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Contribution of Mining Practices on Forest Degradation in Rwanda

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Abstract: Mining is among the sources of income to communities but also one of the key drivers to deforestation and water and soil pollution as well. This study assessed the contribution of mining practices on forest degradation, case of DUMAC, Rwamagana district, Eastern Rwanda between 2018 and 2021. Secondary datasets on DUMAC's applied mining practices, occupied land and mining production were analyzed by using Microsoft Excel form its record/database. Landsat images collected from the United States Geological Survey (USGS) generate periodical land over images. These maps were then analyzed by Spatial Analyst tool of Geographic Information System (GIS) toward detecting changes on forest cover. The Pearson Correlation Analysis of Statistical Package for Social Sciences (SPSS) estimated how mining practices affect forest cover. The results show that mining area increased form 18.4 ha to 64 ha in 2018 and 2021, respectively. The mining harvest showed an upgrading record of 32,738 to 81,835, respectively. For forest cover change within mining areas, the record decreased form 15.3 percent in 2018 to 14.3 percent in 2021. The statistical analysis of the relationship between mining practices and forest degradation generated a low statistical significance, P value of 0.028. This can be resulting from the reason that regardless the reduction in forest cover, other land uses increased mainly built-up lands, croplands and grassland which expresses that mining practices are not the only factors of forest degradation in this area. This study shows that mining practice contribute to forest degradation and the provided recommendations can help in better practicing mining in a friendly land management manner.

Keywords: Deforestation, DUMAC, GIS, Mining, Land Management, Rwamagana district, Rwanda

1. Introduction

Mining consist on valuable minerals or other geological materials extraction from the earth, from an ore body, vein or seam including the removal of soil (de Quadros et al. 2016). Some of the products obtained by mining activities can cover base metals, precious metals, iron, uranium, coal, diamonds, limestone, oil shale, rock salt and potash. Mining in a wider sense comprises extraction of any non-renewable resource (e.g., petroleum, natural gas, soil or even water) (Tesfaye et al. 2017; de Araujo Alves et al. 2021). The rapid human population growth associated with increasing urbanization and industrialization is continuously leading to issues of landownership (acquisition) and land rights across different countries. In addition, human activities like clearing forest and expanding cropland, search for building areas and mining activities posed pressure on sustainable land use management (Xu et al. 2018; Dixit and Chi 2021).

In both Africa and Asia, wood is the dominant energy source, providing, for example, more than 80% of the total energy requirement in Nepal and Bhutan (Devkota et al. 2013). People living at high altitudes require more wood for cooking and heating than those living at the lower altitudes. This is associated with differences in both climate and atmospheric pressure: at high altitudes, temperatures are lower, thus requiring more energy for cooking and heating, and water boils at a lower temperature, thus increasing cooking times (Lamsal et al. 2017; Bulti et al. 2020).

In Rwanda, mining sector/industry is in a state of transition, with recent privatization of big concessions and moving from artisanal mining to a sustainable economic and competitive industry (Muhire and Ahmed 2015).–Although mining sector contributes to livelihoods and economic development, it is now recorded among water and soil quality polluters and land degradation sources and deforestation as well. The major challenges to forest management in Rwanda include illegal logging, charcoal production, and bushfires. In Rwanda, the major activities which largely affect forest movement are illegal tree cutting (78.3%), charcoal making (4.9%), livestock grazing (2.5%), farming activities (1.9%), bushfires (1.9%), stem debarking (0.6%), mining (0.5%) and beekeeping (0.4%) (Karamage et al. 2016; Nishimwe et al. 2021).

However, due to higher and fast growing human population under limited land resources, deforestation and continuous degradation are the major features of forests.

In Rwanda, recent studies (Hirwa et al. 2019; Yager 2004; Perks 2012) were conducted to assess the impact of mining on socio-economic development and others analyzed how mining might be amongst the conditioning factors of disaster occurrence which affect land, water and soil quality across different parts of the country. Nevertheless, as long as human population is increasing and expanding its mining activities, it is good to undertake a study on how mining impact on forestland management. The objective of this research was to analyze the impact of mining practices on forest degradation in Rwamagana district from 2018 and 2021.

2. Methods and Materials

2.1 Study area

This study was considered by considering Rwamagana district, one of seven districts that compose the Eastern Province of Rwanda, it combines what was Muhazi district before, the former Gicumbi district, two former sectors of ancient Gasabo district, i.e. Fumbwe and Muyumbu as well as three sectors of former Kabarondo district, which are Kaduha, Rweru and Nkungu plus the previous city of Rwamagana. The actual district of Rwamagana is made of 14 sectors, 82 cells and 474villages. It has 74,175 families extended on its surface area of 682 km^2. Its population amounts to 313,461 at the population density of 460/Km^2 (Olivier et al. 2013).

