The Impact of Agricultural Productivity on Deforestation in Central Africa

Novice Patrick Bakehe

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The Impact of Agricultural Productivity on Deforestation in Central Africa

By

Novice Patrick Bakehe
Research Group in Applied and Theoretical Economics (GRETA),
University of Douala

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Abstract

This paper examines the effect of agricultural productivity on the environment, using deforestation as an example. We examined this relationship using a sample of nine countries in Central Africa, with data from the 1990s to 2020. The econometrics results show that an increase in agricultural productivity reduced the rate of deforestation in these countries. This suggests that policies that facilitate the adoption of modern inputs and investment in technology leading to an increase in yields from agriculture could lead to a reduction in the demand for agricultural land.

Key Words: Deforestation; Agricultural productivity; Central Africa; Feasible generalized least squares.

1. Introduction and statement of the problem

Low levels of agricultural production constitute a major problem in developing countries (Barbier and Hochard, 2014). According to FAO (2012), lack of food security affects close to 870 million people, or close to 12% of the world population (a percentage that increases to 27% in sub-Saharan Africa). According to forecasts given by Bruinsma (2009), the global population will increase by 40% by 2050. This, coupled with an increase in the rate of food consumption, means the population growth will need an increase in agricultural production by 70% (100% in developing countries) (Bruinsma, 2009).

Improvement in agricultural production is quite often seen as a solution to problems related to both the production of a larger quantity of food and protection of forest land. Indeed, an increase in productivity per hectare meets the set production targets using less acreage, which could lead to weakening the demand for more agricultural land. (Ngoma et al., 2021; Lundberg and Abman, 2022). However, Lambin and Meyfroidt (2011) have demonstrated that an increase in productivity does not necessarily lead to land conservation. In certain cases, one observes increased deforestation[1] following an increase in productivity. This could be explained mainly through "the rebound effect", whereby increased productivity would make agriculture more attractive, leading to an increase in the demand for farm land, which generally comprises "virgin lands that provide easy access" to farmers (Angelsen and Kaimowitz, 2001).

It is therefore necessary to understand the underlying relationship between an increase in agricultural productivity and deforestation in the developing world. If the increase in agricultural productivity increases the demand for farm land, development policies targeting an improvement in agricultural productivity could have negative effects on the environment. However, if an increase in productivity allows farmers to defer the need to put new land under cultivation, these development policies could have positive environmental benefits for forest conservation.

In this study, we examined the impact of agricultural productivity on deforestation in Central Africa. We defined Central Africa as all the countries belonging to the Commission for Central African Forests (COMIFAC), namely Gabon, The Republic of Congo, The Democratic Republic of Congo, Equatorial Guinea, Cameroon, Central African Republic, Burundi, Rwanda and Chad. Sao Tomé and Principe was excluded from the analysis due to lack of data. COMIFAC is the reference subregional institution in matters related to harmonization of forest and environmental policy in Central Africa. It guides, coordinates and makes decisions on subregional actions and initiatives in the domain of conservation and the sustainable management of forest ecosystems. Member countries of COMIFAC develop national forestry programmes and/or environmental action plans (NFAP, etc.) within the framework of implementing COMIFAC policy. Some countries have national action plans in place and others have yet to formulate theirs.

To the best of our knowledge, this study provides the first empirical analysis of the influence of agricultural productivity on deforestation in Central African countries. The relationship between agricultural productivity and deforestation is a fundamental question. It has significant implications for development policies which support use of agricultural inputs and also encourage the adoption of technologies for improving yields in the Central African region, which is at the heart of global concerns on preservation of biodiversity. Indeed, the Congo Basin, the second largest forest ecosystem in the world after the Amazon Forest, is situated in Central Africa. The Basin plays an important role in the preservation of biodiversity.

The paper is divided into five sections. After the introduction, the second section examines deforestation factors in Central Africa. The third gives a brief literature review on the relationship between agricultural productivity and deforestation. The fourth presents the econometric model used as a method of research and describes briefly the variables used in this study. The results are discussed in the fifth section, before the conclusion.

