EJSIT
European Journal of Science, Innovation and Technology
ISSN: 2786-4936
www.ejsit-journal.com
Volume 5 | Number 3 | 2025

Population Growth, Urbanization and Deforestation of the City of Kindu

Stanislas CHOMA NYEMBO[1], Léopold NSHIMBA LUBILANJI[2],
Alphonse MATAND TWILENG[2], Claude KAMANDA WA KAMANDA JEAN[2],
Roland KAKULE KASEREKA[2]
[1]University of Kindu, Faculty of Social, Political and Administrative Sciences, DR Congo
[2]National Pedagogical University, Faculty of Sciences,
Department of Geography and Environmental Sciences, DR Congo

ABSTRACT

The findings on the evolution of the population of the city of Kindu during the study period on population growth, urbanization, and deforestation are alarming. The analysis of correlation reveals, on the one hand, a significant relationship between population growth and deforestation in the city, and on the other hand, a strong correlation between urban expansion and forest loss. This situation is largely due to the expansion of the city of Kindu, which has occurred through the densification of former colonial subdivisions and horizontal sprawl, including the creation of more than 50% of de facto (unplanned or informal) settlements.

Keywords: population growth, urbanization, deforestation

INTRODUCTION

Demographic pressure is an omnipresent and overriding concern in urban areas (Boneti, 1991), and the city of Kindu is no exception. Located south of the equator at 2° 57' South latitude and 25° East longitude, it is facing profound and rapid transformations, driven by sustained population growth, uncontrolled urbanization, and alarming deforestation. With a population growth rate of 5.2% per year, this provincial metropolis is experiencing an increase at a rate that exceeds its capacity to adapt.

The consequences of this population explosion are manifested in particular by poverty and unemployment, which have become recurring problems for the inhabitants.

Furthermore, according to some literature, it should be noted that rapid and often poorly planned urbanization contributes to environmental degradation, with a deforestation rate reaching 4.8% per year (Kyale et al., 2019). These changes highlight the complex challenges that entities must face, both at the socio-economic and ecological levels.

This article aims to analyze the interactions between population growth and deforestation on the one hand, and urban expansion and deforestation of the city, on the other.

WORKING PROCESSES AND MATERIALS

In this context, we used induction, comparison, statistical analysis and diachrony. For data collection, these processes were supported by disengaged observation, documentary research, free interview, written questionnaire survey. 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. The creation of the maps required data collection using Garmin GPS. We also used non-biological materials such as smartphones, etc.

Population Growth and Urbanization

Table 1: Evolution of the population of the city of Kindu from 1986 to 2023

YEAR	POPULATION
1986	190245
1987	192038
1988	201230
1989	204252
1990	206471
1991	206541
1992	207102
1993	207521
1994	208569
1995	209422
1996	210321
1997	210503
1998	211205
1999	212034
2000	212350
2001	213861
2002	215314
2003	221092
2004	233426

Source: Kindu Town Hall Report 2015 and INS

YEAR	POPULATION
2005	246879
2006	249263
2007	262779
2008	275751
2009	309757
2010	339578
2011	366487
2012	394198
2013	415705
2014	433841
2015	453653
2016	503949
2017	509752
2018	546302
2019	600511
2020	614588
2021	629004
2022	649908
2023	664588

Source: Provincial Division of the Interior Report 2023 from 1986-200

The data in the tables above show that the population of the city of Kindu experienced a general growth between 1986-2000, continuous and quite rapid in the observation period 2001-2023. This leads us to evaluate, through the subsequent point and by the appropriate mathematical formula, the growth rate of the urban population relating to the above-mentioned observation period.

Evaluation of the Population Growth Rate of the City of Kindu in the Periods of 1986-2000 and 2001-2023

Calculating the growth rate of a population requires knowledge of its volume at the beginning of the observation period and at the end of the same period. In other words, it is necessary to know the state of the observed population at the initial date of the observation period and that of the observed population at the recent date of the same period.

