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# RELATIONSHIP BETWEEN HUMAN ACTIVITIES AND DEFORESTATION IN KARONGI DISTRICT OF RWANDA

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## *ABSTRACT*

Karongi District of Rwanda is one among districts with high rate of forest clearance resulting from unmanageable human activities and change on land use. This study was conducted in order to analyze the relationship between human activities and deforestation on the period between 2013 and 2019. The authors employed secondary data on forest cover collected from the Rwanda Forestry Authority (RFA), National Institute of Statistics of Rwanda (NISR), and Karongi District report. Thereafter, the Geographic Information System (GIS) helped to map forest cover and Microsoft Excel was used to indicate the percentage of land cover change over the study period. The Pearson correlation analysis of the Statistical Package for Social Sciences (SPSS) analyzed the relationship between human activities and deforestation in Karongi District. The results showed that between 2013 and 2019, cropland, built up and population growth rate increased at the rate of 5 %, 2.15%, and 6.07% respectively. The forestland which reduced by 5.4% in the same period generated a positive significant relationship between population growth and forestland with correlation r1= 0.993. The results also revealed a positive significant relationship between settlement and forestland with r2=0.990. The negative significance relationship between cropland expansion and forestland with r3 = -0.970 at 0.05 level of significance was noticed. Since the analysis generated a positive effect of settlements and population growth on deforestation, it can be concluded that human activities contribute to deforestation in Karongi District of Rwanda, and that relevant measures should be applied.

**Contribution/Originality:** This paper provided information which is necessary in country like Rwanda or similar regions with high population density looking for food security and development as well. Thus, areas in need of sustainable resources natural management under human pressure can benefit from this study.

## 1. INTRODUCTION

From the 16th Century onward, population growth and economic expansion in Europe and parts of Asia led to widespread forest clearance to make way for agriculture and new settlements [1]. Forests then became valued principally for their timber, which was used in construction, and of critical importance in an age of growing international trade and colonization ship-building. As a result, forest cover declined dramatically [2, 3].

In 1990, the world had 4 128 million ha of forest; by 2015 this area had decreased to 3 999 million ha. This is a change from 31.6 percent of global land area in 1990 to 30.6 percent in 2015 [4]. Deforestation, the conversion of

tropical forest to agricultural land shows signs of decreasing in several countries but continues at a high rate in others [5]. Around 13 million hectares of forest were converted to other uses or lost through natural causes each year in the last decade compared with 16 million hectares per year in the 1990s [6, 7].

Over the last centuries, vast forest areas worldwide have been deforested to meet the needs of a growing population. About 30% of global forest cover has been cleared and further 20% has been degraded [8]. However, deforestation mainly resulting from forest conversion to other land uses is more complicated [9]. Natural forest and planted forests change dynamics differ across national circumstances and forest types. This rapid deforestation significantly endangers the global biodiversity [10].

The land use/land cover change (LULCC) remains a global challenge: one estimate indicates that109hectares of natural ecosystems may be converted to agriculture by 2050 [11]. In addition, forests cover nearly one-third of the earth's land area and experienced a total loss of 2.3 million $Km^2$ from 2000 to 2012 due mainly to human disturbance [12, 13]. However, there remains a critical lack of information about the complex processes leading to deforestation, including the roles of direct and indirect drivers of forest loss, at national and regional scales [2, 11]. This knowledge gap limits the ability of decision makers to design forest conservation and management approaches that effectively address pre-dominant causes of deforestation and influence the relevant actors responsible for forest loss [14].

Nevertheless, despite the fact that some countries are presently advanced in routinely and systematically monitoring the spatial and temporal trends in different types of agricultural, and non-agri-cultural, drivers of deforestation [15, 16]. Although progress on forest management and deforestation factors identification was recorded in the last centuries, there is still lack of assessment on the indirect or underlying drivers of deforestation, which collectively predispose. For example, the studies [17, 18] conducted to evaluate the effects of biophysical and anthropogenic predictors on deforestation in Brazilian Amazonia, highlighted that the Amazon forest is challenged by the three proximate factors. These factors are namely human population density, highways and dry- season severity, all of which increase deforestation [17].

The above studies omitted to establish how deforestation is statistically associated with settlements and agriculture expansions in Brazilian Amazonia. However, the findings of Binsangou, et al. [16] conducted on Urban Growth and Deforestation by Remote Sensing in the Humid Tropical Forest of Congo Bassin: Case of Impfondo in the Democratic Republic of Congo, indicated that direct drivers to deforestation are agriculture and urban growth merged with population growth. However, this study did not evaluate how settlement can also contribute to deforestation.

