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Dynamics of the Deforestation of the City of Kindu between 1986 and 2020

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ABSTRACT

This study explores the factors underlying deforestation in the city of Kindu, Democratic Republic of Congo. It concludes that deforestation in Kindu is a serious problem, exacerbated by population growth and unsustainable agricultural practices.

Keywords: deforestation, climate change

BACKGROUND AND RATIONALE

The destruction of forests in the world has concerned scientists for a long time, as forests appear to be an effective means of combating climate change, as observed today through its manifestations sweeping across the world (historic floods in Pakistan, repeated heat waves in Europe, hurricanes, fires, drought, etc.).

These various disasters recorded in the world have pushed the Secretary General of the UN, Antonio GUTERRES, to say: *The fight for climate change is a matter of life and death, for our security today and for our survival tomorrow* (Werner, 2022).

Deforestation caused by human activities also threatens the survival of forest biodiversity, increasing the risk of extinction for many species. This problem led world leaders to decide at COP 15 in Montreal (Canada) to protect 30% of terrestrial and marine ecosystems by 2030; as they contribute significantly to the conservation of the world's biodiversity and provide a range of ecological functions essential to the planet's well-being. Claude Gerald adds that they also help stabilize soils, reduce erosion, and ensure a continuous supply of fresh, drinkable water (Claude, 2004).

Because they store atmospheric carbon, CIFOR points out that forests also reduce the main greenhouse gases that exacerbate climate change (CIFOR, 2020).

To assist decision-makers in their efforts to implement forest conservation strategies in the DRC for sustainable development, we found it essential to take stock of deforestation in our country, especially in Kindu in Maniema, because the Maniema Province has a forest that contains enormous potential to ensure sustainable development (PIREDD/Maniema Project Report, 2022).

Given the scale of the deforestation phenomenon observed on the ground, the problem of deforestation in the city of Kindu is worrying for a population that, for the most part, lives from the forest, because the forests are increasingly far from the city and are threatened with disappearing, giving way to grassy vegetation, the *Chromolaena odorata* locally known as "KITAWALA". This is why this study helps to understand the explanatory factors of deforestation in the city of Kindu.

METHODOLOGY

To achieve the explanation, we used induction, comparison, statistics and diachrony. For data collection, these processes were supported by disengaged observation, documentary research, free interview, and written questionnaire survey. Regarding sampling, the household is the survey unit used in this study. In the city of Kindu, being populated in 2023 by 664,588 inhabitants, we obtained the number of households by dividing the number of inhabitants by 6 which is the average number of people in a household in the city of Kindu according to survey 1, 2, 3 and the DSRP-Maniema. This calculation gave us the figure of 110,765 households for all 3 communes of the city of Kindu. The sample size is 382 households; it was obtained by applying the statistician's formula "Yamane". The surveyors were distributed across the city's nine districts. The households to be surveyed were distributed proportionally to the size of each district making up the three municipalities of the city of Kindu according to the quota sampling plan. In relation to data processing, we used Excel and STATA version 14, Google Earth Pro and ArcGIS 10.5 software. Remote sensing allowed us to develop satellite maps (Kakule, 2021).

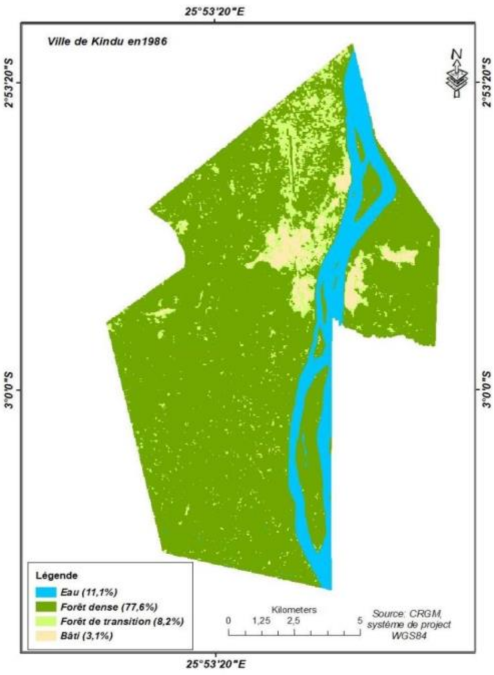
Creating the maps required data collection using a Garmin GPS. This GPS contained a precise barometric altimeter and an electronic compass that allows the user to find north, even when stationary.