For the case in point, the observed population of Kindu is equal to 190,245 inhabitants, in 2000 it is equal to 212,350 inhabitants, in 2001 it is equal to 213,861 inhabitants and that observed in 2023 is equal to 664,588 inhabitants.

That being said, the evaluation of the population growth rate of the city of Kindu will be done using the following mathematical formula:

$$r = \sqrt[t]{\frac{Ptn}{Pto}} - 1$$

Where r = average annual growth rate of a population;
t = time, expressed in years and which elapses between two census dates;

Ptn = Population observed at the recent or current time of the observation period;
Pto = Population observed at the initial time or start of the observation period.

For the period 1986-2000, P1986 = 190245 inhabitants; P2000 = 212350 inhabitants and t = 15 years, we replace each term of this formula by its numerical value and the expression becomes:

$$r = \sqrt[15]{\frac{212350}{190245}} - 1$$
$$r = \sqrt[15]{1{,}116192} - 1$$
$$r = 1{,}007355109 - 1,$$

or $0.74\% r = 0{,}007355109$

For the period 2001-2023, P2001 = 213861 inhabitants; P2023 = 664588 inhabitants and t = 23 years, we replace each term of this formula by its numerical value and the expression becomes:

$$r = \sqrt[23]{\frac{664588}{213861}} - 1$$
$$r = \sqrt[15]{3{,}10756987015} - 1$$
$$r = 1{,}05053277056 - 1,$$

or $5.1\% r = 0{,}050532771$

So, from 1986 to 2000, the population of the city of Kindu increased at a rate of 0.74%, while from 2001 to 2023 the growth rate increased to 5.1%. This is a fairly high growth rate and generally characterizes young populations in developing regions or countries. This strong population growth is illustrated by the figure below.

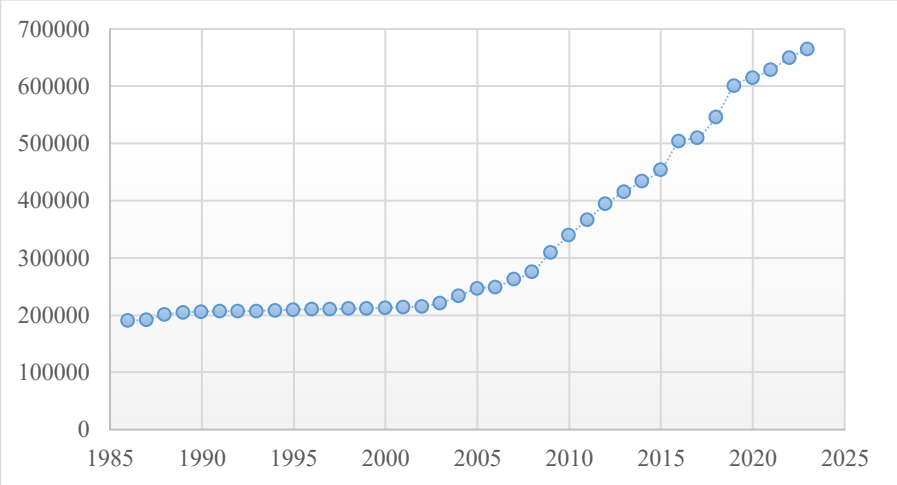

Figure 1: Evolution of the population of the city of Kindu from 1986 to 2023

The analysis of the population growth curve above shows a slow increase between 1986 and 2000 and a strong increase in the City's population between 2001 and 2023.

Considering the growth rate of 5.1%, we project the population of the city of Kindu in 2050 using the following mathematical formula:

$$Ptn = Pto \times (1+r)t$$

Where: Ptn = Population observed at the future date (population in 2050);
Pto = Population observed at the reference date (population in 2023);
$r = 0{,}050532771$;
t = Time elapsed between 2023 and 2050, or 27 years.