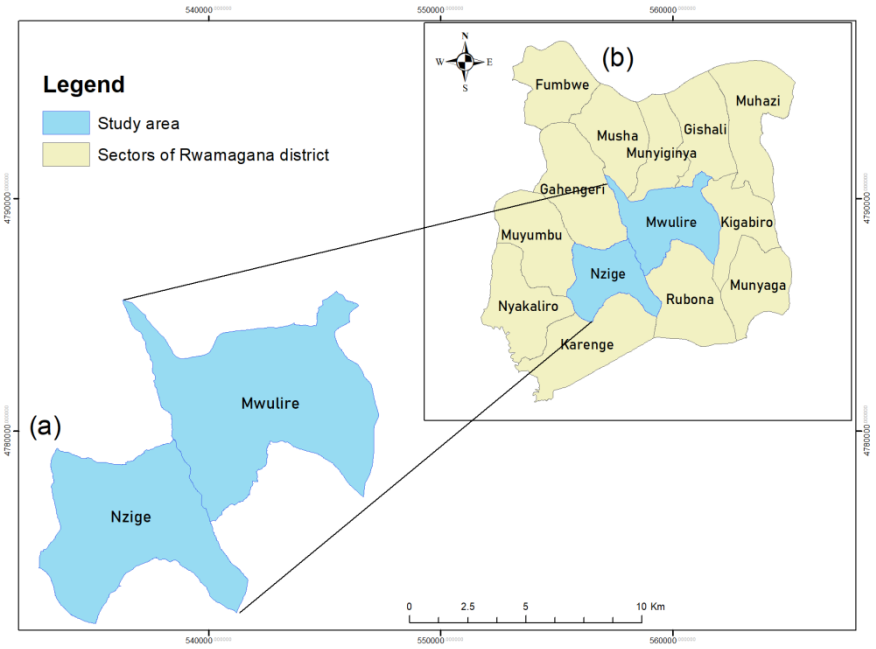

Figure 1**: Map indicating the location of the study area (sectors under mining) and (b) their neighboring sectors of Rwamagana district**

In Rwamagana district, the major economic activity is the agriculture with some other secondary economic activities which include fishing done in different small lakes found in this district, tourism attracted by some caves as well as the crafts. The main crop in Rwamagana is banana and the area is known in the whole country for that crop. Together with Kayonza, Ngoma, Kirehe, Rwamagana is the food basket of that crop in Rwanda, together with rice, beans and sweet potatoes (Olivier et al. 2013). This study was conducted in Rwamagana district with specific emphasis on Mwurire and Nzige sectors in which DUMAC operates its mining practices (Figure 1).

2.2 Data collection and analysis

For the current study, the desk review and secondary data were employed to evaluate the extent to which mining practices contribute to forest degradation. The employed data were data on mining land; mining practices applied and mining production were utilized. The considered mining production of DUMAC was the so-called Mixte: Casserite/tin and tantarum/coltan. The data on forest cover change over the mining zone in surface (km/ha) and/or percentage were also utilized

These data were collected from the annual report of DUMAC and field visit which helped the authors to detect mining areas occupied by DUMAC in Rwamagana district. The data on forest

cover were collected from the United States Geological Survey (USGS), Rwanda Forestry Authority (RFA). The shapefiles of the study area which facilitated in delimiting the study area from the global/national maps which were employed especially for forest degradation mapping were used from the National Institute of Statistics of Rwanda (NISR), and Rwamagana District report. The above secondary data on mining practices and forests cover change were ranging from 2018 to 2021 as the predefined research timeline.

Regarding data analysis, the collected data on mining practices, their land occupancy and annual mining practices mainly the so-called Mixte: Casserite/tin and tantarum/coltan were presented into Tables and/or Chart by using the Microsoft Excel. The data on forest cover were analysed by using the extraction by mask technique of the Spatial Analysis Tools Geographic Information System (GIS). Finally, the Pearson Correlation of the Statistical Package of Social Sciences (SPSS) tested the extent to which mining practices contributed to forest degradation. In order to successfully perform the Pearson Correlation analysis, the researcher based on the fact that a p-value smaller than 0.05 indicated a statistically significant association (at 5 % level) and a p-value larger than 0.05 reveals no statistically significant association between two variables tested.

3.Results

3.1 Mining practices of DUMAC

The field visit indicated that mining practices appluied by DUMAC are underground mining as shown in Figure 4.1 below. These practices contribute to removing ground vegetation and tree cover in order to obtain the area for mining and as shown in Figure 2 (a,b) and the tree cut off while preparing the mining zone are in turn used for underground tracing of the mining area (Figure 2, (b,d)). Hence, mining contributes to forest degradation in one or another way.