In Rwanda, forest encroachments through various human activities are the major threats to forests. These activities include illegal logging, charcoal production, and bushfires [19]. The recent national forest inventory conducted in 2007 identified several factors of deforestation in Rwanda. These include mainly the illegal tree cutting (78.3 per cent), charcoal making (4.9 per cent), livestock grazing (2.5 per cent), farming activities (1.9 per cent), bushfires (1.9 per cent), stem debarking (0.6 per cent), mining (0.5 per cent) and beekeeping (0.4 per cent) as the main threats [20-22]. Accordingly, as recently reported, the above factors of deforestation in Rwanda are at high extent, accelerated by its rapid increase of human population which is leading to forest encroachment and deforestation, mainly in search of settlement, agriculture and grazing land. And this dense and rapidly increasing population on a fragile land resource, has led to deforestation and continuous degradation [9, 23].

The deforestation in Rwanda is experienced differently by each area of the country. Previously, the district of Bugesera in the eastern Rwanda recorded immense deforestation and this led to drought and food insecurity among the residents. And presently, the afforestation and reforestation policies contributed to restoring the forest lost/degraded [24, 25]. Similarly, Karongi district of the western Rwanda has recorded the fact of hosting refugees from the Democratic Republic of Congo and large areas were deforested in order to get where to camp. Not only,

this but also, its high population growth, unsustainable human activities and change on land use for settlements and agriculture expansions contribute to forest cover change/deforestation [26, 27].

Although the above studies were conducted, it was noted that conducting statistical correlation between human activities sand deforestation is needed in Karongi district in order to indicate the extent to which human activities contribute to deforestation and those major human activities. The authors believe that the results of this study will advance the local community and leaders' awareness on how people's activities lead to deforestation and the best effect minimization policies.

## 2. METHODS AND MATERIALS

### *2.1. Description of Study Area*

This study was conducted in Karongi District Figure 1, one of the seven districts forming the Western Province of Rwanda. The Karongi District stretches over an area of 993 Km2; it has an altitude varying between 1,470 to 2,200 meters. The District is among the most mountainous districts and is part of the Congo Nil Crest (Watershed) which falls in both Kivu and Upper Nyabarongo Sub catchment [28]. Due to its relief and topography, soil erosion and landslides are frequent in most areas of the district. The climatic situation of the district does not differ from North-Western part of the country [28].

