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Deforestation Driven by Agriculture Cash Crops, Animal Husbandry, and Population Growth in Rwanda (1992 - 2018).

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ABSTRACT: In this study, the impact of population increase, animal husbandry, and the expansion of cash crops on Rwanda's exploitation of its forests over a 30-year period is investigated. In this study, we use extensive samples of high resolution satellite observations (30m) and regression estimators to explore the lower resolution (500m) data. We use a spatially explicit analysis of forest loss (not including regrowth) for the entire country on both natural and planted forests across the country. utilizing STATA 14 as a data analysis tool and over 30 years' worth of meteorological, demographic, and agricultural data, respectively. The findings of this study demonstrate that, during the past 30 years, deforestation has increased by 15.47% while population has increased by a larger pace (2,750,456 [22.36%]). The proportion of cropland, arable land, irrigation-ready land, and agricultural regions used for organic farming has expanded significantly over the past 30 years, rising at rates of 18.48%, 26.33%, 15.47%, and 60.37%, respectively. The government of Rwanda should carefully limit population growth and adopt new rules regarding grouped settlements in order to reduce forest vulnerability, according to this study, which noted that the rapid population growth and its activities have gradually harmed our ecosystem.

Key words: Deforestation, Population Growth, Agriculture, Land Use.

I. INTRODUCTION

Deforestation is the removal of natural vegetation cover that already exists, particularly when the native cover is predominately forest. Due to rising demand for food, building materials, crops, and livestock, more forests are being cleared around the world. 7–11 million km2 of forest have been cleared in the last 300 years. Given that forests are home to around 70% of all land-dwelling animals and plants, deforestation can have a devastating effect on biodiversity. Environmentally harmful effects include soil erosion, river sedimentation, and land deterioration in the absence of forest regrowth. To accommodate a growing population, enormous forest areas have been cleared around the world over the past several centuries. 20% of the world's forest cover has been degraded, and another 30% has been cleared. As a result, biomass, biodiversity, and ecological services provided by forests have significantly decreased. Since the 1990s, Rwanda's natural forest acreage has decreased as a result of the increased demand for towns and agricultural land. But since 2007, there have been initiatives to slow down forest loss and boost forest cover. These initiatives consist of vigorous tree-planting activities, the designation of one more natural forest as a national park, and the rehabilitation of degraded woods (Ministry of Land and Forests, 2018).

Although it has not yet attained its full economic and ecological potential, Rwanda recognises the crucial role that the forestry sector plays in sustaining the livelihoods of the inhabitants. Natural forests and man-made forests are the two main types of forests that can be distinguished by their physical characteristics and functional roles in the national forest landscape. Although at distinct levels, both types may simultaneously address ecological and economic roles. Natural forests, which make up 11.9% of all land in the country, have ecological functions such preserving biodiversity. The management issues they have can also be resolved locally or in collaboration with the international community because the solutions will benefit both Rwandans and the rest of the world's population (Ministry of Land and Forests, 2018). 90% of the people in

Rwanda works in subsistence agriculture, which may be why the area of natural forests decreased from 634000 to 221200 ha over a 40-year period. Rwanda's economy is mostly dependent on primitive agriculture. In other words, it has been noted that between 1960 and 2000, the amount of forest decreased by 65%, or 1.65% year (Habiyaremye et al., 2018).

Natural grassland and forests in Rwanda underwent a substantial conversion to agricultural land usage. About 6183.41 km2 (56.26%) of forest, 3183.24 km2 (59.56%) of grassland, and 166.88 km2 (15.23%) of wetland were turned into croplands between 1990 and 2016, which increased runoff depth by 2.33 mm/year (0.38%). Due to severe deforestation and the conversion of grassland to cropland, spatial statistical analysis showed that 16.18% of the country's total area, which has a steep slope of 28% and a high mean precipitation of 1222 mm/year, experienced a significant increase in runoff depth >200 mm from 1990 to 2016. A total of 132.64 km2 of grassland and 418.77 km2 of forest were lost in these regions. Over 6.83 percent of the country is covered by a mean annual rainfall of 1108 millimeters. The observed afforestation in 869.70 km2 (50.19) and the roughly 47% increase in grassland (201.8 km2), whilst agricultural and built-up land declined by 75% (675.2 km2) and 77% (34.85 km2), respectively, may have contributed to this decrease (Habiyaremye et al., 2018). Rwanda has established a goal to enhance its forest cover to 30% of the entire country land area through afforestation and replanting by 2020 as part of its conservation effort. Forest plantations, whose primary purpose is to meet the demands of the people in terms of biomass energy, timber, and service wood, currently occupy 18.7% of the total area. It is also important to note that agroforestry complements the aforementioned role (Ministry of Land and Forests, 2018). The effects of human activity on the environment are astounding everywhere, and Rwanda is not exempt. Between 1930 and 1990, the population growth and rate sharply rose, rising from 4.7 to 93%. Due to terrible occurrences like war's aftereffects and genocide, the population growth has barely increased from 1990 to 2010 with a figure of 50.6%. Deforestation rates increased from 0 to 103% between 1930 and 2010, which is in line with population growth, which inevitably calls for additional space to occupy for a variety of uses. It is notable that the precipitation had a monthly decrease of 10mm due to the significant forest loss brought by population growth, which has caused an increase of 0.50C. Land transfers on a large scale are nothing new. The worldwide food and financial crises have compelled investors to externalise and secure their food production on a global scale by leasing out enormous tracts of agricultural land for lengthy periods of time. About 20 large-scale land acquisition projects for the cultivation of maize, rice, rubber rice, and palm oil on the national territory have been finished in the recent several years. However, the Southwest, South, Coastal, and Central regions south of the Fifth Parallax have seen the most notable initiatives (Hoyle and Levang, 2012; Oyono, 2013). Rowe et al. (1992) identified commercial timber production, land clearing for agriculture and urban growth, and the harvesting of wood fuel and charcoal as the primary drivers of deforestation. By building access roads to logging sites, these activities also split forests, allowing people and commercial entities to remove more land for grazing, resource extraction, and other activities (Rowe et al., 1992). According to the United Nations Framework Convention on Climate Change, the overwhelming direct of deforestation is agriculture. Subsistence farming is responsible for 48% of deforestation, commercial agriculture is responsible for 32% of deforestation, logging is responsible for 14% of deforestation and fuel wood removals make up 5% of deforestation. According to Rodgers, Salehe and Olson, 1999, the indirect (underlying) causes of deforestation include population growth, policies, agreements, legislation, lack of stakeholder participation and market factors that encourages the use of forest products, leading to loss, fragmentation or degradation (Rodgers et al., 2000). Other causes of forest loss are conflict, civil wars, and lack of good governance (Verolme, and Moussa, 1999).