Figure 2**: Mining practices applied by DUMAC**

Source: Researcher's Field Report, 2022

In addition, the results from field visit and Repot of DUMAC indicate that between 2018 and 2021, the total occupied land is 40 hectares. This land is explored into plots and/or small mining zones which have been increasing over time. The results in Figure 3 showed that between 2018 and 2021, these mining zones increased from 9.2 to 23, respectively. Moreover, during field visit, each mining zone was measures and its total surface was e hectares. Hence, to calculate the total mining zone's surface, each year's occupied mining zones were timed to 2 ha (Figure 3).

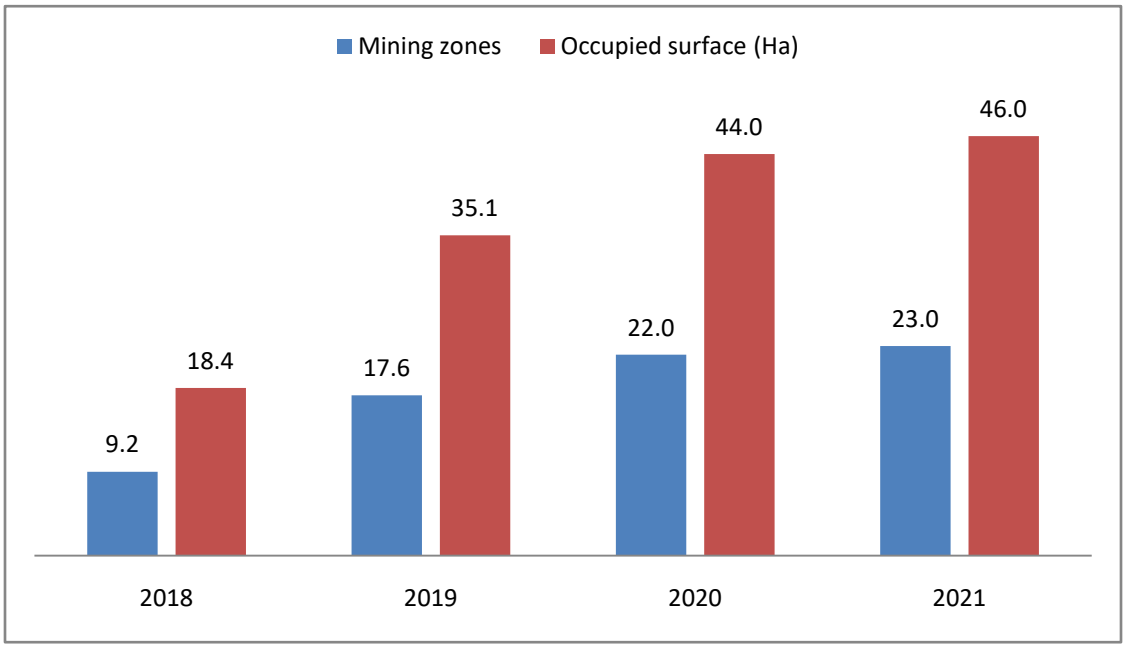

Figure3 **:Occupied mining zones and their size**

Source: DUMAC Report 2022 and Researcher's Field Report, 2022

Similarly, with regard to mining production registered by DUMAC between 2018 and 2021, the research finding illustrated in Figure 4 reveal that production was increasing since 2018 at 32.738.5 up to 81.835.8 in 2021.