By replacing each term in the equation stated above with its numerical value, this mathematical expression becomes:

P2050 = P2023 x (1 + r)t
= 664,588 x (1+)270,050532771
= 664,588 x ()271,050532771
= 664,588 x 3.78494283528
= 2,515,428 inhabitants.

So estimated in 2023 at 664,588 inhabitants for the city of Kindu, this population will increase to 2,515,428 inhabitants in 2050 with the hypothesis of a demographic growth rate (factor "r") equal to (or 5.1%). This result shows that by 2050 the city of Kindu will be a millionaire city with the consequence of spatial sprawl and an increase in socio-economic needs.

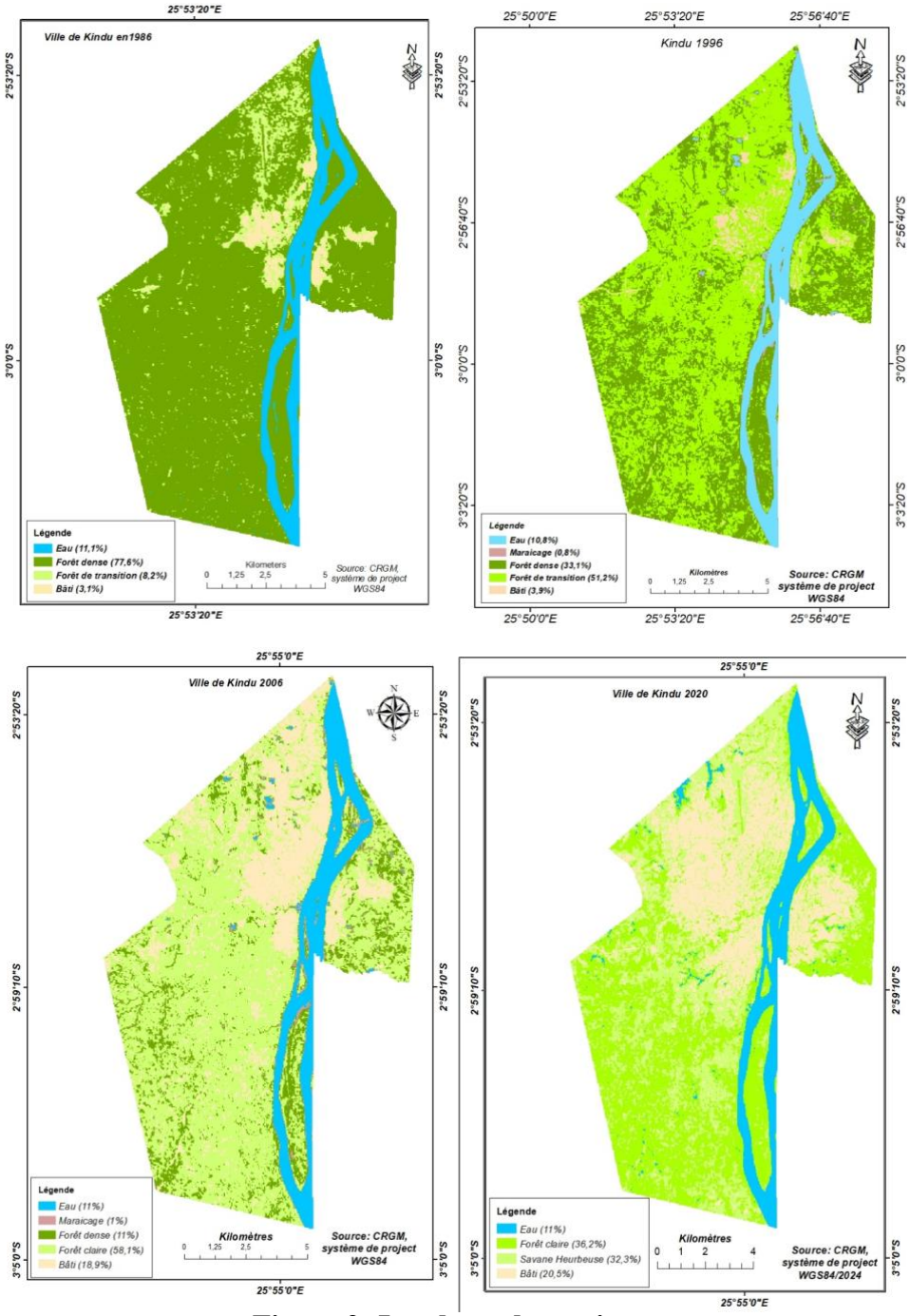

Figure 2: Land use dynamics

The four maps above clearly show the decline in forest areas over the past thirty-four years. The percentage of dense forest decreased from 77.6% in 1986 to 33.1% in 1996, to 11% in 2006 and to 0% in 2020. In 2010, it disappeared completely, and was replaced by grassy vegetation (32.3%) and open forest (31.7%). This evolution follows that of the population, which shows rapid growth from 2001.

The built-up areas have experienced an inverse evolution. They increased from 3.1% in 1986, to 4.4% in 1996, to 18.9% in 2006 and to 20.5% in 2020. The growth of the city is more significant on the left bank, seat of political-administrative institutions, banks, wholesale and retail trade, the ESU institutions are also located on the left bank.

The Congo River poses a natural obstacle to attacks on the city. All rebellions that have taken place in the city have entered through the right bank. For their safety, populations from the right bank have migrated to the left bank, particularly during the AFDL and RCD rebellions.