Deforestation was brought on by a combination of natural and human forces in Africa as well as other regions of the world, with the conversion of forest lands to agricultural land being the main culprit (Adesina, 1997; Rowe et al., 1992). According to Williams (1990), the introduction of new crops and exploitation techniques circa 1600 drastically changed tropical forests. In order to make room for lucrative crops like rubber in Malaysia and Indonesia, coffee in Brazil, tea in India and China, sugar cane in the Caribbean, tobacco and oil palm in Asia, it was stated that forests had been removed (Williams, 1990). Ola-Adams (1981) ascribed intensive agricultural techniques as the cause of the disappearance of wooded regions. According to reports, the western edge of the Nigerian forest

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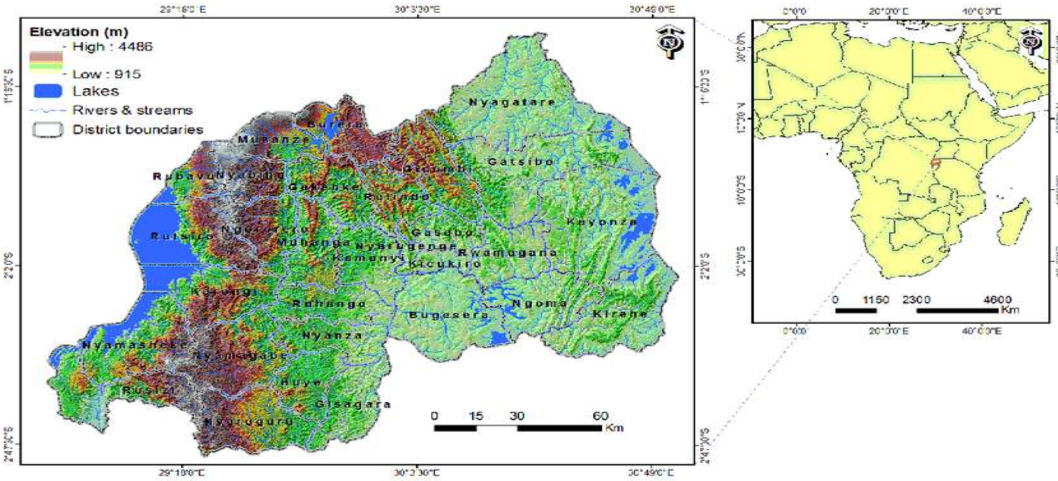
reserve Ogbesere had about 2,000 hectares cut over and converted to permanent agriculture. The investigation found that numerous forest estate sections in other high forest regions were being de-reserved to make way for the planting of agricultural crops (Ola-Adams, 1981). Some claim that because they have no other options and cannot afford the goods and labour required to clear the forest, persons who are impoverished are more likely to do so (Angelsen et al., 1999). In one study, it was shown that just 8% of tropical deforestation was caused by population growth driven on by high birth rates (Geist, H. J. and Lambin, 2002). Over the past 30 years, there has been a change in the causes of deforestation, nevertheless. By the 1990s, the majority of deforestation was caused by industries, extensive cattle ranching, and extension agriculture, as opposed to subsistence activities and government-sponsored development projects like transmigration in nations like Indonesia and colonisation in Latin America, India, Java, etc (Butler et al., 2008; Rudel, 2005). Deforestation results in extinction, climatic changes, desertification, and population displacement (Sahney et al., 2010). It increases the greenhouse effect and is frequently cited as one of the main drivers of global warming. The intergovernmental panel on climate change estimates that deforestation, particularly in tropical regions, may be responsible for up to one third of all anthropogenic carbon dioxide emissions (Defries et al., 2010).

Given the aforementioned trends, adjustments must be made in order to prevent the country from losing its certification, and efforts must be strengthened to control population growth in order to prevent excessive environmental pressure given that most populations depend on ecosystem services for survival, and without such control, it will be difficult to achieve a sustainable environment or natural resources not only for ourselves but also for future generations as well as the Rwanda vision. The overall goals of this study were to identify the deforested areas in Rwanda caused by the expansion of agricultural cash crops, animal husbandry, and population growth, with a primary focus on estimating and outlining the forest areas that were converted to agricultural areas. The study also aimed to connect the facts that the government of Rwanda was compelled to expand its agricultural and housing areas due to population growth .