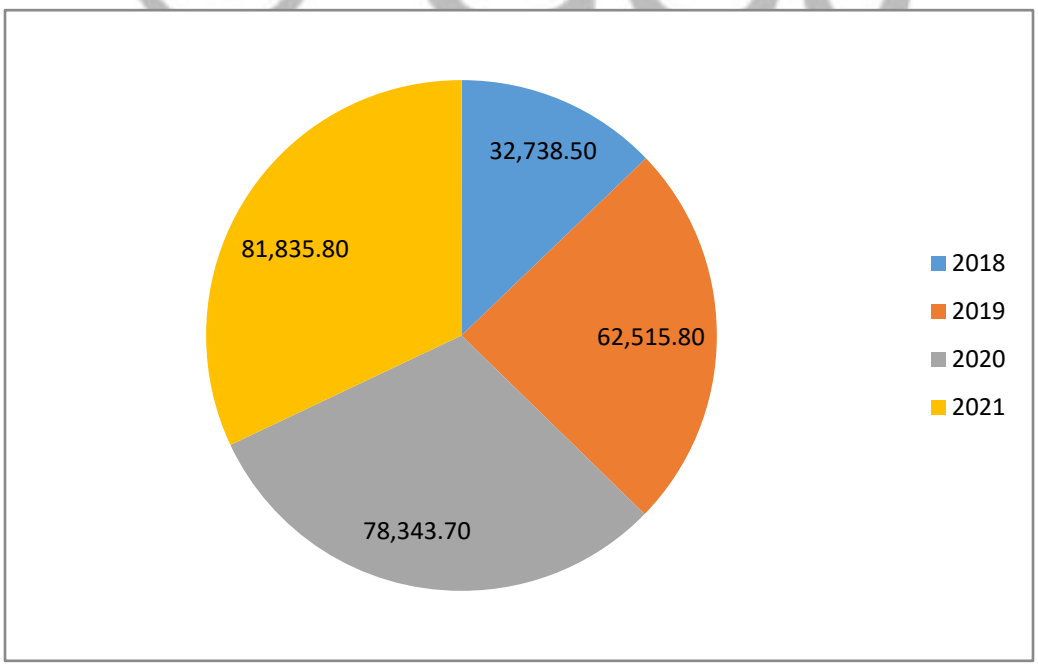

Figure 4**:Mining production of DUMAC 2018-2021**

Source: DUMAC, 2022

The results of this research in both Figures 2, 3 and 4 clearly indicate that the land occupied by DUMAC and its mining production recorded a growing trend. This likely can explain that the forest has been cleared in order to obtain the mining area. This was then recognized and then the forest cover analysis was conducted and detailed in the following section.

3.2 Forest cover change

With regard to forest cover change, the results in Figure 5 indicate that in 2018, the forestland was at 15.3 percent of the total occupied land while cropland was the major land use at 58.29 percent.