The materialization of urban space is noted by the creation of multiple subdivisions from the year 2000.

Demographic pressure leads to a rapid and disorderly expansion of urban space, and also to significant deforestation illustrated by the correlation study.

Correlation Study

Table 2: Correlation between population growth and expansion of the city of Kindu

YEAR	SUPBAT (ha)	POP	DEFOREST (ha)
1986	4934127.1	190245	121164055.4
1987	4942512.2	192038	120256324.4
1988	4956215.1	201230	118256368.9
1989	4968794.5	204252	115245874.2
1990	4985987.4	206471	110256489.7
1991	5235145.7	206541	105968319.8
1992	5326451.8	207102	87562365.4
1993	5468952.4	207521	75215623.1
1994	5568412.2	208569	65256321.4
1995	5856231.1	209422	59458752.6
1996	6253242.7	210321	52715687.6
1997	6325147.9	210503	45123201.2
1998	6425632.2	211205	39842120.5
1999	6526452.2	212034	29892750.3
2000	6632124.8	212350	23562180.9
2001	7238427.3	213861	18020595.2
2002	7356235.4	215314	15562820.3
2003	7458963.4	221092	8256236.1
2004	7589632.5	233426	2123564.8
2005	7689452.3	246879	980795.3
2006	10583414.8	249263	419083.6
2007	11562352.5	262779	425680.7
2008	13589742.6	275751	398122.8
2009	14562485.7	309757	256841.5
2010	16985568.4	339578	162480.7
2011	20263584.8	366487	113206.1

2012	22562315.1	394198	99850.2
2013	23569845.6	415705	67456.4
2014	24562326.4	433841	55420.6
2015	26120320.2	453653	49560.1
2016	27562312.4	503949	44125.4
2017	28458952.7	509752	1268.2
2018	28963255.4	546302	0
2019	29584255.6	600511	0
2020	31791776.2	614588	0
2021	34152484.2	629004	0
2022	36456489.7	649908	0
2023	38456325.1	664588	0

Source: Combined reading of the INS reports from 1986-200 and that of the provincial division of the interior from 2001-2023, as well as the estimation of the areas of deforestation and built-up space by the STATA-16 software