II. RESEARCH METHODOLOGY

- **Study areas**

With an estimated area of 26,338 km2, Rwanda is surrounded by Uganda to the north, Burundi to the south, the DRC to the west, and Tanzania to the east. The nation is divided into Kigali City, the Northern, Southern, Eastern, and Western Provinces. There are 30 Districts that make up the entire nation. Rwanda is situated between 1o02'40" and 2o50'16" in altitude and between 28o51'29" and 30o53'56" in longitude (Sirven et al., 1974). The projected population of Rwanda is 12.43 million, with a further 71 percent living in rural areas and 29 percent in urban areas. Between 2005 and 2015, population growth was 3.18 percent (FAOSTAT, 2015). With an estimated 434 people per square kilometer, the country has a fairly high population density for Africa (EU, 2014). The gross domestic product (GDP) per person in Rwanda increased from $800 in 2000 to $1584 in 2015, representing a remarkable annual growth rate of 7% since 2000. (Hjelm, 2015).



Source: Research Design, 2020

b. Methods of Sampling and Data Collection

For this study, there was no need for sampling because the entire nation was included. In this study, we employ a large sample of high resolution satellite observations (30m) and regression estimators to investigate the lower resolution (500m) data to conduct a spatially explicit analysis of forest loss (excluding regrowth) over the entire country on both natural and cultivated forests (UNESCO, 1968). (Compton J Tucker et al., 1985). The assessed demographic factors—Male, Female, Urban and Rural Population—Land use—Artificial Surface, Grassland, Herbaceous crops, Inland Waterbodies, Shrub Covered Areas, Tree Covered Areas, and Woody Crops—and Share in Agriculture Land—are linked to the loss of forests in Rwanda, particularly the size of population growth in both rural and urban areas. The images utilized from the advanced very high resolution radiometer (AVHRR) data from the National Oceanic and Atmospheric Administration (NOAA) meteorological satellites for the years 1990 to 2019 were obtained without the use of any satellite data from the FAOSTAT website. It has been demonstrated that these data hold a great deal of promise for evaluating and mapping forests across relatively small areas. and similar levels of classification accuracy have been reported between Landsat MSS and NOAA AVHRR data for some natural forests or vegetation types (C.J. Tucker, 1978). AVHRR data have a much coarser resolution (1 and 4 km at nadir) and hence a lower data, and their temporal resolution is much higher with 4-km imagery globally.

C. Methods of Data Analysis

The size of the task is evident in the maps and supporting materials on the forest land cover in Rwanda from 1992 to 2018 as well as in the considerably disparate estimations of the surface area of terrestrial ecosystems around the world. An alternate strategy is to map using satellite remote-sensing data and its synoptic perspective (B.Bolin, E.T. Degens, S.Kempe, 1979; G.L. Ajtay, P.Ketner, 1979),

(Kidwell, 1979). Due to the spatial resolution of the Landsat MSS and the corresponding 185 x 185 km scene, it takes a significant amount of data (about 1100 unique Landsat images) to cover a region as a country. The NOAA satellites' AVHRR sensor was chosen to give the data. (C.J. Tucker, 1978). Global-area coverage (GAC) data with a 4-km resolution were chosen rather than the finer resolution local-area coverage (LAC) data with 1-km resolution, since the 4-km data were available daily for the whole continent. The 4-km GAC data are partly resampled 1-km LAC data, the first four 1-km picture elements are averaged, and this average is then used to represent a 3 by 4 pictures element (11). The GAC data are tape recorded onboard the satellite and subsequently transmitted to receiving stations in either Virginia or Alaska.

STATA 14 was used to conduct statistical analysis. The datasets were first examined, looked over for any potential anomalies, and then analysed to make sure the data met the various requirements for linear regression analysis. The investigations that were conducted included correlation analysis to look into potential links between the variables and regression analysis to find the parameters needed to build a model for forecasting the loss of forests in Rwanda over a 30-year timeframe.

Land use change downscaling:

At regional level
At SimU level
Land use type: i
Region: r
Time: t
Simulation Unit: l
Land in land use:
Land converted from i to j:
Share of area change from i to j:
Downscaling Problem: Find such shares of area change transformed from i to j in l that
i.e.

Cross-entropy: Maximize Kulback- Leibler information
Prior probability:
Forests to cropland:
Cropland production value:
Forest production value:

We examined many possible correlates with forest loss at national scale, including demographic and agricultural production statistics. After eliminating variable that were highly correlated or poor data quality, we formally tested for collinearity using a number of regression diagnostics including variance inflation factors, and condition indexes and variance decomposition proportions of the design matrix.

III. RESULTS AND DISCUSSION

The aggregated statistics regarding the demographic population are presented in figure 2. The figure shows the progressive increase of Rwandan population from 1950 up to 2019. A

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higher population increase begins from 1966 up to 1990.