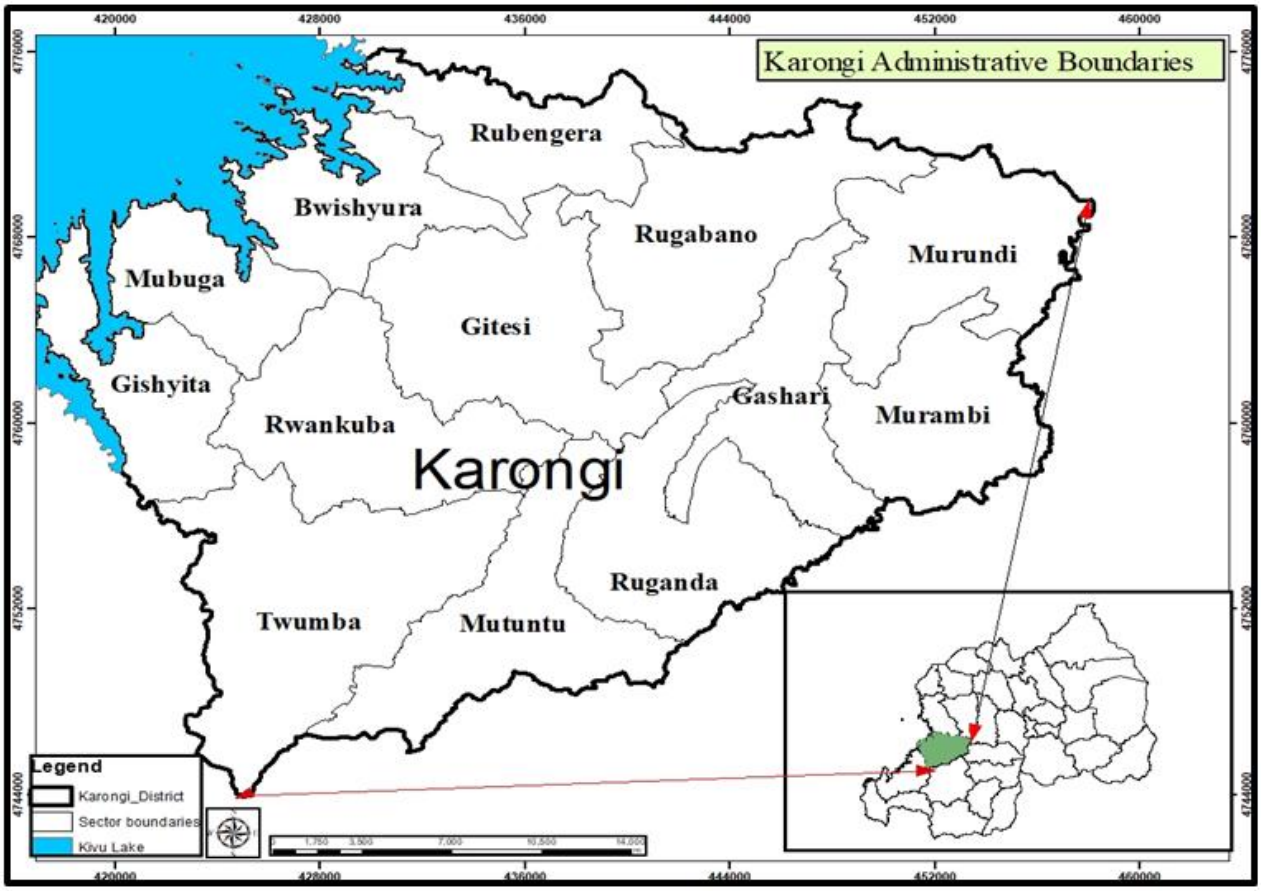



**Figure-1.** Karongi District in Map of Rwanda.

Karongi District experiences tropical climate of high altitude. It is one of Rwanda regions which have high rainfall. The amount of rainfall in the district benefits the area and is characterized by two dry seasons covering the period from December to January and from June to mid-September. The district is also characterized by two rainy seasons where the long rain season starts in mid-September and ends in December and from February to June with an annual average of temperature varying from 16°C to 21.5°C [29]. The annual rain falls ranging from 1,100 to

1,500 mm, thus these features are favorable to agriculture and livestock development. But they are the source of erosion and environmental degradation in the regions of high altitude. So, there should be a continuous protection of environment in these areas [29].

Karongi district is characterized by high lands area with steep features. Karongi District has an altitude varying between 1,470 to 2,200 metres. On one hand, the topographical characteristics allow the district to be faced with soil erosion. The various land uses decrease forest area accentuates the erosion phenomena, bring heavy siltation downstream, and in some cases, the floods may occur [28].

### *2.2. Data Collection and Analysis*

The study mainly used secondary data related to human activities like cropland, (agriculture) settlement, and population growth along with forest cover in Karongi District. The secondary data mainly gathered the forests cover change in different years (as by the study period), the land use and land cover change, population growth and settlement recorded. Also, secondary data on shapefiles of the study area helped the authors to make maps of each item under consideration (land use and land cover change, forest cover, cropland) across the study area. The desk review used recent reports, research papers, magazines, journals, news and other documents.

The study considered the period ranging from 2013 to 2019 which was chosen based on the reason that the available data could enable the authors to complete the study, and that the results of this period would enable policy makers to better understand changes on land and land cover and the associated factors as well as best way forward.

The data employed by this study were collected from different sources and they were analyzed by using the Geographic Information System (GIS) and Statistical Package of Social Sciences (SPSS). Figure 2 details the methodological steps undertaken by this study for its completion.