For the sake of understanding, let us point out in passing that the dynamics of deforestation designates all the processes and factors that lead to the reduction of forest areas while deforestation is a phenomenon that leads in the long term to the definitive loss of forest space to the benefit of other uses such as agriculture, urbanization, and mining activities. As stated in some literature, it most often manifests itself through clear-cutting that does not respect natural balances, but also through almost permanent and visible deliberate or involuntary fires (https://www.kloranebotanical.foundation/).

RESULTS AND DISCUSSION

Comparative Maps of the Evolution of Land Use between 1986 and 2020

The satellite maps below show the decline in forest areas over the past thirty-four years. Land use has been defined into five main classes. The first class is primary forest (PF) or dense forest. The second class corresponds to transitional forest (TF) or secondary forest. The third class represents open forest. The fourth class consists of bare soils and built-up areas. The fifth and final class consists of streams and rivers that flow through the city.



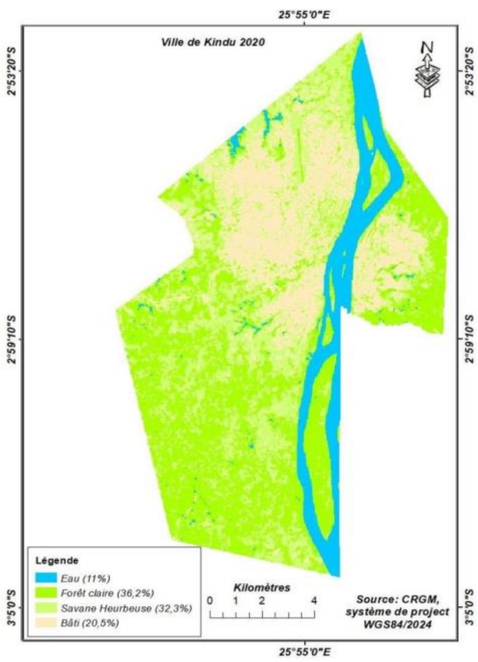


Figure 1: Land use of the city of Kindu **Figure 2: Land use of the city of Kindu**

The maps above show the evolution of forest loss in the city of Kindu. In 1986, 2/3 of the city of Kindu was occupied by primary forest. This gradually disappeared: 33% in 1996, 11% in 2006. In 2020, the city was covered with 36.2% open forest and 32.3% grassy vegetation. This scale of deforestation is explained by the variability of deforestation rates, which is the subject of the following point.

Deforestation Rate during the Study Period

As a background to this point, note that the deforestation rates were calculated using the following formula proposed by Caloz and Collet (as cited by Schure et al., 2011):

Deforestation rate (in %) $x = \frac{S2-S1}{S1}.100$, where S2 is the extent occupied by dense forest or secondary in the final year, S1 is the area occupied by dense or secondary forest in the initial year; the result is multiplied by 100. The annual deforestation rate for the periods studied is obtained by dividing the result by the number of years in the period considered.

Tables 1 and 2 below present the deforestation report for the city of Kindu between 1986 and 2020.

Table 1: Extent and loss of forest cover in the city of Kindu between 1986-2020

AREA (ha)								
Classes	**1986**	**1991**	**1996**	**2001**	**2006**	**2011**	**2016**	**2020**
FP	1211640,554	1059683,198	527156,878	180205,958	4190,836			
FT	128325,627	229131,115	805074,825	1116042,265	868406,789	895011,044	565727,307	565727,307
FC	-	-	-	-	-	311182,815	495731,617	495731,617
SNB	49341,271	49341,272	46932,037	72384,273	105834,148	86868,299	86868,299	317917.76
Water	171905,323	158016,029	169142,758	169142,758	169142,758	181977.70	181977.70	181977,696

Source: Estimates by ARCGIS software

Table 2: Deforestation assessment of the city of Kindu between 1986-2020

BALANCE SHEET (ha)							
Classes	**1986-1991**	**1991-1996**	**1996-2001**	**2001-2006**	**2006-2011**	**2011-2016**	**2016-2020**
FP	-151957,356	-1006967,512	-346950,918	-176015,122			
FT	100805,488	575943.71	-624868.87	-247635,476	26604,255	-329283,737	0
FC	-	-	-	-	-	184548,802	0
SNB	0.01	-2409,235	25452,236	33449,875	-18965,849	0	231049,461
WATER	-13889,294	11126,729	0	0	12834,942	0	-0.04

Source: Estimates by ARCGIS software

The examination of Tables 1 and 2 above shows a significant loss in the extent of the primary forest of the city of Kindu across the seven periods considered: it is -151,957 ha between 1986-1991, -1,006,967 ha between 1991-1996, -346,950 ha between 1996-2001, -176,015,108 ha between 2001-2006. The built-up area, on the other hand, increased from 49,341 ha in 1986 to 317,917 ha in 2020, an increase of 268,576 ha, which represents 84.5%.