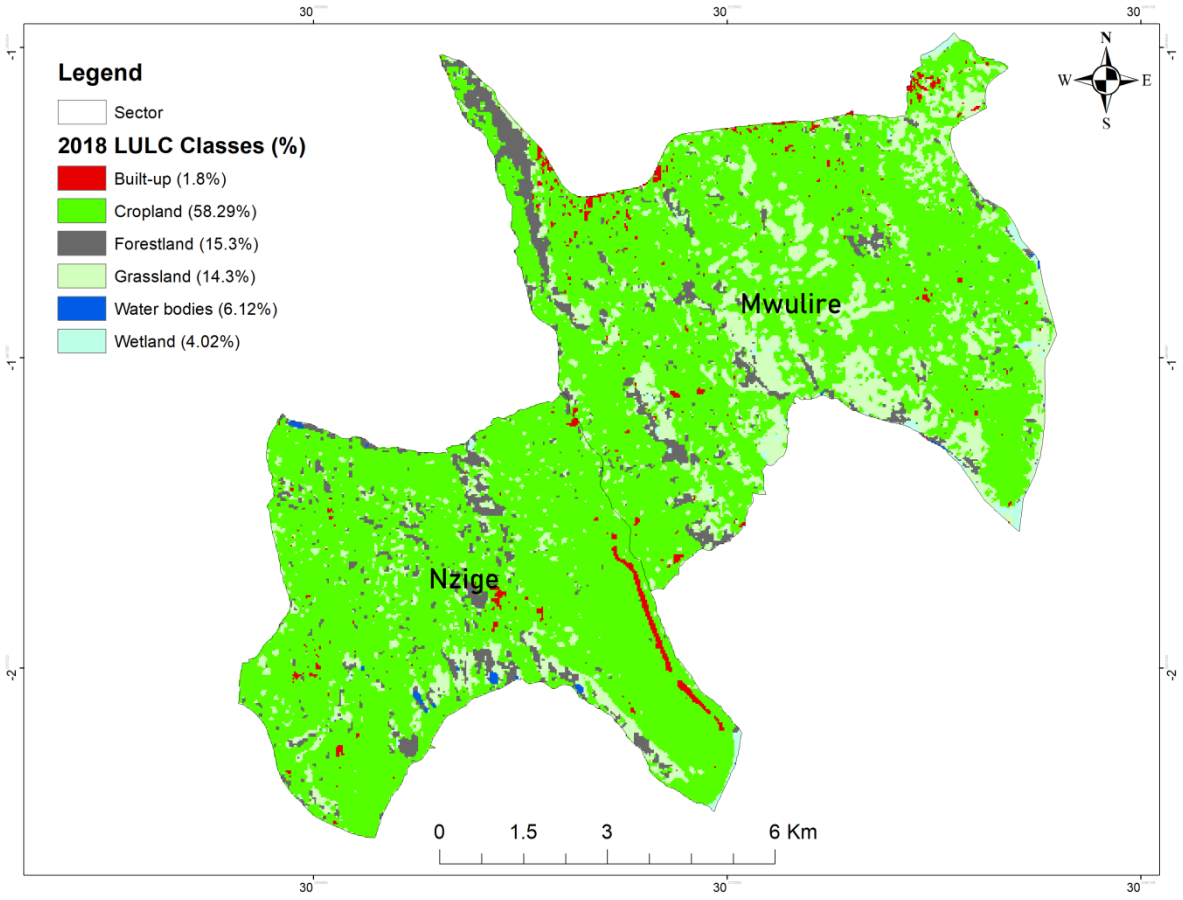

Figure 5**:2018 Land cover in DUMAC boundaries**

Source: Researcher, 2022

In 2019, as illustrated in Figure 6, forestland decreased up to 9.78 percent compared to its record of the year 2018 (15.3%). The cropland and built-up registered a growing record of 60.1 and 6.81 percent, respectively.

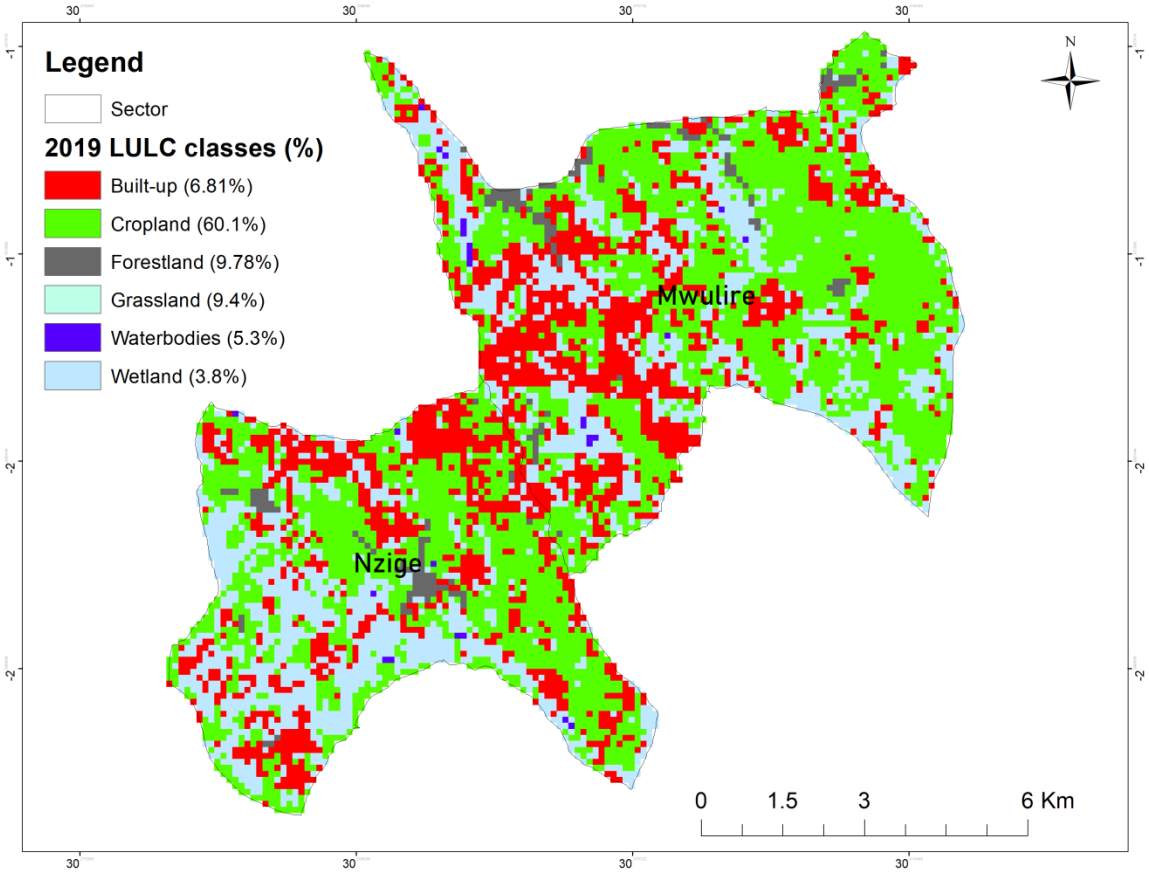

Figure6 **:2019 Land cover in DUMAC boundaries**

Source: Researcher, 2022

Moreover, in 2018 and 2019 (Figures 5 and 6), the land occupied by forest kept on decreasing due to mining activities and other human activities which likely were placed within areas under forest in previous years. However, it was realized that in 2020 (Figure 7), the land under forestland increased up to 16.4 percent and that of cropland fell at 40.8 percent from 60.1 percent in 2019.