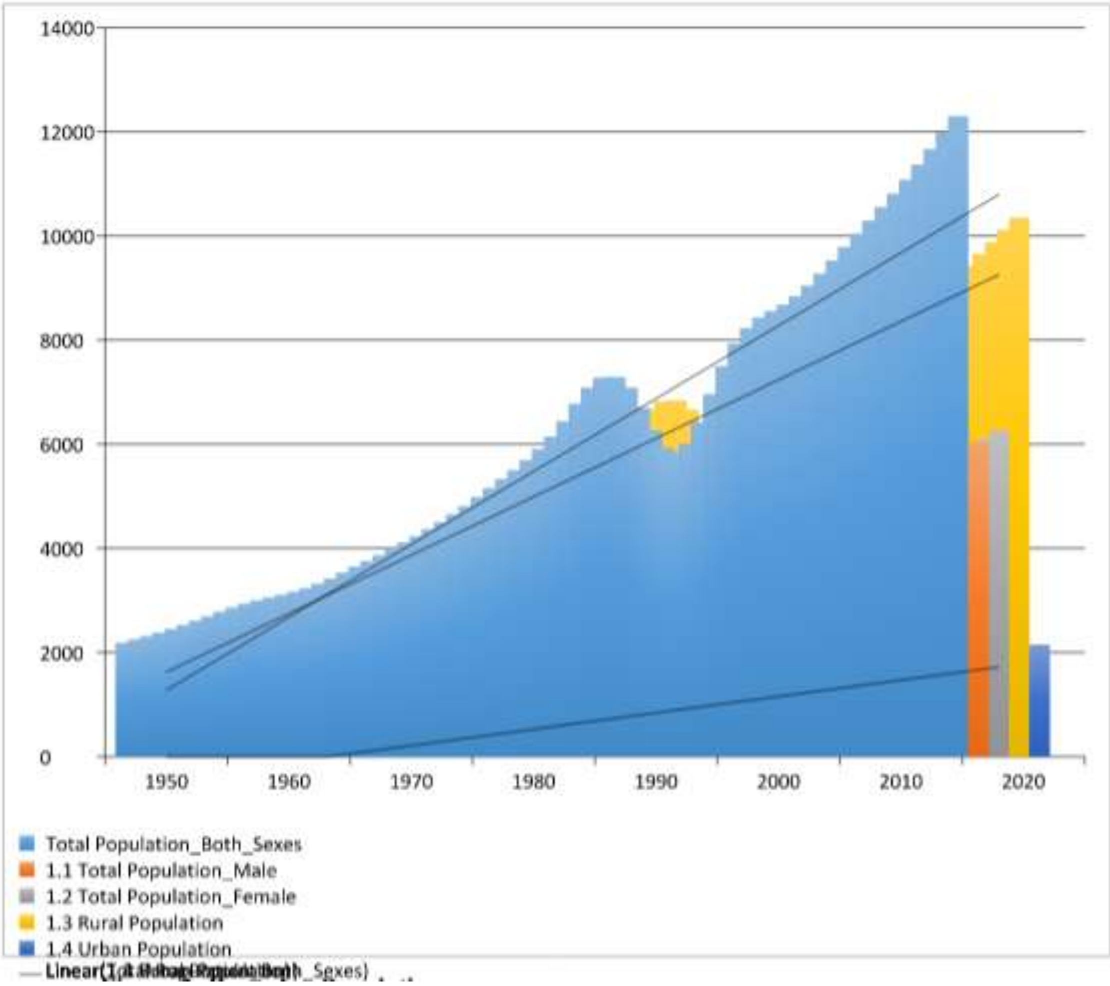

Figure 2: Rwandan Population
Source: Research Design, FAOSTAT data, 2020

The Rwandan population decrease from 1990 up to 1994 due to political instability and civil war ended to genocide of Tutsi committed in 1994. The Rwandan population increase later from 1994 up to 2008, from 2008 there were an exceptional higher increase of Rwandan population due to the immigration of Rwandan refugee from all neighbor country.

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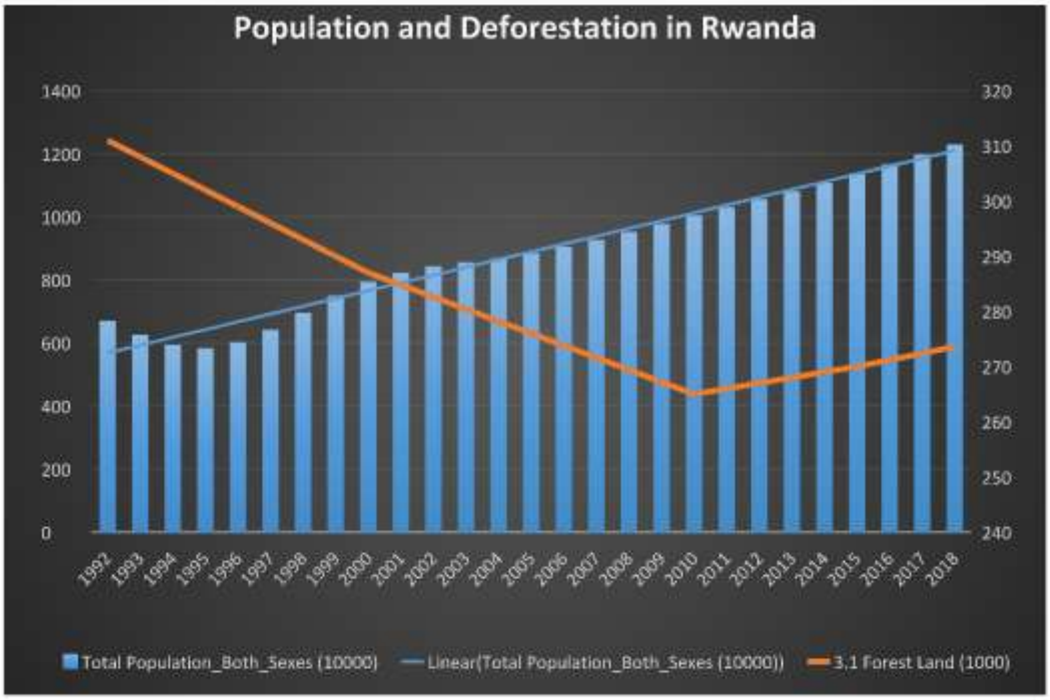