Table 3: Deforestation rate of the city of KINDU between 1986-2020

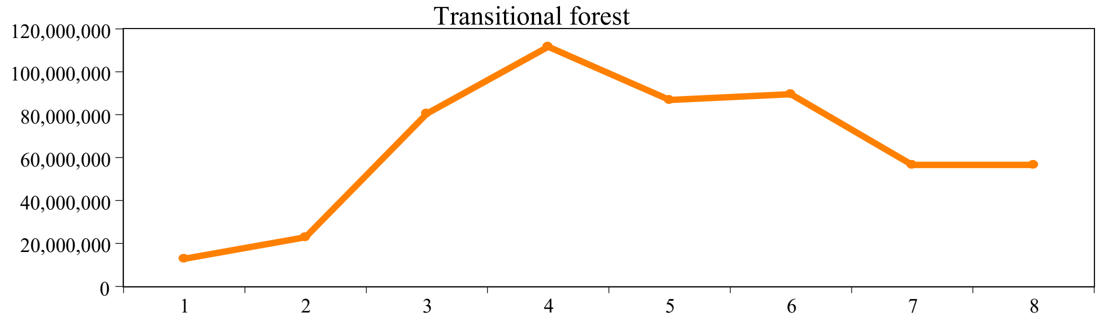
PERIODS							
Classes	**1986-1991**	**1991-1996**	**1996-2001**	**2001-2006**	**2006-2011**	**2011-2016**	**2016-2020**
FP	-12.5	-50.2	-65.8	-97.7	-100		
FT	78.5	251.3	38.6	-22.1	+3.0	-36.7	0.10

Source: Estimates by ARCGIS software

The annual rates of deforestation of primary forest during the above-mentioned periods increased from 2.5% per year between 1986-1991, to 10% per year between 1991-1996, to 13.1% per year between 1996-2001, to 19.5% per year between 2001-2006 and finally to 20% per year between 2006-2011. The average annual rate of deforestation of primary forest over the 20 years of study was 4.98% per year (1,211,640 ha in 1986 and 4,190 ha in 2006), which is high compared to the national average estimated at 0.22% per year according to the writings of Wasseige (Kyale et al., 2019).

Table 3 also informs us that the secondary forest, whose extent increased from 1986 to 2001, experienced a loss of its extent during the periods 2001-2006 with a deforestation rate of 22.1%, or 4.4% per year, and 36.1% between 2011-2016, or 7.3% per year.

This diametrically opposed evolution of deforestation rates between dense forest and transition forest is illustrated in Figure 3 below:



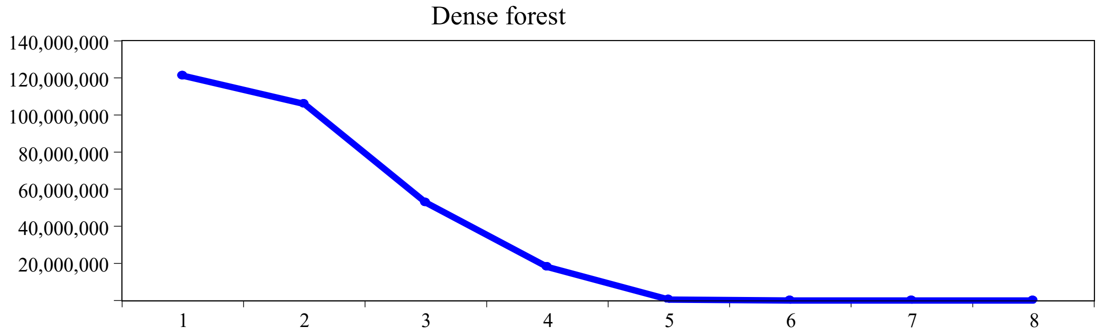


Figure 3: Assessment of the dense forest and the transition forest (in ha)
Source: The survey data

We note that the curve of the dense forest or primary forest is decreasing and is zero at the 5th class (therefore in 2006), while the curve of the transition forest has experienced growth accompanied by explosive fluctuations and a downward trend from the 4th tranche (therefore in 2001) and stagnation from the 7th tranche (therefore in 2016).