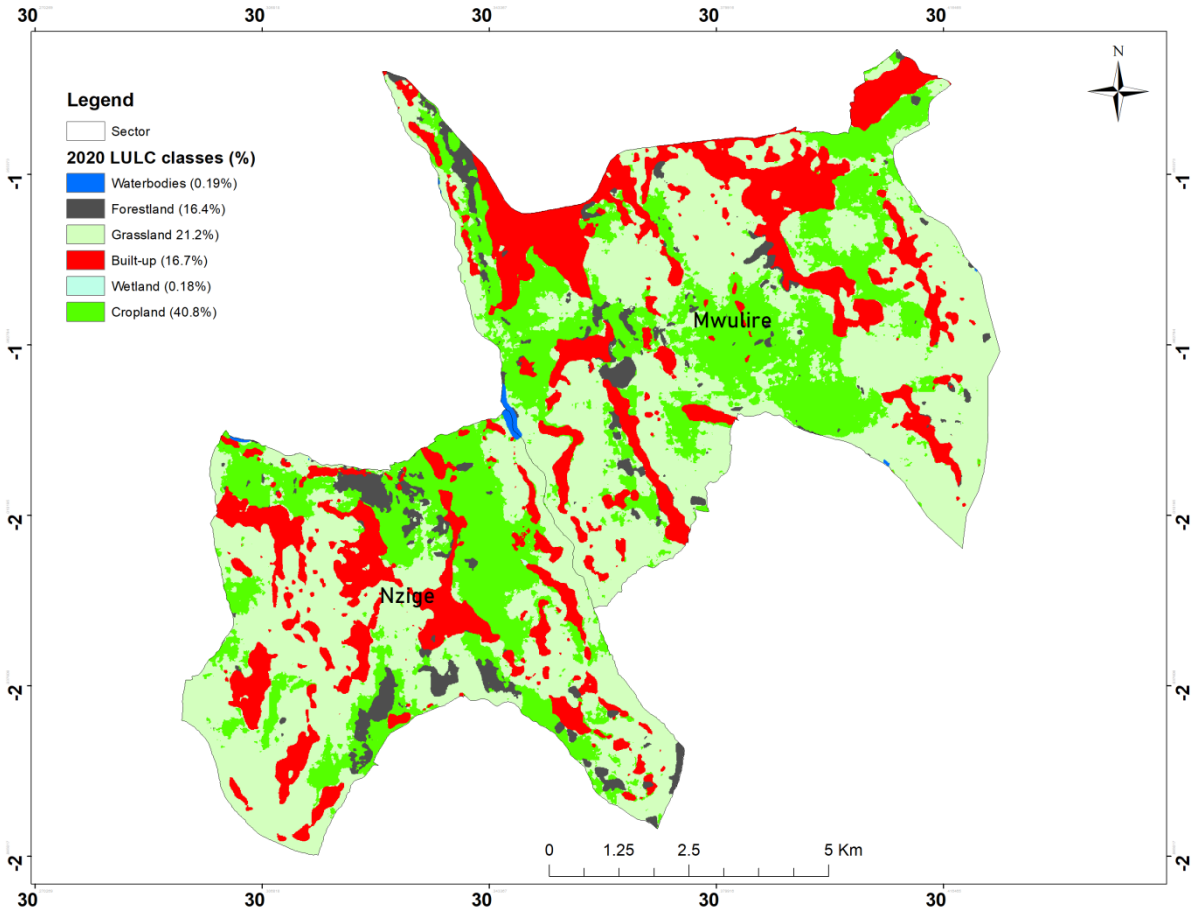

Figure 7**:2020 Land cover in DUMAC boundaries**

Source: Researcher, 2022

Finally, the 2021 land cover analysis shown in Figure 8 demonstrated that cropland kept on increasing its record up to 41.9 percent along with built-up land which registered 18.41 percent. However, the forestland decreased to 14.3 percent from 16.4 percent registered in 2020.