Figure 3: Rwandan Population and deforestation trend
Source: Research Design, FAOSTAT data, 2020

The Rwandan forest was seen to be shrinking as population grew. It has been demonstrated that Rwanda's forest areas decreased from 310000 ha in 1990 to 265000 ha in 2010, while its population increased from 7,288 million to 10,039 million. As it has been demonstrated that as populations grow, forests shrink, an increase of 2,750 people in ten years will result in a loss of 46,000 acres of forest. This significant decline in just ten years has prompted the Rwandan government to implement a variety of steps to enhance the management of the country's forests. In contrast to the research done by Song et al (2018) It has been demonstrated that 60% of all land changes worldwide are related to direct human activities and 40% are related to indirect factors like climate chang (Song et al., 2018).

According to HABIYAREMYE et al. (2011) Between 1930 and 1990, Rwanda's population grew drastically, from 4.7 to 93%. The genocide and other terrible events that occurred during this time caused a little population growth of 50.6%. Deforestation rates increased from 0 to 103% between 1930 and 2010, which is in line with population growth, which inevitably calls for additional space to be occupied for a variety of uses (Habiyaremye et al., 2011).

The results of various policies and initiatives implemented over the last ten years have shown that there was a rise of 8600 ha for every growth in population of 2,262 million. If these policies and actions are implemented sustainably, the tremendous advances for Rwanda's forest recovery will result in a sustainable forest recovery through Rwanda Vision 2050. In contrast to the widely held belief that forest area has been declining globally, tree cover has increased by 2.24 million km square (+7.1% compared to the level of 1982), according to research by Xiao-Peng Song et al. (2018) (Song et al., 2018). The outcome demonstrated that Rwanda's forests covered a total area of 668,324.1ha, including as natural and cultivated forests. The entire area of Rwanda's forest cover is approximately 686,636 ha of the total country land, according to the conclusions of this study, which differ from those reported by MINERENA (2014). Included in this are approximately 428,569 hectares of forest plantations (62.4%) and 258,067 ha of wild forest cover (MINIRENA, 2016). It has been demonstrated that artificial surface in Rwanda refers to all urban areas or related features that are mainly artificial surface, which has expanded up 8934.3ha (82.24%) in the previous 30 years. Land use in Rwanda has changed from time to time due to various causes. The findings show that the grassland—areas where wild herbaceous plants predominate—has shrunk to 5146.1 ha (3.75%) . Herbaceous plants, primarily graminids or forbs, all non-perennial plants that do not last for more than

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two growing seasons, all plants whose tops are regularly harvested while their roots can stay in the ground for more than a year, such as sugar cane, and herbaceous plants used for hay have all increased more than twofold, while they have increased up to 120815.1 ha (100.79%) .

Inland water body (full flooded for more than 11 months) have been also increased the unnegligible areas, whereas it has been shown that the water bodies have been increased up to 4578.8 ha, it is at least 2.8% in past 27 years.

Figure 4: Land use change and its effects on the forest of Rwanda
Source: Research Design, FAOSTAT data, 2020

The shrubs covered areas mainly dominated by unmanaged marshland, shrub covered areas permanently or regularly flooded by inland fresh water have been increased up to 10211.6 ha (3.4%), which is the large areas that increased due to deforestation effects on agriculture land in Rwanda in the past 27 years.

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The results have been shown that, the trees covered areas and woody crops have been reduced in considerable manner. It has been shown that, there were a decrease of 115828.5ha (44.52%) of tree covered areas, mostly dominated permanent crops (trees and/or shrubs) and includes all types of orchards and plantations (fruit trees, coffee and tea plantations, oil palms, rubber plantations, etc.).

The results have been proven that 15.47% of Rwanda forests areas have been decrease in 30 past years.