Class Relationship Model

This linear model is a function of primary forest as shown in the table below:

Table 4: Descriptive statistics of variables

	Dense forest	Transition forest	Forest clear	Water	Area built
Mean	37285968	64668078	16283076	17291034	10193592
Median	9219840.	68540107	0.000000	17052406	7962629.
Maximum	1.21E+08	1.12E+08	49573162	18197770	31791776
Minimum	0.000000	12832563	0.000000	15801603	4693204.
Std. Dev.	50556796	34066446	23183232	855307.4	8987971.
Skewness	0.833228	-0.307292	0.679819	-0.300010	2.016105
Kurtosis	1.989033	1.916057	1.614351	2.138495	5.507327

Jarque-Bera	1.266376	0.517549	1.256212	0.367405	7.515137
Probability	0.530896	0.771997	0.533602	0.832183	0.023340
Sum	2.9E+08	5.17E+08	1.30E+08	1.38E+08	81548736
Sum Sq. Dev.	1.79E+16	8.12E+15	3.76E+15	5.12E+12	5.65E+14
Observations	8	8	8	8	8

Source: Estimates by Eviews-09 software

Table 4 above presents the averages in ha. The variability, presented by the standard deviation, is very significant for each of the variables; which shows a correlation between the classes demonstrated by the correlation matrix presented in Table 5 below.

Table 5: Correlation matrix

Covariance Analysis: Ordinary					
Date: 12/23/23 Time: 2:41 PM					
Sample: 1 8					
Included observations: 8					
Correlation					
Probability	FORDENSE	FORTRANSI	FORCLAIRE	WATER	SUPBATIE
FORDENSE	1,000,000				

FORTRANSI	-0.747776	1,000,000			
	0.0329	-----			
FORCLAIRE	-0.591998	-0.005402	1,000,000		
	0.1221	0.9899	-----		
WATER	-0.650226	0.211962	0.850967	1,000,000	
	0.0809	0.6143	0.0074	-----	
SUPBATIE	-0.483410	0.034987	0.650701	0.525017	1,000,000
	0.2249	0.9345	0.0806	0.1815	-----

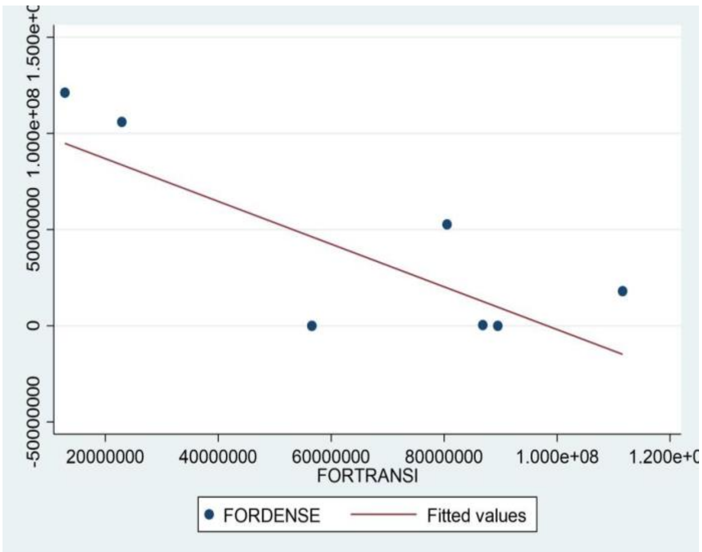


Figure 4: Relationship between primary forest and transition forest

This correlation matrix shows that the transition forest is negatively and significantly correlated with the primary forest, that is to say, the decrease in the primary forest leads to the appearance or growth of the transition forest; with a correlation rate of -74.77%.