2. Drivers of deforestation in the Central Africa: A multisectoral analysis

In Central Africa, expansion of agricultural land is the most commonly cited precipitating cause for deforestation. The migration of farmers and the concentration of new immigrants in certain countries of Central Africa are major reasons for the clearing of forests. Bessat (1996) demonstrated that the massive exodus of Chadian farmers towards the north of Cameroon or towards the north of the Central African Republic is a major cause of deforestation in these regions. The researcher showed how forest land was rapidly disappearing in certain regions of Central Africa (such as, the case in the Savannah region of Pool in Congo or close to Bangui) whereby farmers are settling in peri-urban zones, seeking to move closer to large urban agglomerations so as to engage in the production of food crops that would find a ready market. In the two cases, deforestation occurs not only through the clearing of land that was previously uncultivated, but also because the traditional know-how of the new arrivals does not allow for them to easily adapt to local conditions. This illustration applies, for example, to immigrants coming from Mount Mandarah in the north of Cameroon (Bessat, 1996). The speed of the degradation of the newly occupied lands quickly led to a fresh migration towards new zones. In the mid-1990s the poor soils in several zones led to an increase in cultivated land to compensate for the reduction in yield (Bessat, 1996). Through an analysis based on a geographic information system (GIS), Zhang et al. (2002) highlighted how subsistence farming is the main cause of deforestation in Central Africa, particularly in places where the forests are more accessible. However, in Chad, Cameroon or Central African Republic, forest–savannah transitional zones were set aside for the development of cotton farming and, to a great extent, crops amenable to mass and regular production. These then led to a rapid decrease in forest land. For example, from the beginning of the 20th Century, forests in the south-west of Cameroon were rapidly converted into oil palm, cocoa and rubber plantations. These plantations, held by both small-scale farmers and large multinational firms, progressively mushroomed and now practically cover the entire region, which has thus lost the quasi-totality of its forest cover (Nke Ndih, 2008). With the implementation of the structural adjustment plans imposed by the Bretton Woods institutions, agricultural enterprises, which had been created by the States[2], were privatized and their new owners engaged in cutting down large swathes of forests in order to extend their plantations. The presence of some large commercial farms, belonging generally to multinational companies that are active in certain countries such as Gabon and Cameroon, notably in the production of palm oil and rubber (and of bananas in the case of Cameroon), could further increase deforestation in those countries (Megevand et al., 2013).

More than 90% of the total volume of wood harvested from most Central African countries is used as firewood (Marien, 2009). In 2007, the total production of firewood in Central Africa was higher than 100 million cubic metres, and continues to increase (Megevand et al., 2013). However, the impact of energy demand on deforestation is more pronounced in certain countries. Indeed, energy profiles vary from one country to another in the region, according to the wealth of that particular country, but also according to the country's access to electricity. In the Democratic Republic of Congo, renewable fuels and waste material (essentially firewood and charcoal) were evaluated at more than 93% of the total energy consumed in 2008, in a context whereby close to 12% of the population had access to electricity in 2009 and where fossil fuels could only cover 4% of the energy needs of the country in 2008 (World Bank, 2012). With a population of close to 10 million people, Kinshasa consumes 5 million cubic metres of firewood or the equivalent, per year. In the Democratic Republic of Congo, the human population is forecast to double by 2030. Other countries such as Cameroon and Equatorial Guinea will experience similar demographic growth that will certainly lead to a higher demand for wood-energy[3]and therefore have a significant impact on the forest cover of these countries (Megevand et al., 2013). Furthermore, statistics from demographic and health surveys show that more than 80% of households use wood-energy as their primary source of energy, whether in the form of charcoal, firewood, sawdust or wood chips in Republic of Congo, Central African Republic, Burundi, Rwanda and Chad. However, in Gabon, dependence on wood-energy is considerably lower, thanks to a vast electricity network and subsidized cooking gas.

The logging industry, which has a two-sided nature, is also a cause of deforestation in the Congo Basin. Indeed, there exists a formal sector that is highly visible, dominated by big Western companies and almost entirely geared towards exports. However, there exists an informal sector that can be hardly identified. Industrial forestry exports constitute the most extensive forms of land exploitation in Central Africa, with 44 million hectares in concession, or almost a quarter of the total surface of low altitude evergreen rainforest. Production in the formal sector reaches an average of 8 million cubic metres of wood a year, with Gabon being the largest producer (Megevand et al., 2013). However, with the adoption of principles of sustainable forest management (SFM) as well as increased number of species harvested, the impacts of industrial forestry are still limited. The movement towards GDF has proved to be significant. Until 2010, more than 25 million hectares had been placed under a framework of state-approved plans. The rates of log harvesting are, on average, lower than 0.5 cubic metres per hectare. Compared to the two other major regions of tropical forests (Latin America and Asia), the countries of Central Africa remain relatively small players in wood production at the international level, with less than 3% of global production of tropical timber (OFAC, 2011). The second type of exploitation, often called informal and which for a long time has not been studied, is that of local small-scale loggers oriented towards supplying the large urban centres in the region. This informal sector is today recognized as a major component of the timber harvesting sector. Even though the information is scanty in terms of countries such as Republic of Congo, Central African Republic, Burundi, Rwanda and Chad, in some countries such as Cameroon and the Democratic Republic of Congo, production in the informal sector is higher than that of the formal sector (Lescuyer et al., 2012).