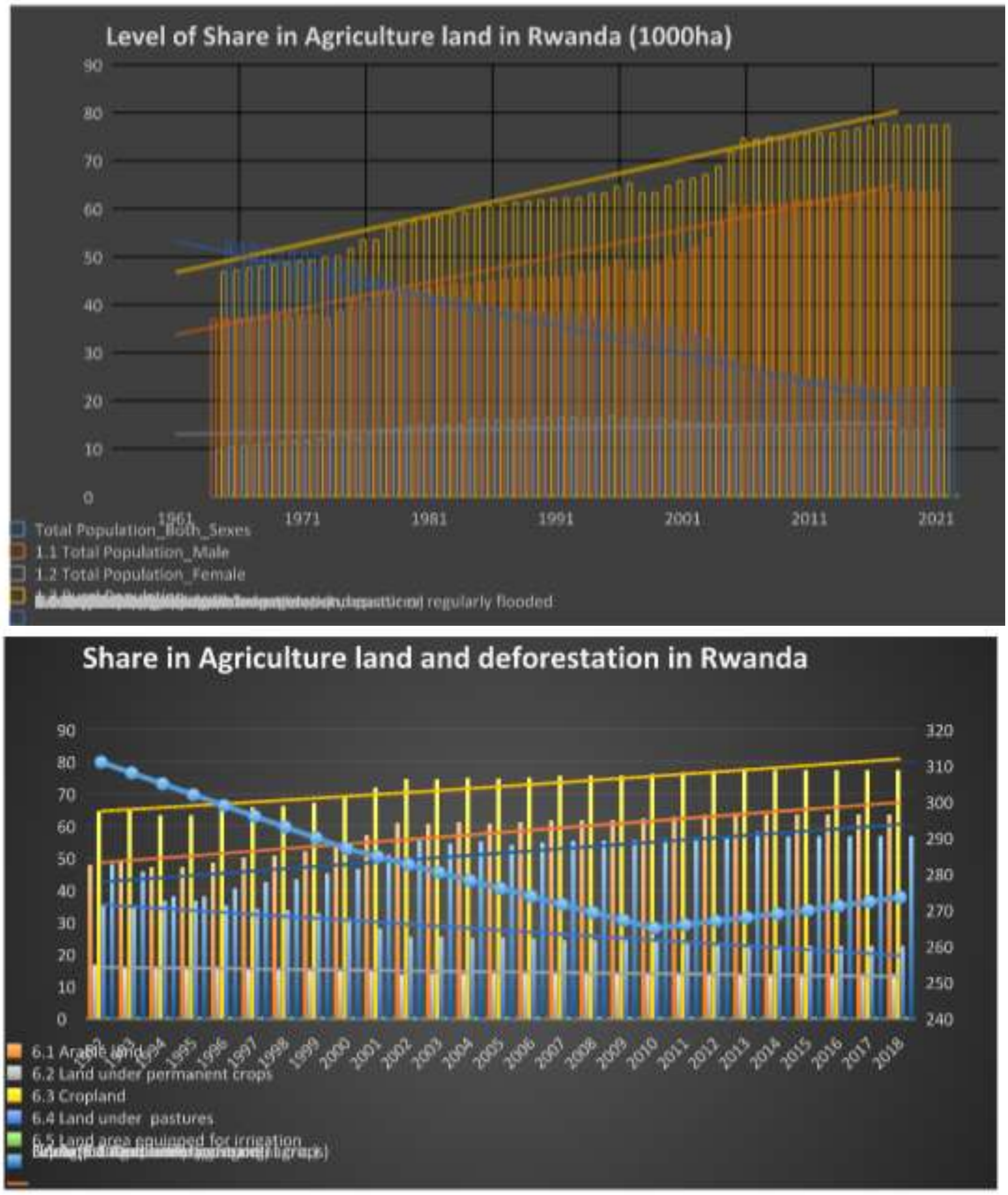

Figure 5: Share of Agriculture land use its effects on the forest of Rwanda
Source: Research Design, FAOSTAT data, 2020

Research by Masozera and Alvapati (2004), who claimed that in 1930, Rwanda's total area wooded made up 30% of the country's total land area, declined to 25.7% by 1960, and finally to 8.9% by 2000, confirmed this finding (Masozera MK, 2004).

The proportion of cropland, arable land, irrigation-ready land, and agricultural regions used for organic farming has significantly increased, increasing at rates of 18.48%, 26.33%, 15.47%, and 60.37%, respectively. These additional agricultural lands have been provided from permanent crops, pastures, and meadows as well as from woods. The findings showed that over the last 27 years, land under permanent crops decreased at a pace of 17.61%, land under permanent meadows and pastures decreased at a rate of 63.19%, and woods decreased at a rate of 15.86%.

Share in Agriculture Land		
Item	**Level of change**	**% of change for 27 years**
1.Arable land	16.74	26.33
2.Land under permanent crops	-2.43	-17.61
3.Cropland	14.30	18.48
4.Land under permanent meadows and pastures	-14.30	-63.19
5.Land areas equipped for irrigation	0.32	60.37
6.Agriculture areas under organic agriculture	8.79	15.47
7.Forest land	- 43.40	-15.86
Share in Cropland		
1.Land areas equipped for irrigation	0.34	50.00
2.Planted forest	18.36	33.88
3.Naturally regenerating forests	-18.36	-39.32
4.Agricultural land	2.73	3.71
5. Cropland	8.78	15.47
6. Land under permanent meadows and pastures	-11.51	-69.25
7.Forest land	-1.74	-15.86

The sign-in table means: * significant at 10%, ** significant at 5% and *** significant at 1%. Test of differences for deforestation through independents t-test and chi-square.

Source: Research Design, FAOSTAT data, 2020

The findings demonstrate that pastureland has seen a similar transition to forestland toward agriculture. While forestry land has drastically declined from 1990 to 2010, both pasture and permanent land have experienced bigger declines. Later in 2011, pasture and permanent land were both reduced, albeit slowly, as the land's forest cover gradually recovered. According to estimates, 155652.6 ha of permanent crops, permanent meadows, and permanent pastures have been converted to agricultural land.