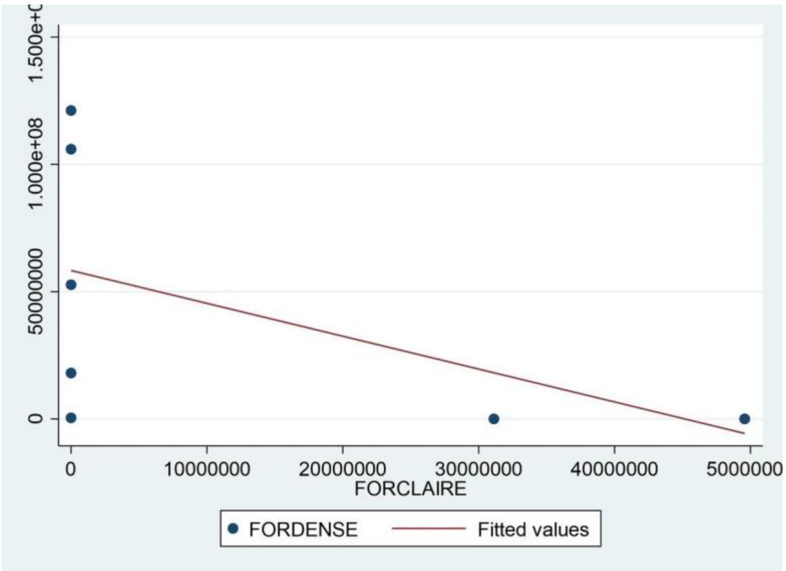


Figure 5: Relationship between primary forest and open forest

The relationship between primary forest and open forest is decreasing, that is, the decrease in primary forest leads to an increase in open forest.

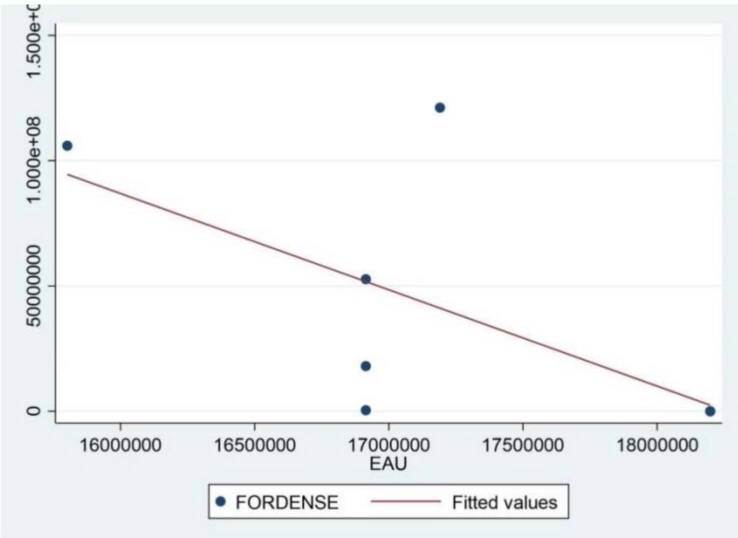


Figure 6: Relationship between primary forest and water space

The relationship between primary forest and water space is decreasing, that is, the decrease in dense forest leads to an increase in the space occupied by water. The disappearance of the canopy reveals the water surfaces.

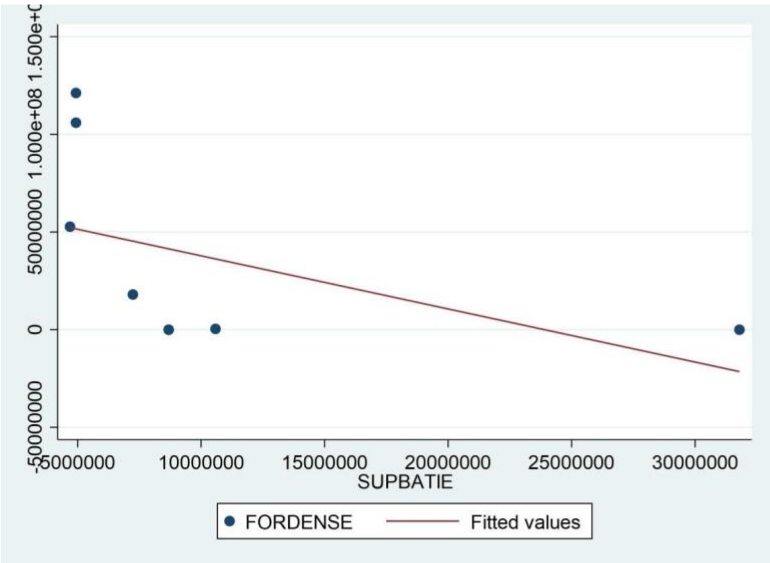


Figure 7: Relationship between primary forest and built-up area

The relationship between dense forest and built-up area is decreasing, that is, the increase in built-up area leads to a decrease in dense forest or primary forest.

