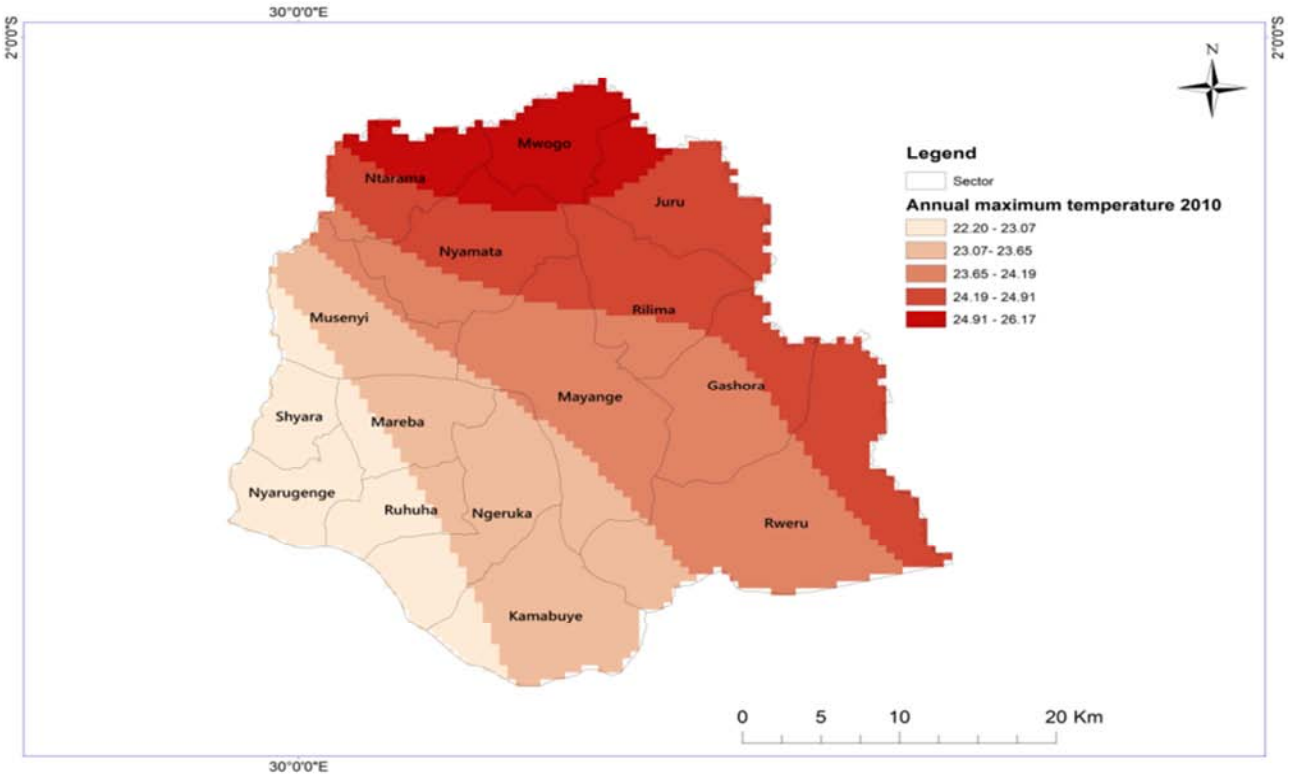


Figure 14. Annual maximum temperature in Bugesera district in 2010.

The results in Figure 14 revealed that the highest annual maximum temperature recorded in 2010 ranged between 24.91°C and 26.17°C while the minimum temperature was ranging between 22.20°C and 23.07°C.