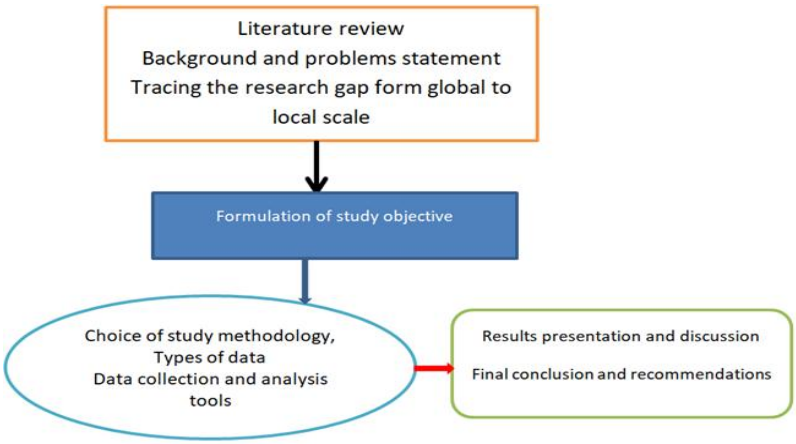



**Figure-2.** Proposed study methodological flowchart.

## 3. RESULTS AND DISCUSSION

The results presented in this part of the study are related to the trend of forest cover change in Karongi District between 2013 and 2019. These results helped the authors to interpret the rate of deforestation over the last 6 years. It also presented the change in cropland and build up in mentioned District between 2013 and 2019.

### *3.1. Human Activities that Likely Cause Deforestation in Karongi District*

The results on the key causes of deforestation in Karongi district were collected from different sources mainly the reports of the Rwanda Forestry Authority [30] National Institute of Statistics of Rwanda [31] and Karongi District. While consulting these reports, the authors kept in mind that the needed data were from 2013 to 2019. The review of these reports highlighted among others that the major drivers to deforestation which have been

registered in Karongi district from 2013 to 2019 were mainly rapid human population density, expansion of agriculture (cropland) and settlement (search for place to build houses).

Therefore, as indicate in the following section (forest cover change in Karongi district), the authors chose to analyze these factors with reference to the study period (2013-2019) in order to indicate how they affected forest cover within the District of Karongi.

### *3.2. Forest cover in Karongi District from 2013 to 2019*

It is reported that in most cases, the major drivers to deforestation and forest degradation are agricultural expansion and its practices, unstainable forest management, fire and mining, development of infrastructures. The incidence is largely recorded within largely populated areas in search for the above benefits while possible restoration measures if well applied can contribute to restoring the available forest for both present and future generations.

The authors recognized the above facts and then applied the Geographic Information System to indicate periodical changes on land use and land cover which covered forestland, cropland, settlement, water bodies and grassland. The findings of the study presented in this subsection are based on the map extracted from GIS data indicating the trend of forest cover change in Karongi District between 2013 and 2019 which are taken as the basis of deforestation in this study. The change of forest cover was measured with reference to land use and land cover change mainly forestland, cropland, built up in Karongi District of Rwanda within the considered 6 years of the study.