Table 6: Correlation between the deforestation rate and the demographic pressure of the city of Kindu

Covariance Analysis: Ordinary
Date: 08/16/23 Time: 08:14
Sample: 1991-2023
Included observations: 33

Correlation TXDFOREST Probability		TXACCPOP
TXDFOREST	1,000,000	
TXACCPOP	-0.075855 0.6748	1,000,000

Source: Data processing by STATA-14

The study of the correlation between the population growth rate (TXACCPOP) and the deforestation rate (TXDFOREST) is negative, with a Bravais-Pearson correlation coefficient of -0.075855; but not significant because the associated P-Value is greater than 0.05 or 5% (0.6748 > 0.05). Therefore, any increase in the population of 1% leads to the disappearance of the forest of 0.07 ha. Hence, the increase in the population leads to the progressive disappearance of the forest of the city of Kindu.

The results of our study show that the high rate of deforestation in the city of Kindu is linked to strong population growth.

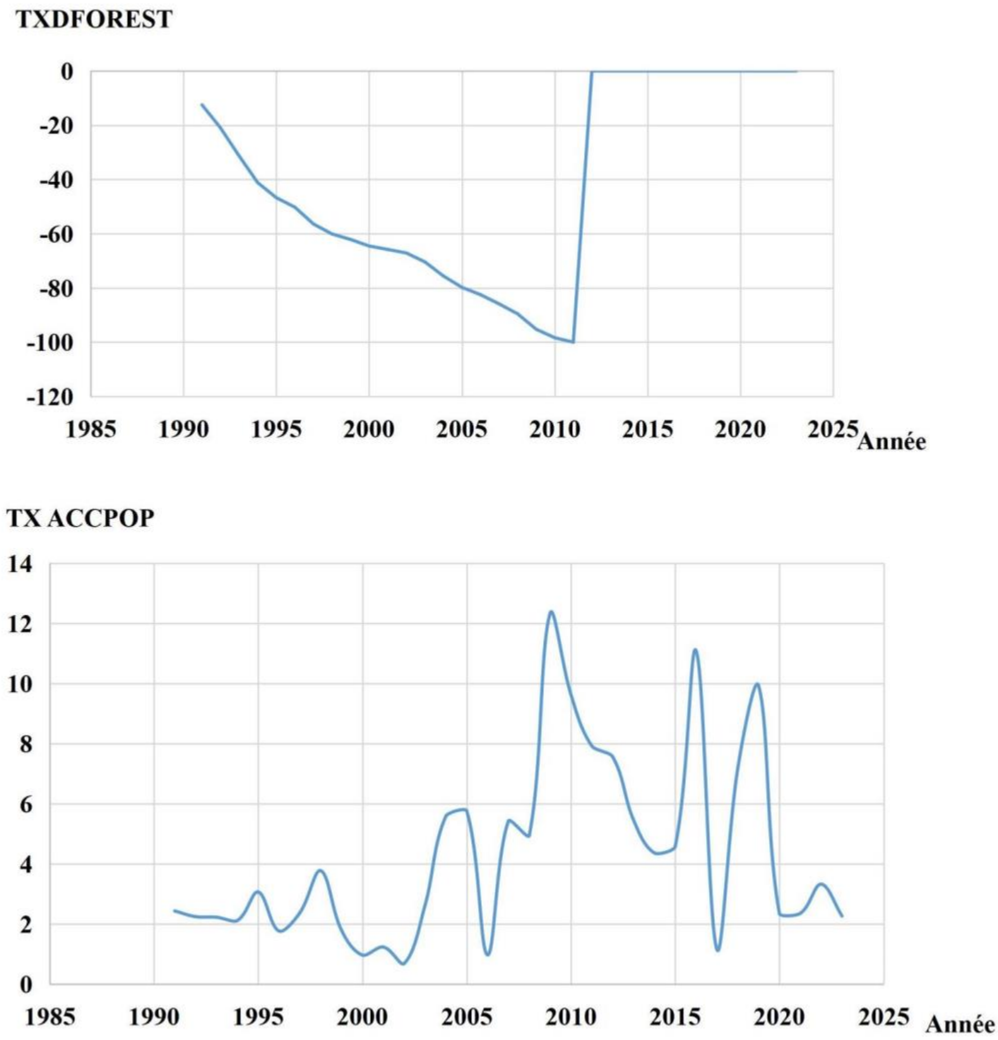


Figure 8: Evolutionary curves of the deforestation rate (TXDFOREST) and the population growth of the city of Kindu (TXACCPOP)