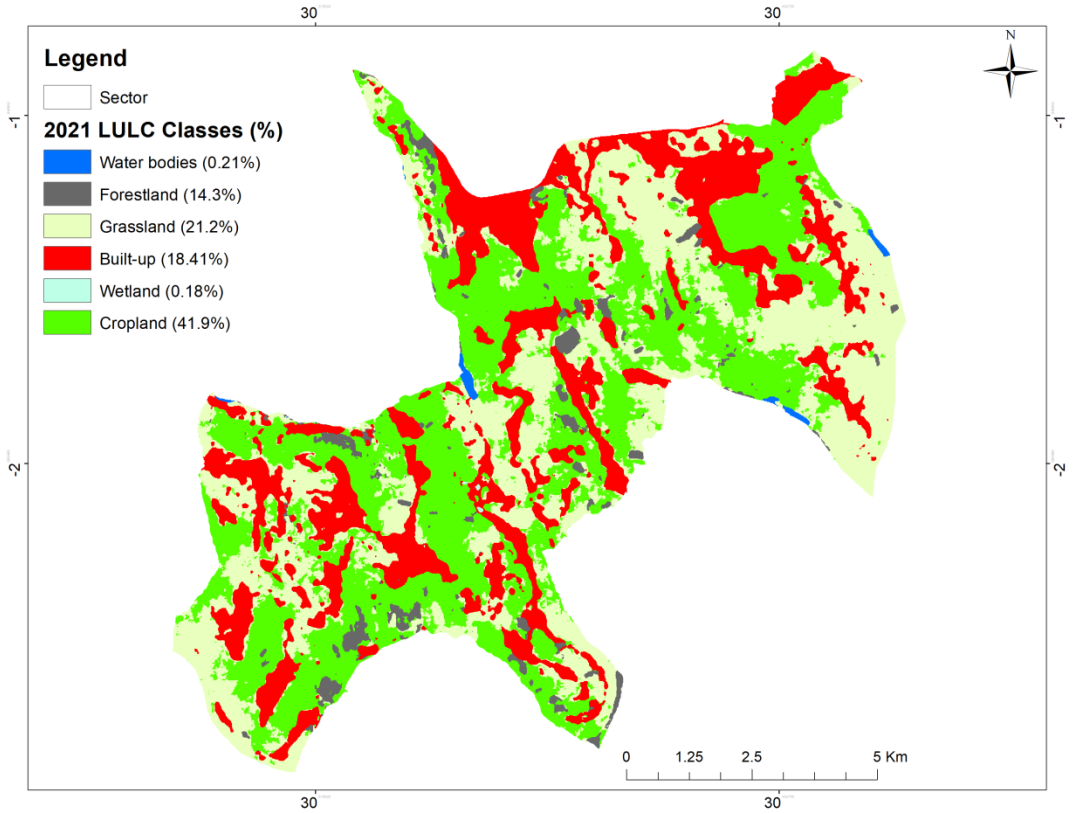

Figure 8**:2021 Land cover in DUMAC boundaries**

Source: Researcher, 2022

Between 2018 and 2021, the current research findings show that there has been forest degradation within the mining areas of DUMAC. The results of the study in Figure 9 revealed that forestland which was the center of this research noted a decreasing record from 15.3 percent to 9.87 percent in 2018 and 2019, respectively. Regardless the fact that the year 2020 registered the highest percentage of forest cover at 16.4 percent, the following year (2021) revealed a decreasing record at 14.3 percent. Therefore, it can be mentioned that DUMAC mining practices contributed to decreasing forest cover within its mining zones.

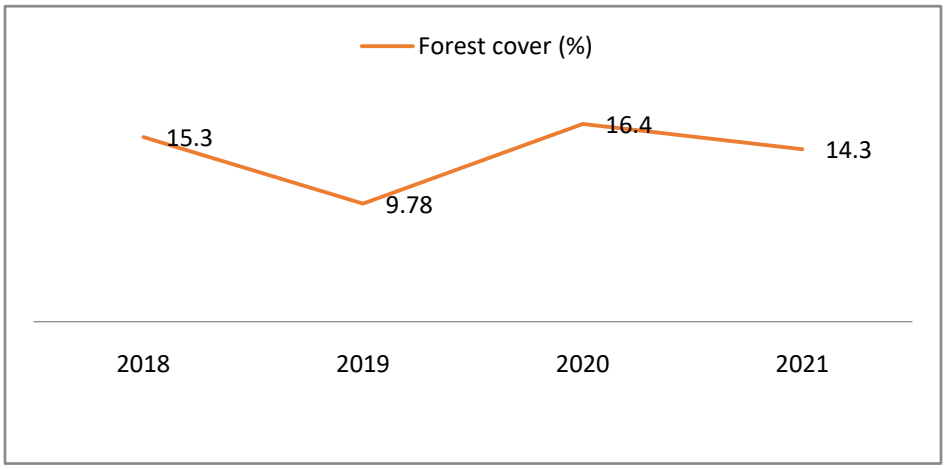

Figure 9**:2018-2021 annual forest cover 2018-2021**

Source: Researcher, 2022

3.3 Mining practices and forest degradation

In order to estimate the extent to which mining practices of DUMAC contribute to forest degradation, the exercise was complete by using the Pearson Correlation test of the SPSS software which facilitated the research to determine the extent to which mining practices of DUMAC contribute to forest degradation within its mining practices. The researcher refereed to Pearson correlation values (coefficient r) suggested in Table1.