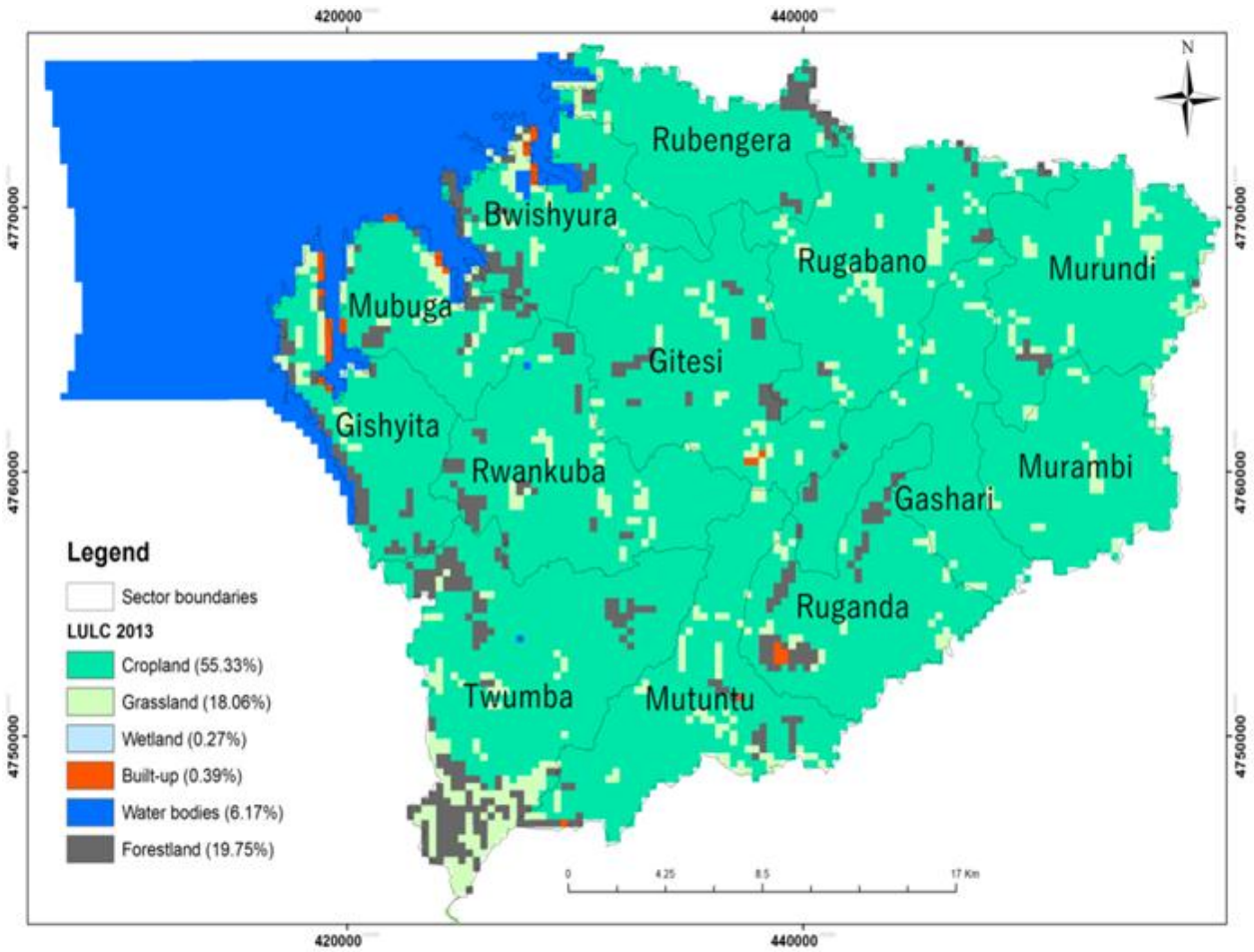



**Figure-3.** Forest cover change over 2013 in Karongi District.

Based on the results represented in Figure 3, it was noticed that the cropland occupied the majority of the land (55.33%) in Karongi District followed by forestland which occupied 19.75 percent of the total land in Karongi district. The largely inhabited sectors of Karongi district were namely Bwishyura, Mubuga, Gishyita and Ruganda sectors.

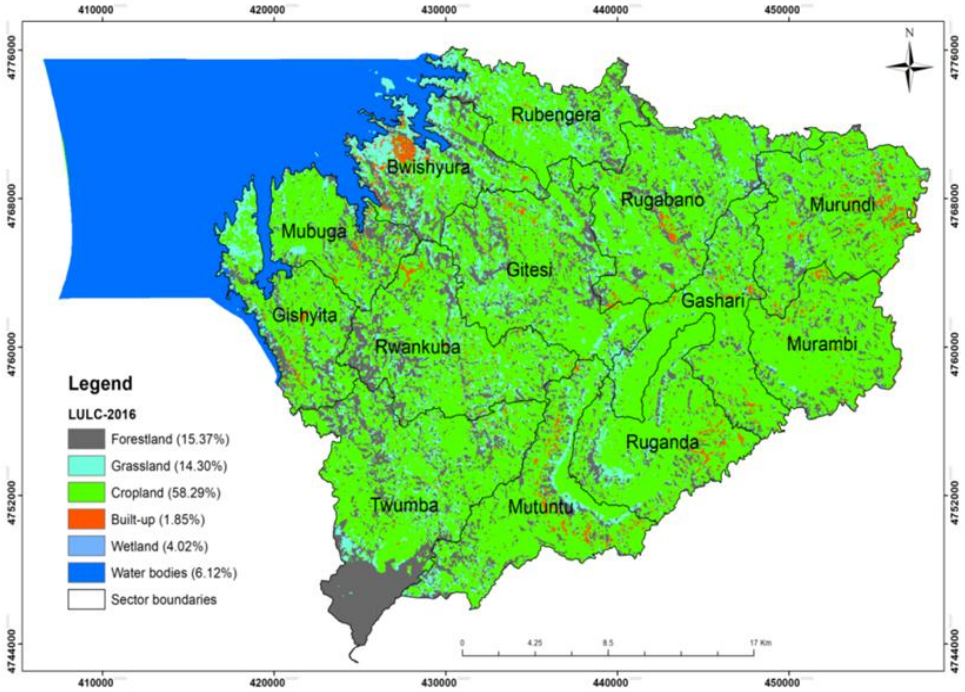



**Figure-4.** Forest Cover change over 2016 in Karongi District.

The results as shown in the above Figure 4 revealed that in 2016, the forestland reduced from 19.75 percent recorded in 2013 up to15.37 percent in 2016. However, the crop and built-up lands increased from 55.33% and 0.39 percent up to 58.29 and 1.85 percent in 2013 and 2016, respectively.