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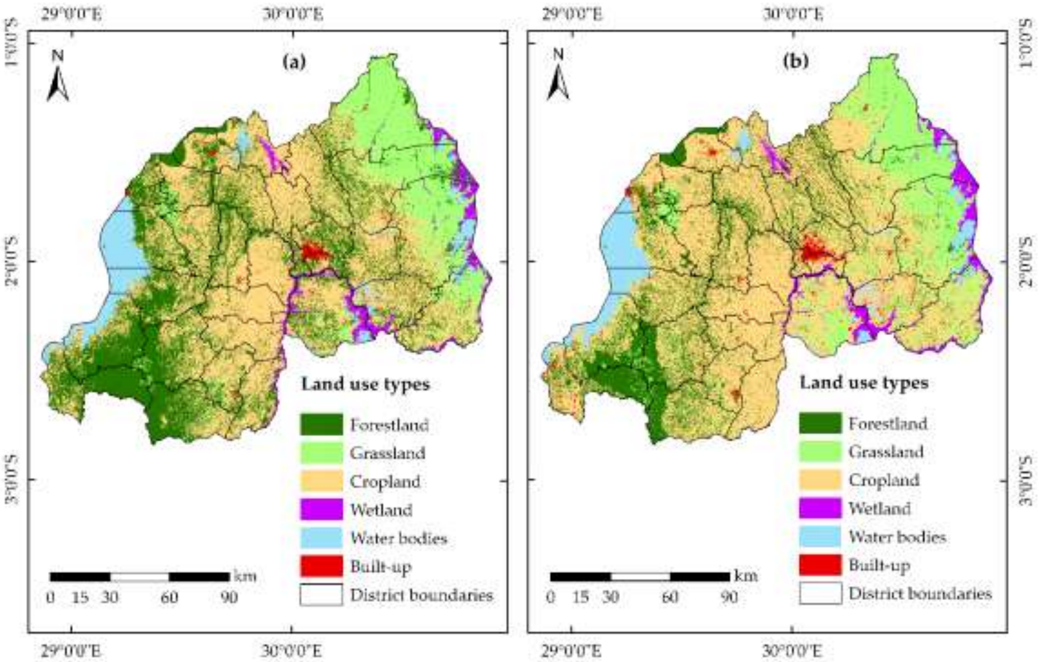

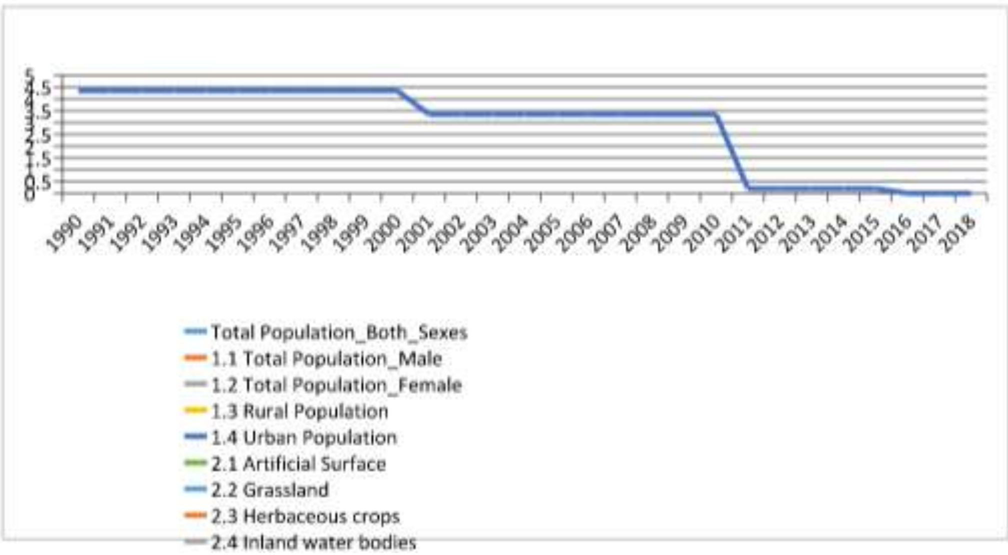

Figure 6: Net of forest conversion in Rwanda
Source: Research Design, FAOSTAT data, 2020

According to the findings, Rwanda's net forest conversion has steadily declined over the past four decades, reaching a low point of almost zero in 2016. It dropped from 4.5 in 1990 to 3.4 in 2001 before making a significant change to 0.3 in 2011. These details may have contributed to the FAO analysis' findings, which showed that between 1990 and 2010, Rwanda lost an average of 5,850 ha, or a net loss of 1.84% annually. From 1990 to 2010, Rwanda's forest cover increased by 36.8%, or around 117,000 ha (Karsenty, 2016)

Linear regression analysis

The Rwandan population, both urban as rural are mildly significant ($p < 0.01$), with a negative coefficient (rural=-0.0253 and Urban=-0.0079) refuting the claim that the increasing of population causes the deforestation. The increase of urban population was highly associated with deforestation more than the rural population in Rwanda. This result have been complemented by the study conducted by Defries et all, 2010, whereas the results of that study revealed that, the total population growth is statistically significant ($p < 0.01$), with also the negative coefficient, that

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implied the population increase delegated to deforestation but rural population growth rates related to local demand of forests products demand are not significantly correlated(Defries et al., 2010).