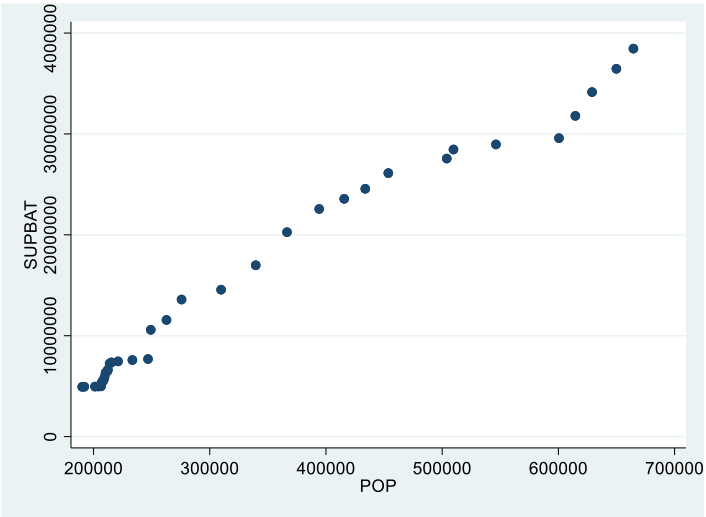

Figure 3: Graphical analysis according to our estimates by STATA-16 software

This curve shows that population growth and city expansion are positively correlated. Therefore, the growth of the population of the city of Kindu is accompanied by its strong spatial expansion.

Table 3: Matrix analysis between population growth and city expansion according to our STATA-16 estimates

Variables	**Correlation coefficient**	**Probability**
Demographic growth	**0.9894**	**0.0000**
City expansion		
Statistical interpretation	**Very strong correlation**	
Clinical interpretation	**Significant correlation**	

The correlation coefficient being positive, and between 0.80 and 1, there is therefore a strong correlation between demographics and the expansion of the city.

In doing so, this correlation between demographic and the expansion of the city of Kindu is significant because the P-value is less than 0.05 or 5%.

Population Growth and Forest Loss (Deforestation)

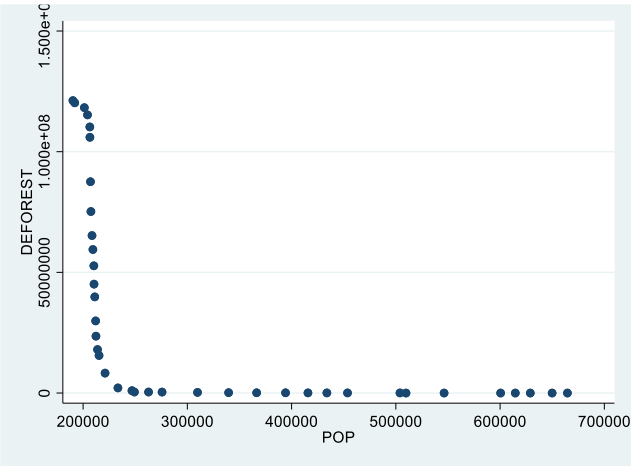

Figure 4: Graphical analysis according to our estimates by STATA-16 software

This curve shows that population growth and forest loss are negatively correlated. Therefore, population growth in the city of Kindu is accompanied by a significant decline in forests. Therefore, there is significant deforestation.

Table 4: Matrix analysis between population growth and deforestation according to our STATA-16 estimates

Variables	**Correlation coefficient**	**Probability**
Demographer	**-0.5993**	**0.0000**
City expansion		
Statistical interpretation	**Strong correlation**	
Clinical interpretation	**Significant correlation**	

The correlation coefficient being negative, and between 0.50 and 0.80, there is therefore a strong moderate correlation between population growth and forest decline (deforestation).

In doing so, this correlation between population growth and forest decline is significant because the P-value is less than 0.05 or 5%.