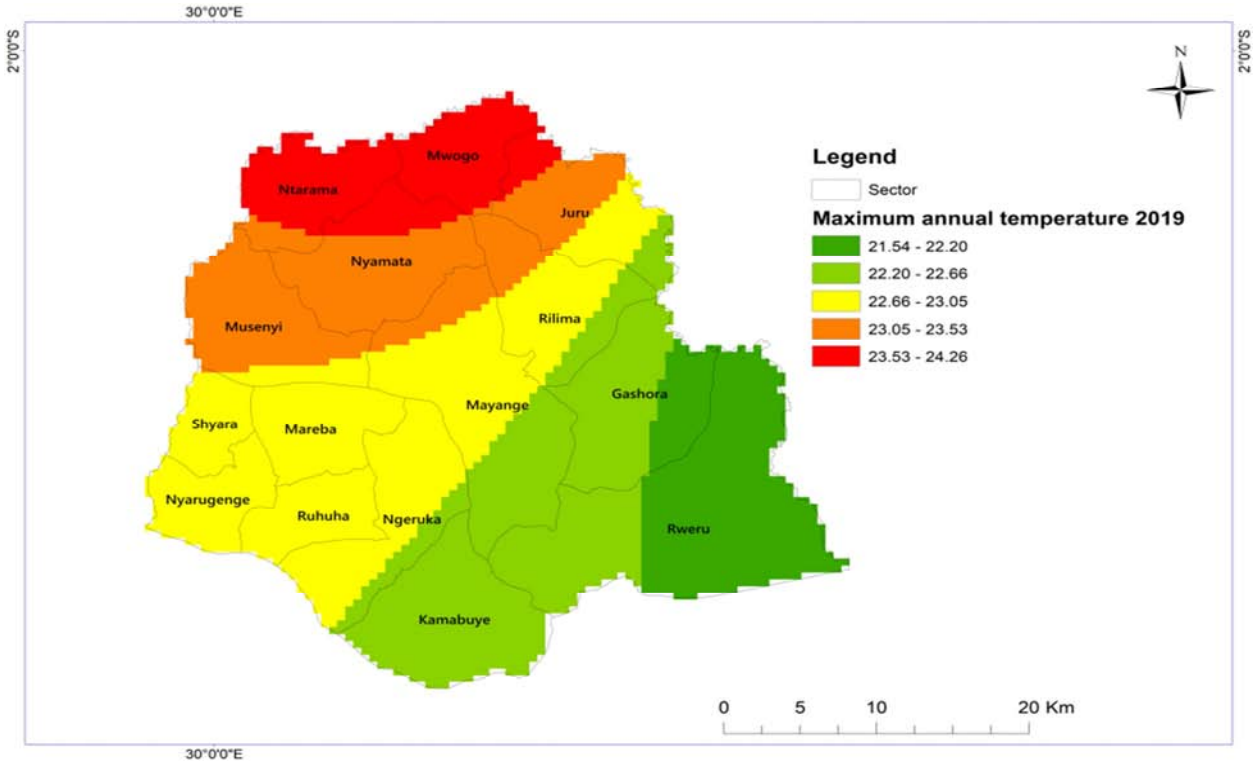


Figure 15. Annual maximum temperature in Bugesera district in 2019.

The results in Figure 15 revealed that the highest annual maximum temperature recorded in 2019 ranged between 23.63°C and 24.26°C while the minimum temperature was ranging between 21.54°C and 22.20°C.

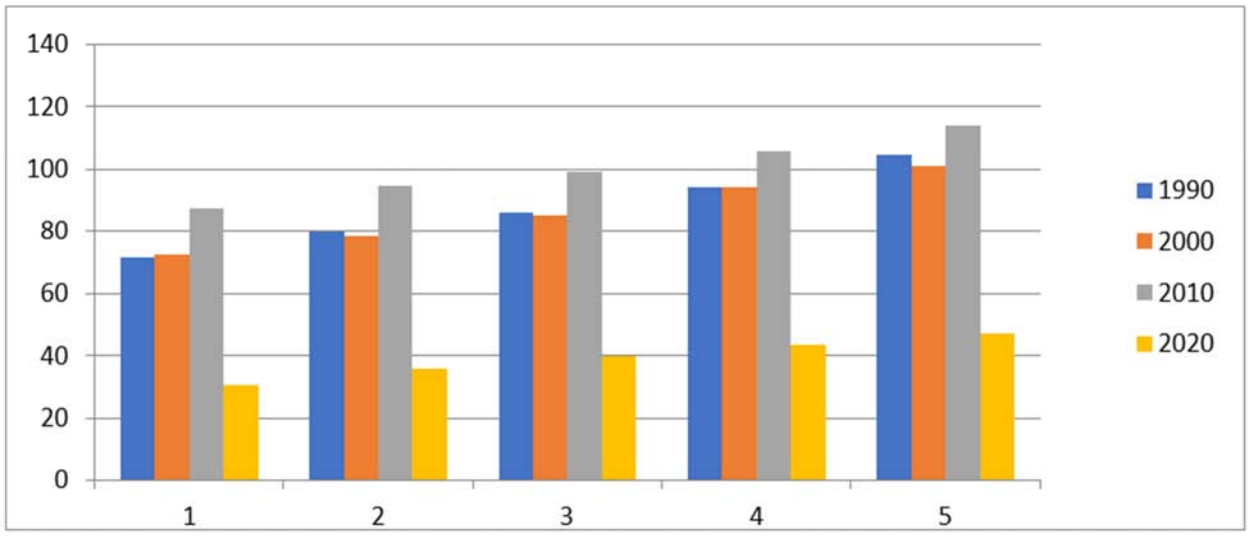


Figure 16. Minimum Rainfall Averages in Bugesera District between 1990 and 2020.

The results in Figure 16 indicated the raw data of minimum rainfall averages that indicate the decrease of rainfall from 87.242mm in 1990 to 39.394 mm in 2020, even though the year of 2010 has a high average of minimum rainfall millimetres. Other years have kept the total average of rainfall millimeters on 78.2675mm. Thus, results also showed that the rainfall millimeters were reducing as per the forestland. This means that deforestation affect minimum rainfall of Bugesera District in the last 30 years.

The results also showed that the rainfall has decrease in 2020 compared to other years even though the year is not over yet while in 2010 the rainfall was a bit higher; only because the forest land has dramatic reduction form 43.32% in 1990 to 15.37% in 2020. Hence, this study is supported by the findings of [16] that deforestation (shown by dramatic loss of forest land) leads to changes in average temperatures, rainfalls at the same time soil erosion.