Table 2. Association of demographic, land use and agriculture share factors on deforestation in Rwanda

Factor	Variable	Coef.	Std. Err.	t	P>t	[95% Conf.	Interval]	R-squared
Population	Urban	-.0253192	.0016627	-15.23	0.000***	-.0287435	-.0218949	= 0.9027
	Rural	-.0078992	.0009824	-8.04	0.000***	-.0099224	-.005876	= 0.7212
Land Use	Artificial Surface	-3.699027	.4370497	-8.46	0.000***	-4.599147	-2.798906	= 0.7413
	Grassland	7.074832	.9784276	7.23	0.000***	5.059723	9.089942	= 0.6765
	Herbaceous crops	-.2735133	.0178215	-15.35	0.000***	-.3102174	-.2368092	= 0.8040
	Inland water bodies	-2.755095	1.523888	-1.81	0.083*	-5.893601	.3834117	= 0.1156
	Shrub-covered areas	-.3926092	.9980313	-0.39	0.697	-2.448093	1.662875	= 0.0062
	Shrubs and/or regularly flooded	-12.07707	2.670268	-4.52	0.000***	-17.57659	-6.577549	= 0.4500
	Terrestrial barren land	1595.105	868.365	1.84	0.078*	-193.3263	3383.536	= 0.1189
	Woody crops	-3025.782	388.6476	-7.79	0.000***	-3826.217	-2225.347	= 0.7080
Share in Agricultural	Arable land	-2.180695	.1314586	-16.59	0.000***	-2.451439	-1.90995	= 0.7167
	Land under permanent crops	13.27501	.8354602	15.89	0.000***	11.55435	14.99568	= 0.7099
	Cropland	-2.583405	.1638169	-15.77	0.000***	-2.920792	-2.246017	= 0.7087
	Land under perm. Pasture	2.583405	.1638169	15.77	0.000***	2.246017	2.920792	= 0.7087
	Land area equipped for irrigation	-137.4482	16.35662	-8.40	0.000***	-171.1353	-103.7611	= 0.7385
Temperat	Temper	-	5.34112	-1.57	0.129	-19.38825	2.612234	= 0.0898

ure	ature Change	8.388008						

The sign-in table means: * significant at 10%, ** significant at 5% and *** significant at 1%. Test of differences for deforestation through independents t-test and chi-square.

Source: Research Design, FAOSTAT data, 2020

The linear regression analysis confirming the significance of increase of artificial surface, grassland, herbaceous crops, Shrubs and/or regularly flooded and woody crops as drivers of forest loss in 1992-2018. All of these variables have the R-Square ranged 0.6765 to 0.8040 with the negative coefficients for all those variables. The results have been provided that the woody crops and shrubs or regularly flooded were most affecting the deforestation in Rwanda. Those coefficients were -3025.782 and -12.07707 for woody crops and shrubs or regularly flooded respectively.

Through the share of agricultural, the results have been proven that, the land area equipped for agriculture irrigation cropland and arable land as the main factors associated with deforestation in Rwanda. The results have been proven that, the higher coefficient associated with deforestation was -137.45 with the R-square of 0.7385, cropland (-2.58, R-Squared=0.7087) and arable cropland (-2.18, R-Squared=0.7167).

IV. CONCLUSION AND RECOMMENDATION

If no substantial actions are taken to defend the environment, the ecosystem is burdening the environment, making it difficult to achieve sustainable environmental development. There is evidence that human actions hurt the environment when they utilise its resources, and most of the time the environment is degraded in some way. This study found that net forest conversion increased significantly in direct proportion to population growth. It has been established that the war's aftereffects and the genocide that occurred in 1994, which resulted in the displacement and death of more than 2 million people, are what caused the population growth rate to slightly slow down from 1990 to 2000 (relative to earlier years). Later, a sharp rise in population was seen from 2008 to 2018, when there were more than 12 million people living there. With a population density of more than 418 people per km2, Rwanda is now the most populous country in Africa. The result of this study proven the higher increase of population (2,750,456 [22.36%]) with deforestation rate of 15.47% in the past 30 years. The share of cropland, Arable land, Land areas equipped for irrigation and Agriculture areas under organic agriculture have been greatly increased whereas it has been increased at rate of 18.48%, 26.33%, 15.47% and 60.37% in the past 27 years. Because all of these places are sourced from woods and pastures, this has a negative impact on those areas. The Rwandan population is not statistically significant (p 0.01) in either the urban or rural areas, and both have negative coefficients (rural = -0.0253 and urban = -0.0079), disproving the idea that population growth is the primary driver of deforestation. More so than the rural population, Rwanda's growing urban population was strongly correlated with deforestation. The growth of artificial surfaces, grasslands, herbaceous crops, shrubs and/or regularly inundated areas, as well as woody crops, are significant contributors to the decline of forests between 1992 and 2018. This is supported by a linear regression study. The R-Square for all of these variables ranges from 0.6765 to 0.8040 and all of them have negative coefficients.

The ecological effects of population growth include the riskier environment that results from people trying to exploit resources to meet their basic needs, especially those needs based on natural resources like forests. This overexploitation of natural resources eventually results in ecosystem collapse.

Given that the population depends on ecosystem services for survival most of the time, and that without such control, it will be difficult to reach a sustainable level of population growth, it is necessary to adapt to the situation so that the country does not lose its certification. Additionally, efforts must be strengthened to control population growth in order to prevent overburdening the environment. The government of Rwanda should carefully limit population growth and adopt new rules regarding grouped settlements in order to reduce forest vulnerability, according to this study, which noted that the rapid population growth and its activities have gradually harmed our ecosystem.

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