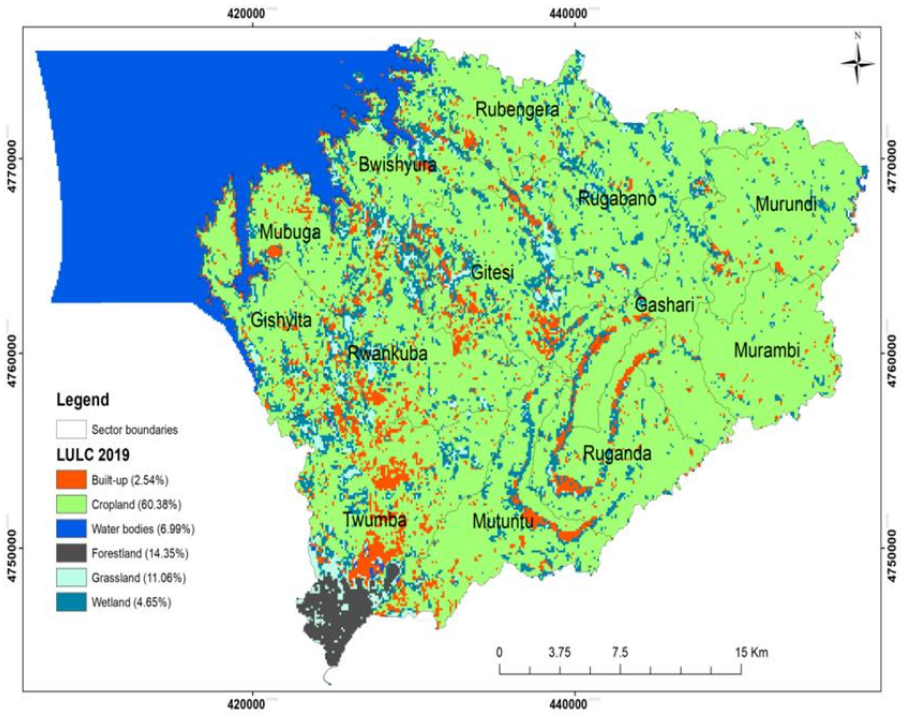
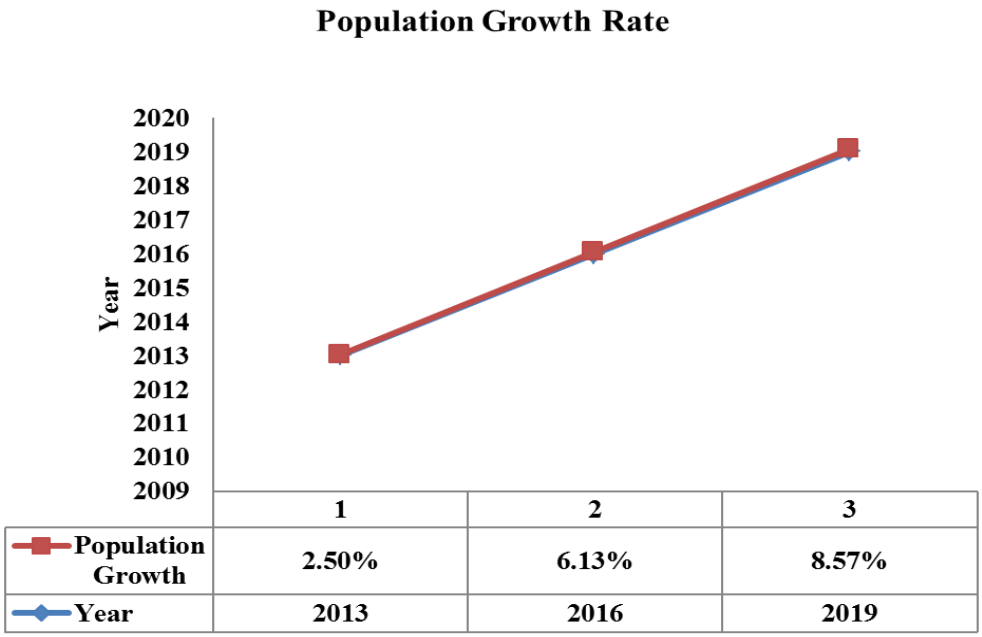