Correlation between City Expansion and Forest Loss (Deforestation)

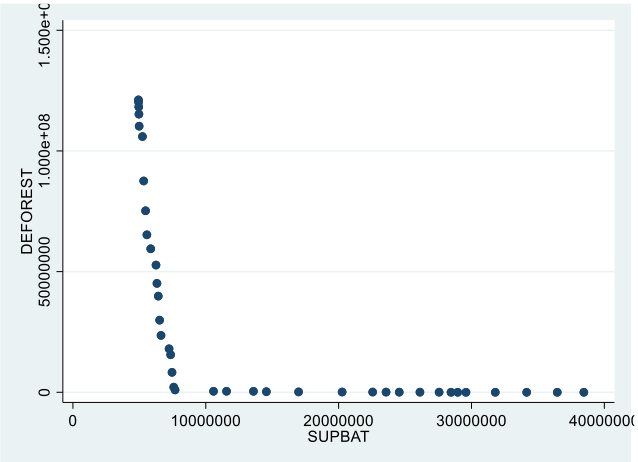

Figure 5: Graphical analysis according to our estimates by STATA-16 software

This curve shows that rapid city expansion and forest loss are positively correlated. Therefore, the expansion of the city of Kindu is accompanied by significant deforestation.

Table 5: Matrix analysis between city expansion and deforestation according to our STATA-16 estimates

Variables	**Correlation coefficient**	**Probability**
Demographer	**-0.6432**	**0.0001**
City expansion		
Statistical interpretation	**Strong correlation**	
Clinical interpretation	**Significant correlation**	

The correlation coefficient being negative, and between 0.50 and 0.80, therefore there is a strong moderate correlation between the expansion of the city of Kindu and the decline of the forest (deforestation).

In doing so, this correlation between the expansion of the city of Kindu and the decline of the forest is significant because the P-value is less than 0.05 or 5%.

Study of the Impact or Incidence of Population Growth and Urbanization on Deforestation in the City of Kindu

The linear regression carried out below allowed us to analyze the impact of population growth on city expansion and forest decline.

Table 6: Impact of population growth in the town of Kindu on forest decline

```
Linear regression Number of obs = 38
                                  F(1, 36) = 29.59
                                  Prob > F = 0.0000
                                  R-squared = 0.3508
                                  Root MSE = 3.6e+07
------------------------------------------------------------------------------
             | Robust
   DEFOREST | Coef. Std. Err. t P>|t| [95% Conf. Interval]
-------------+----------------------------------------------------------------
         POP | -165.1197 30.35439 -5.44 0.000 -226.6812 -103.5581
       _cons | 8.61e+07 1.45e+07 5.94 0.000 5.67e+07 1.15e+08
------------------------------------------------------------------------------
```

Source: STATA-16

This estimate shows that population growth has a negative and significant impact on the forest. Every increase of 1,000 individuals results in deforestation of 165.12 hectares.

Table 7: Impact of population growth on the expansion of Kindu City

```
Linear regression Number of obs = 38
                                  F(1, 36) = 1351.20
                                  Prob > F = 0.0000
                                  R-squared = 0.9789
                                  Root MSE = 1.6e+06
------------------------------------------------------------------------------
             | Robust
    SUPBAT | Coef. Std. Err. t P>|t| [95% Conf. Interval]
-------------+----------------------------------------------------------------
```

POP | 69.11322 1.880185 36.76 0.000 65.30003 72.92641
_cons | -7848468 514110.5 -15.27 0.000 -8891133 -6805804

Source: STATA-16

This estimate shows that population growth has a positive and significant impact on the expansion of the city. Every increase of 1,000 individuals results in a city spread of 69.11 hectares.

Table 8: Impact of Kindu City expansion on forest retreat

Linear regression Number of obs = 38
F(1, 36) = 33.45
Prob > F = 0.0000
R-squared = 0.4137
Root MSE = 3.4e+07

| Robust
DEFOREST | Coef. Std. Err. t P>|t| [95% Conf. Interval]

SUPBAT | -2.566874 .4438066 -5.78 0.000 -3.466956 -1.666793
_cons | 7.00e+07 1.10e+07 6.35 0.000 4.76e+07 9.23e+07

Source: STATA-16

This estimate shows that urban sprawl has a significant negative impact on forests. Urban sprawl of 1-hectare results in deforestation of 2.57 hectares.