Figure 8 above shows that the two curves visualize the trend taken by each variable: the increase in the population of the city of Kindu (with explosive fluctuations) led to a very significant decrease in the area of dense forest from 1991 to 2010. We observe that in 2010 the dense forest completely disappeared from the city of Kindu.

The growth of the city's population accelerated during the periods of wars that the city of Kindu experienced in 1997 (AFDEL War) and especially in 1998 (RCD).

The RCD war sparked a revolt among the population, who took up arms to block the road to Rwandan soldiers who wanted to advance to take the town of Mbuji-Mayi; this was the creation of the Mai-Mai movement.

The insecurity created by killings by the Rwandan army in retaliation for losses suffered during clashes with the Mai-Mai has forced people from villages around Kindu to migrate to Kindu. Many of them settled there and worked in the fields, hence the heavy pressure on the primary forest.

The correlation between deforestation and population growth is demonstrated by numerous studies; we can cite those of Issouf BAMBA which focused on the “Influence of population density on the spatial structure of a forest landscape in the Congo Basin in the Democratic Republic of Congo, case of Kisangani (Bamba et al., 2022).

CONCLUSION

To conclude, let us remember that the average rate of deforestation in the city of Kindu is high, at 4.8% per year. There is a correlation between population growth and deforestation in the city of Kindu. The primary forest is now located more than 20 km or more from the city. Built-up areas also contribute to deforestation; they increased by 84.5% between 1986 and 2020. This analysis shows that agricultural activities and wood energy are the main explanatory factors for the high deforestation in the city of Kindu. In other reflections, we will present the drivers, impacts, and solutions to deforestation in the city of Kindu.

REFERENCES

Bamba, I., et al. (2022). Effect of roads and cities on the forest in the Orientale province of the Democratic Republic of Congo. *European Journal of Scientific Research, 43*, 45-55.

CIFOR. (2015). Deforestation and forest degradation in the Congo Basin: Current status, current causes and prospects. CIFOR.

Claude, G. (2004). *Geography and Population Dynamics*. Ellipses, Paris, p. 104.

Global Forest Watch, FAO. (n.d.). Causes and consequences of deforestation. Retrieved March 25, 2022, from https://www.kloranebotanical.foundation/

Kakule, R. (n.d.). Study of intra-urban erosion in Mbuji-Mayi (KASAI ORIENTAL, DRC), Impact and geomorphological risks of ravine erosion on cryptokarstic terrain in a tropical climate, Thesis, UNIKIN, 2020-2021, unpublished.

Kyale, J. K., Wardell, D. A., Mikwa, J.-F., Kabuanga, J. M., Monga, N. A. M., Oszwald, J., & Doumenge, C. (2019). Dynamics of Deforestation in the Biosphere Reserve of Yangambi (Democratic Republic of Congo): Spatial and Temporal Variability over the Last 30 Years. *Trees and Forests of the Tropics, 341*, 5-28.

Mary, F. (2011). Pressures on the forests of the Congo Basin. *Tropical Wood and Forests, 307*(1), 73-84.

N'shimba Lubilanji, L. (2014). *Introduction to research methods in human geography*. Gravita, Kinshasa, 182p.

PIREDD/Maniema Project Report. (2022).

Schure, J., et al. (2011). Wood energy in the DRC: Analysis of the sector in the cities of Kinshasa and Kisangani. MAKALA Project, CIFOR, December 2011, 84p, unpublished.

Werner, H. (2022). Opening speech at the Sharm el-Sheikh Climate Change Conference (COP 27), Egypt, held from November 6 to 18, 2022.

Yuma, M. P. (n.d.). Diversity of Forest Products other than timber of plant origin in the vicinity of Kindu and the impact of their exploitation: on environmental sectors and the daily lives of stakeholders. Province of Maniema, Thesis, UNIKIS, 2019-2020, unpublished.