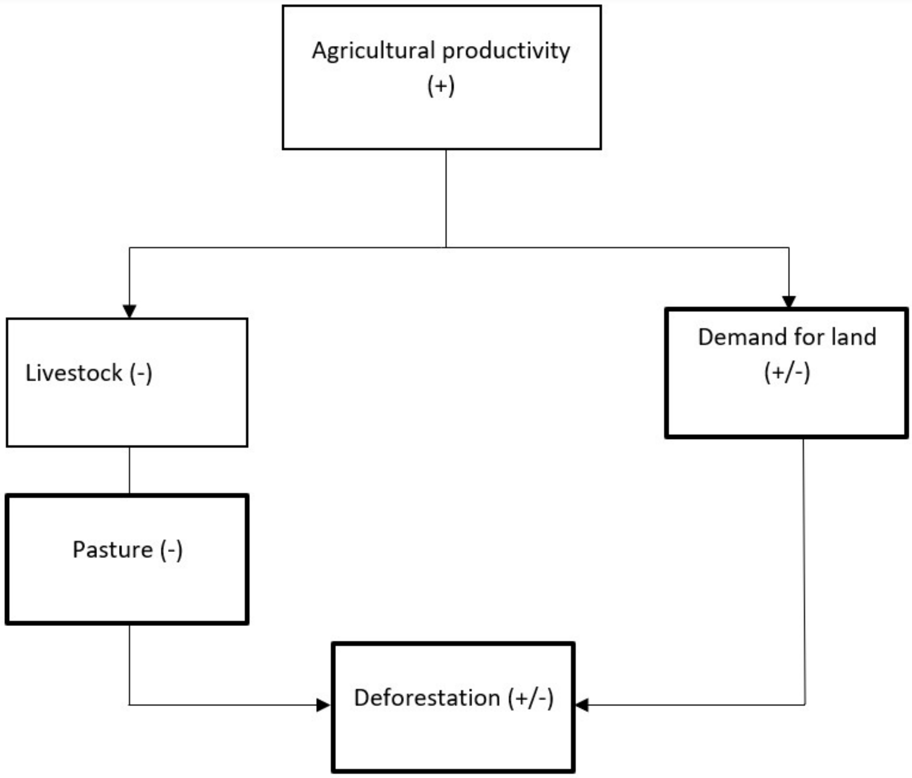
Corruption and lack of good governance also affect progress towards the preservation and the sustainable management of forest resources in the Central Africa. A lack of transparency and of good governance procedures in the attribution of foresting licences in several countries leads to corruption and bad business practices. This does not stimulate long-term investments, which are indispensable in efforts to improve sustainability in the forestry sector. Bad governance also limits the aptitude to maximize the collection of benefits derived from forestry resources and to distribute them equitably among the populations of Central Africa (Megevand et al., 2013). Tacconi (2009) highlighted the fact that the process of corruption is a vicious cycle because the need to remunerate the agencies responsible for forest management increases logging costs, obliging logging companies to increase illegal deforestation in order to cover a part of their costs.

Conceptual Framework

Agricultural production in Central Africa remains largely dominated by traditional systems. In the region, the agriculture sector is dominated by small-scale farmers who practise traditional farming, with a system of cultivating over two years and leaving the land to lie fallow for seven to 10 years (Megevand et al., 2013), which increases demand for new land for farming.

Generally, in countries or regions where laws on deforestation do not exist or are difficult to implement, increasing agricultural productivity and intensification of agriculture could be used as an indirect policy instrument to reduce forest pressure. Such a strategy is known as the Borlaug hypothesis. According to the hypothesis, "increasing crop yields can prevent cropland expansion and deforestation, thus alleviating hunger and poverty without dramatically increasing environmental impact." However, increasing agricultural productivity could have ambiguous effects on the protection of forests. Conversely, it could extend the land surface covered by agriculture, in other words, the quantity of forest land cleared for agriculture, which could effectively increase deforestation, or, it could encourage or incite farmers faced with constraints related to market conditions to abandon their grazing land — which requires large tracts of land — for less harmful forms of agriculture (see Figure 1).

Figure 1. Transmission channel for increased agricultural productivity over deforestation



Assunção et al. (2017) demonstrated how electrification in Brazil increased crop productivity with the result that farmers: (i) enhanced their farming by converting their unused land into agricultural land; but also (ii) abandoned livestock breeding for crop farming. Given that farming had enabled farmers to preserve more of their indigenous vegetation in their rural farms, the researchers concluded that electrification increased agricultural productivity, leading to a net decrease in deforestation.

3. The relationship between agricultural productivity and deforestation: Brief literature review

A number of studies highlight the relationship between agricultural productivity and deforestation (Villoria et al., 2014; Ehui and Hertel, 1989; Bhattarai and Hammig, 2001; Brady and Sohngen, 2008; Rudel et al. 2009; Burney et al. 2010; Barbier et al. 2017).