Table 1:Pearson correlation analysis guideline

	Coefficient, *r*	
Strength of Association	Positive	Negative
Small	.1 to .3	-0.1 to -0.3
Medium	.3 to .5	-0.3 to -0.5
Large	.5 to 1.0	-0.5 to -1.0

Source:

For the current research, the Pearson Correlation analysis between the research independent variable (mining practices) and dependent variable (forest degradation), the estimated P value was 0.028 (Table 2). This was value was considered as positive but at small extent.

Table 2**:Relationship between mining and forest degradation**

		Mining practices	Forest degradation
Mining practices	Pearson Correlation	1	.028
	Sig. (2-tailed)		.972
	N	4	4
Forest degradation	Pearson Correlation	.028	1
	Sig. (2-tailed)	.972	
	N	4	4

Regardless, it smallest extent, the estimated P value of 0.028 indicates that mining practices of DUMAC have contributed to forest degradation and that in case current practices are not operated in favor of forest, large losses would be recorded in the near future. It is from this fact that the authors confirmed that Mining practices contribute to forest degradation in Rwamagana district.

4. Discussion

In Africa, between 1990 and 2010, forests covered about 23 % of the total land and 75 million ha of forest land (about ten percent of the total forest area) have been converted to other land uses (Hansen et al. 2013). Apart from mining, there other sources of forest degradation including not limited to growing food demand leading to forest clearing in order to expand agricultural lands, wood energy dependency for cooking, wood is the main source of fuel; about 80% of all wood used in the region is for fuel (Bodart et al. 2013; Desclee et al. 2013).

In 1960, Rwandan forests were estimated to cover 659,000 ha in 1960. Nevertheless, between 190and 2017, the forestland reduced at approximately 64 percent (Ordway 2015). Rapid human population growth along with its daily activities (mining, construction of houses, roads and schools, agriculture, etc.) has been posing a growing pressure on forests in terms of encroachment and deforestation (Ordway 2015).

This study assessed the extent to which one of the rapidly economic sectors growing in Rwanda contributes to forest degradation. The results in Figure 2 show that DUMAC mining practices remove forest and vegetation cover in its mining areas and no restoration measures are under place. In addition, the findings of the research, as illustrated in Figures 3 and 4 reveal that the occupied mining zones and their size along with mining production registered a growing trend.

However, with regard to forest cover within areas of operation of DUMAC, decreasing trend is under record.

The results in Figures 5,6,7 and 8 confirmed that after DUMAC started mining, forest cover registered a decreasing trend from 15.3 percent in 2018 to 14.3 percent in 2021 (Figure 9). The results of this research agree with previous studies (Macháček and Dušková 2016; Dushin et al. 2020) which highlighted that mining contribute at large extent to removing vegetation and forest cover within mining zones and that low number of mining companies is in turn restoring the degraded landscape. This is similar case to this research where DUMAC exposes the soil to runoff and erosion due to the reason that its mining zone is empty as shown in Figure2 (a-d).

It is reported that in rural areas of Rwanda, above 95% of rural communities use the wood for fuel, and the national dependency level is over 85% despite strong efforts applied (Ordway 2015; Andrew and Masozera 2010). This agrees with results of this study in term of extent to which mining contributes to forest degradation, the obtained P value is 0.028 which is statistically low (Table 3). This is in addition, expresses that although DUMAC is conducting mining practices but also other factors such as expanding cropland and settlements, which revealed growing record between 2018 and 2021 (Figures 5,6,7,8). Hence, to ensure forest restoration within the mining areas, more reforestation and afforestation are suggested but also the entire land despite its occupancy should be considered in order to conserve forest within the expanding cropland and settlements.

5 Conclusion

This study was conducted in order to evaluate the extent to which mining practices lead to forest degradation. The study used secondary datasets on mining and forest cover change collected from different sources. The study considered DUMAC as case stud, one of mining companies operating in Rwamagana district, Eastern Rwanda. The result show that between 2018 and 2021, the DUMAC mining area increased form 18.4 ha to 64 ha in 2018 and 2021, respectively. Similarly, the harvest showed an upgrading record of 32,738 to 81,835, respectively. However, in terms of forest cover change within the areas occupied by DUMAC mining company, the record has been decreasing form 15.3 percent in 2018 to 14.3 percent in 2021. However, the statistical analysis of the relationship between mining practices and forest degradation generated a low statistical significance, P value of 0.028. This is quite due to the fact that although forest

decreased other land uses increased mainly built-up lands, croplands and grassland which expresses that mining practices are not the only factors of forest degradation in this area. However, based on the reason that DUMAC possess 400 ha which will be used for mining, and that only 46 ha are employed, it is good to undertake forestation and afforestation measures at this early stage in order to minimize future forest losses which will likely keep on increasing as long as the mining area expands.

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