Table 9: Forest cover loss in the city of Kindu between 1486 and 2023

	Area (ha)					
Classes	1986	%	2016	%	2020	%
Fp	1211640,554	77.6	0	0	0	0
SNB	49341,271	3.1	86868,299	20.5	317,917.76	20.5

Source: Estimate by ARGIS software

Table 4 shows a huge loss of forest cover which went from 77.7% to 0% in 1916; on the other hand, the built-up area increased from 3.1% in 1986 to 20.5% in 2020.

DISCUSSION

In this reflection, we have deduced that the expansion of the city of Kindu was done by densification of the old colonial subdivisions and by horizontal sprawl with the creation of more than 50% of de facto subdivision. This strong demand for land pushes the population to occupy non-aeficandi areas which are subject to flooding and old cemeteries disused by the provincial authority in violation of the law. The search for agricultural land for subsistence leads to the disappearance of forest covers in 2006 and the population of the city cultivates far from the city more than 30 km. This aspect is consistent with the studies of Julien and his collaborators who have highlighted that the expansion of subsistence activities is the most commonly cited cause of deforestation in the Congo Basin (Brice et al., 2023).

The results of our study show that population growth has a negative and significant impact on the forest. Every increase of 1000 individuals leads to a deforestation of 165.12 ha. It notes that population growth has a positive and significant impact on the expansion of the

city. Every increase of 1000 individuals leads to a city sprawl of 65.11 ha. Conversely, the city sprawl of 1 ha leads to a deforestation of 2.57 ha.

This conclusion has a direct link with the observation made by some authors (Tungi Tungi et al., 2021) in the sense that, according to their assertion, there is a close positive correlation between deforestation and population growth estimated at 0.81 and between deforestation and urban expansion whose value is 0.63.

CONCLUSION

In this study, we analyzed the evolution of the population of the city of Kindu from 1986 to 2023, with a particular focus on population growth, urbanization, and deforestation. It had the advantage of drawing an analogy between demography, urbanization, and deforestation.

The correlation analysis shows, on the one hand, that population growth and deforestation in the city of Kindu are significant, and on the other hand, the correlation between urban expansion and deforestation is also expressive. This is justified by the fact that the expansion of the city of Kindu was carried out by densification of old colonial housing estates and horizontal sprawl with the creation of more than 50% of de facto housing estates. The population occupies non-aedificandi zones and former cemeteries abandoned by the provincial authority in violation of the law. The search for agricultural land led to the disappearance of the forest cover in 2006 and the city's population cultivates far from the city, more than 30 km away.

The correlation analysis shows that the population growth and deforestation of the city are significant because (P. value less than 0.05 or 5%). Consequently, the subdivision of the recorded facts constitutes 59.3% against those who have provincial decrees (40.7%); the correlation between urban expansion and deforestation of the city is also significant.

REFERENCES

Bonetti, M. (1991). *Urban social development, strategy and methods.* Harmattan, Paris, 160 p.

Brice, J., et al. (2023). Population growth and sustainable development: the case of the Congo Basin countries. *African Journal of Environment and Agriculture,* 1-10.

Kindu Town Hall. (2015). Annual administrative reports, 163 p.

Kyale, J., et al. (2019). Deforestation dynamics in the Yangambi Biosphere Reserve in the Democratic Republic of Congo: spatial and temporal variability over the last 30 years. *Bois et Forêts des Tropiques, 341*, 15-28.

Provincial Division of the Interior (2023). Annual report, 224 p.

Tungi Tungi, J., et al. (2021). Impact of population growth and urban expansion on the forest dynamics of the surrounding areas of the city of Kikwit in the Democratic Republic of Congo. *African Journal of Environment and Agriculture,* 16-30.