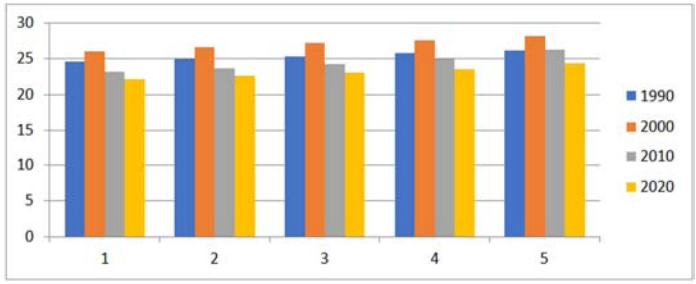


Figure 17. Average of maximum temperature in Bugesera District between 1990 and 2020.

The results in Figure 17 indicated that the maximum temperature averages kept in irregular variability where the average temperature in 1990 was 25.318°C; in 2000 it changed to 27.08°C whereas in 2010 and 2019 the maximum temperature kept low compared to the past 20 years. Thus, the analysis indicated that due to deforestation through decrease in forestland, wetland, water bodies and glass land have led to variability in maximum temperature in Bugesera District.

3.3. Contribution of Deforestation to Climate Change in Bugesera District of Rwanda

The authors performed a correlation analysis of the above findings of the study in order to measure the extent to which deforestation patterns contributed to climate change in Bugesera District.

Table 1. Correlation between deforestation and climate change.

	Forest cover	Maximum temperature	Minimum rainfall
Forest cover	1	-0.279	0.513
Maximum Temperature	-0.279	1	0.590
Minimum Rainfall	0.513	0.590	1

Source: Primary Data, 1990-2020

The results in Table 1 indicated that there is negative significant relationship between forest cover and maximum temperature with correlation r_1=-0.279. The results also indicated that a positive significant relationship between forest cover and minimum rainfall with r_2=0.513; and between maximum temperature and minimum rainfall with r_3=0.590 at 0.01level of significance. This implies that forest cover has a negative effect on temperature because the calculated correlation value is negative. The results also implied a positive effect of forest cover on rainfall and deforestation impacts on both temperature on rainfall because both calculated correlation values are positive, respectively.

Table 2. Regression analysis of deforestation and climate change.

Regression Statistics					
Multiple R	0.885727717				
R Square	0.784513588				
Adjusted R Square	0.353540765				
Standard Error	0.000691619				
Observations	4				
ANOVA					
	Df	Sum Square	Mean Square	F	Significance F
Regression	2	1.741	8.707	1.820	0.464
Residual	1	4.783	4.783		
Total	3	2.219			
	Coefficients	Standard Error	t Stat	P-value	Decision on H_o
Intercept	16.669	0.006	2483.608	0.000	Failed
Max. Temperature	-0.000	0.000	-1.555	0.363	Rejected
Min. Rainfall	3.357	1.854	1.810	0.321	Rejected

Source: Primary data, 1990-2020.

The results in Table 2 indicated that 0.885 multiple R as positive relationship that predicts the coefficient of determination which is 0.784 R square indicating that forest cover affects change in both temperature and rainfall as factors of climate change with the progressive variability of 78.4% on standard error of 0.000 as calculated by regression statistics. This implies that deforestation affected climate change at 78.4% in the last 30 years. The results of Analysis of Variance known as ANOVA in the same Table 2 showed a p-value which is higher than 0.05 (> 0.05) explaining that it

is not statistically significant.

The general assumption of regression analysis showed a p-value: 0.000 less than 0.05 level of significance and indicated a significant relationship between deforestation and climate change. Thus, the authors adopted the following regression model:

$$Y=\beta_0+\beta_1X_1+\beta_2X_2+\beta \quad (1)$$

The model gives a linear regression equation

$$Y=16.669-0.000X_1+3.357X_2 \quad (2)$$

Where Y stands for deforestation, X_1 stands for maximum temperature and X_2 stands for the minimum rainfall. Thus, this liner regression equation showed that there is significant relationship between deforestation and climate change in Bugesera District.

4. Conclusion

The results of this study showed a negative significant relationship between forest cover and maximum temperature with correlation r_1= -0.279. The results also revealed that there is positive significant relationship between forest cover and minimum rainfall with r_2= 0.513; and between maximum temperature and minimum rainfall with r_3 =0.590 at 0.01 level of significance. This implies that forest cover has a negative effect on temperature because the calculated correlation value is negative. The results also generated a positive effect of forest cover on rainfall while it also has an effect on temperature and on rainfall because both calculated correlation values are positive, respectively. Basing on the finding of the study, the authors recommend to the residents of Bugesera District to take part in reforestation and protection of natural forest. The local leaders are suggested to ensure developing capacity for mainstreaming environmental issues into the strategic plan of the development framework.

In addition, local leaders are also recommended to mobilize and sensitize the relationship between poverty, wellbeing and environment and establish indicators to monitor their progress. The authors also recommend the use Liquefied Petroleum Gas (LPG) while cooking and use other source of energy such as biomass, conservative stove and electricity. This will decrease the rate of deforestation.

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