**Figure-5.** Forest covers change over 2019 in Karongi District.

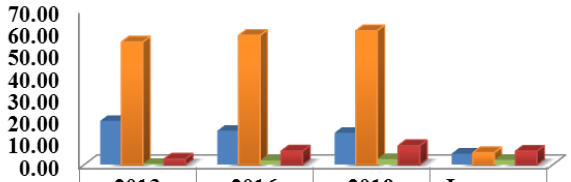
As illustrated in Figure 5, the built-up and crop lands increased compared to 2013 and 2016.Their record was 2.54 and 60.38 percent in 2019, respectively. Nevertheless, the forestland reduced up to 14.35 percent from 19.75 and 15.37 percent in 2013 and 2016, respectively.




| | 1 | 2 | 3 |
|---|---|---|---|
| Population Growth | 2.50% | 6.13% | 8.57% |
| Year | 2013 | 2016 | 2019 |

**Figure-6.** Population growth rate in Karongi District.

Moreover, the results in Figure 6 indicated that rate of human population growth within the district of Karongi recorded increasing trend from 2013 to 2019. The growth rate has comparatively increased in 2016 and 2016 compared to the record of 2013 (Figure 6). Their record was 2.50 percent, 6.13 and 8.5 percent in 2013, 2016 and 2019, respectively. As the conclusion about population growth rate in Karongi District, there is high rate of human population growth and this likely expresses the need for land to grow crops and settlement which can lead to deforestation as well.




| | 2013 | 2016 | 2019 | Increased rate(%) |
|---|---|---|---|---|
| Forestland(%) | 19.75 | 15.30 | 14.35 | 5.0 |
| Cropland(%) | 55.33 | 58.29 | 60.38 | 5.4 |
| Built up(%) | 0.39 | 1.85 | 2.54 | 2.2 |
| Population growth rate(%) | 2.50 | 6.13 | 8.57 | 6.1 |

**Figure-7.** Periodical rate on land cover, forest, settlement and population growth in Karongi District of Rwanda.

The results presented in Figure 7 showed that the forestland land have reduced from 19.75% in 2013 to 14.35% in 2019. The settlement symbolized as built-up land increased from 0.39% in 2013 to 2.54% in 2019 and the cropland have recorded increasing trend from 55.33% in 2013 to 60.38% in 2019.

Based on the results presented in the above Figure 7, it can be noted that for the case of forest cover, the primary agent of deforestation in Karongi district are the increase of human population while looking for wood fuel, making charcoal, and settlement. This expansion of built-up land in Karongi district can be associated to the

refugees from the DRC who settled in Kiziba camp due to insecurity in their home country. And this is in most cases, associated with deforestation in order to claim for cropland and areas where to locate their camps. In addition, as long as the population increases within the area, the likelihood of deforestation could increase as well.

### *3.3. Relationship between Human Activities and Deforestation in Karongi District*

Finally, the authors performed a statistical analysis in order to indicate the extent to which human activities have contributed to deforestation in Karongi district. This analysis was facilitated by the correlation analysis of the SPSS by employing the above findings on the on forestland, cropland, built-up/settlement and human population growth.

**Table-1.** Correlation between forestland with cropland, settlement and population growth.

| | | Cropland | Settlement | Population growth rate |
|---|---|---|---|---|
| Forestland | Pearson Correlation | -0.970 | 0.990 | 0.993 |
| | Sig. (2-tailed) | 0.078 | 0.045 | 0.038 |
| | N | 3 | 3 | 3 |

**Note:** *Correlation is significant at the 0.05 level (2-tailed).

The results in Table 1 above indicated a positive significant relationship between population growth and forestland with correlation $r_1$= 0.993. The results have also indicated a positive significant relationship between forestland and settlement with $r_2$=0.990; and there is negative significance relationship between cropland expansion and forestland with $r_3$ = -0.970 at 0.05 level of significance.

This therefore, implies that cropland has a negative effect on forestland because the calculated correlation value is negative. The results also indicate that there is a positive effect of settlements and population growth on deforestation because both calculated correlation values are positive, respectively. Then, the results enabled the authors to mention that there is a relationship between human activities and deforestation in Karongi District of Rwanda".

## 4. DISCUSSION

It is reported that inn Africa, forests currently cover about 23 % of the total land and that 75 million ha of forest land (10 % of the total forest area) was converted to other uses between 1990 and 2010 (Hansen et al. 2013). The deforestation in Africa is driven by the demand for land for growing a variety of crops and for grazing. An added pressure on forest resources in Africa is that wood is the main source of fuel; about 80% of all wood used in the region is for fuel. An acute fuel wood shortage affects large areas of eastern Africa [32, 33].

In Rwanda, statistics from the Forest department show that forests were estimated to cover 659,000 ha in 1960. However, this forest cover recorded growing loss which reached approximately 64 % of forests loss between 1960 and 2007, which is more than 1.3 % per year [34]. And the rapid increase in population is reported to be the major driver to increasing pressure on forests in terms of encroachment and deforestation in Rwanda [34].

In addition, it is reported that in Rwanda, mainly within rural areas, more than 95% of the rural populations rely on wood for fuel, and the national dependency level is over 85% despite strong efforts to reduce this. There is a severe and increasing gap between wood supply and demand, which is more than twice the sustainable supply [35]. This shortage of fuel wood drives to forest degradation in public forests while private forests are often seriously overcut; both these factors prejudice future productivity [34, 36].

Accordingly, the study conducted on deforestation in Vietnam indicated that 2000 to 2010, there has been deforestation driven by poverty, agricultural production, population density, and provincial-scale governance [37]. The above agree with the results of this study on the extent to which human activities are leading to deforestation.

It was noted that between 2013 and 2019, there has been deforestation in Karongi district of the western Rwanda and the major drivers were human population growth and settlement (Table 1).

This expresses that as long as human population increases in Karongi district, people have been looking for areas to settle in and this lead to deforestation. In addition, refuges in Karongi district were attributed to spreading the speed of deforestation in the district. This resulted from the fact that for their location to be prepared, there has been cut off trees and the trees cut off were not replanted on the same unity of land [38]. This was certified by the results of this study where forestland recorded decreasing percentage from 2013 to 2019 (Figures 3, 4 and 5).

Moreover, the findings of this study indicated that in Karongi district, settlements and population growth are the main contributors to deforestation compared to the contribution of cropland expansion. This was confirmed by the results in Table 1 which demonstrated a positive significant relationship between population growth and forestland with correlation $r_1$= 0.993 and also indicated that there is positive significant relationship between forestland and settlement with $r_2$=0.990.

Furthermore, the results of this study were supported by the findings of several studies which indicated that global forests are recording higher degradation rate mainly resulting from human activities. These activities include the settlement (search for areas to settle in) which at large extent, contributes to deforestation and in most cases, the deforested areas are not replaced which contributes even to desertification and/or complete land degradation [39, 40].

The findings of this study shown in Table 1 agreed on this fact since there was a positive significant relationship between forestland and settlement with $r_2$=0.990. This expresses that for expanding the forestland in Karongi district, policy makers should consider the major causes of deforestation mainly population growth and settlement.

## 5. CONCLUSION

This study evaluated the relationship between human activities and deforestation in Karongi District of Rwanda on the period 2013 to 2019. The human activities mainly identified as contributors to the forest cover loss were settlements (built up), population growth and cropland expansion. The GIS and SPSS softwares were used to analyze the collected data. The results indicated that cropland, built up and population growth periodical rate increases at 5 %, 2.15%, and 6.07%, respectively in the period of 6 years from 2013 to 2019 whereas forestland reduces 5.4% in the same period. The SPSS Pearson correlation data analysis indicated that there is positive significant relationship between population growth and forestland with correlation $r_1$= 0.993. Also, it was noted that there is positive significant relationship between settlement and forestland with $r_2$=0.990. The result additionally, indicated that there is negative significance relationship between cropland expansion and forestland with $r_3$ = -0.970 at 0.05 level of significance. This implies that cropland has a negative effect on forestland because the calculated correlation value is negative. However, as the results implied that there is a positive significant relationship of settlements and population growth on deforestation because both calculated correlation values are positive. Then, the analysis findings make the authors to accept hypothesis stating that there is a relationship between human activities and deforestation in Karongi District of Rwanda. Finally, in order to ensure control of deforestation, it is suggested to ensure strong population growth control measures and further studies are suggested to consider other factors which were not used by this study, but likely contribute to deforestation like roads construction, climate change and infrastructure development including industry constructions.

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