The empirical results giving the relationship between agricultural productivity and deforestation are not unanimous. Various authors have highlighted that an increase in agricultural productivity reduces the rate of deforestation, thus limiting the loss of biodiversity (Ewers et al., 2009; Abman and Carney, 2020; Stabile et al., 2020) and Greenhouse gas emissions (Burney et al., 2010). From this model of fixed effects panel data from a sampled 66 countries over the period 1972 to 1991, Bhattarai and Hammig (2001) found that an improvement in agricultural productivity (measured through the volume of cereals produced) reduced the deforestation rate. Abman and Carney (2020) studied the underlying relationship between agricultural productivity and deforestation by examining the impact of a vast programme of fertilizer and seed subsidies in Malawi. The authors took deforestation data from Global Forest Change, which provides the reference for forest cover in 2000 and a year-by-year loss of forest cover at a resolution of 30 metres, drawn from Landsat imagery (Hansen et al., 2013). The data on the allocation of subsidized fertilizer at the district level was provided by the International Food Policy Research Institute (IFPRI). Specifically, these data are drawn from programme reports and contain data on allocation of fertilizer per district and per year for the years 2001 to 2012, except for the year 2006. Using the instrumental variable method, the researchers demonstrated that an increase in agricultural productivity has a positive impact on forest protection.

Other researchers highlight the negative impact of agricultural productivity on deforestation (Brady and Sohngen, 2008; Marchand, 2012). Marchand (2012) studied the compromise between agricultural efficiency and environmental efficiency by evaluating the impact of the technical efficiency of farms on deforestation using data collected in the Amazon between 1995 and 1996. The results of the stochastic production frontier model indicate that the technical efficiency has a U-shaped effect on the conversion of agricultural lands: the farms that are the least efficient and those that are most efficient use more land for their agricultural activities and therefore have a positive effect on deforestation. The researcher explained this result through the poor environmental evaluation given to the Brazilian forest, the unequal distribution of land and problems of free *de facto* access to forest land. Brady and Sohngen (2008) used the fixed-effect panel and a linear model on data from the period between 1969 and 2001. The researchers found that an increase of 1% in agricultural productivity (measured through the total productivity of agricultural factors) translates into the destruction of the forest by 62,000 hectares.

Finally, a third group of researchers did not find any significant relationship between agricultural productivity and deforestation (Ewers et al., 2009; Rudel et al., 2009; Koch et al., 2019). Indeed, Koch et al. (2019) used panel data from 492 municipalities in the Amazon from a period stretching from 2004 to 2014. Using a difference in difference method and a matching model, they demonstrated that the reduction of deforestation in those municipalities was associated with an increase in production and productivity of livestock (head of cattle/hectare), which is in agreement with a model in which the reduction of the value of clearing of new lands brought about by the implementation of the policy, led farmers facing financial constraints to move their investments away from deforestation towards capital investment in farming.

Ewers et al. (2009) used an ordinary least squares model and examined 124 countries and 23 major food crops in terms of energy on a global scale, covering the period 1979 to 1999. Overall, the researchers found that the impact of an improvement in agricultural productivity (measured through the production of those crops) on deforestation is of very low significance. Using multivariate analyses, Rudel et al. (2009) studied 10 major food crops (wheat, maize, soya, rice, cotton, coffee, cocoa, sugar, potatoes and yam) over the period 1970–2005 on a sampled 161 countries. The econometric study undertaken highlighted a non-significant correlation between crop productivity and the global trends in acreage.

Although several researchers have examined the impact of increasing agricultural productivity on deforestation, they focused on open economies and worked in situations where property rights are relatively well defined (Marchand, 2012; Koch et al., 2019) or on macroeconomic data that takes into account several countries that are heterogenous in terms of their levels of development (Brady and Sohngen, 2008, Ewers et al., 2009; Rudel et al., 2009). Our study focused on a region where agriculture is essentially a subsistence activity and is generally focused towards satisfying a local fixed demand.

4. Methodology

4.1 Data and empirical methodology

a) Data sources

The sampled data is from nine of the 10 countries of the Central Africa Forests Commission (COMIFAC)[4], and covers the period between 1990 and 2020. The choice of country was determined by the availability of data.

The variable that we sought to explain is the rate of deforestation DF_{it} at date t defined as:

$$DF_{it} = -\frac{F_{it} - F_{it-1}}{F_{it-1}}$$

Where, F_{it} stands for the country's forested area *i* during year *t*. The forested area is measured as the sum of the naturally forested zones, the planted areas and the forest land that has already been cleared but will be replanted in the near future. This definition, proposed by FAO (1993), is currently used in most empirical studies (Cropper and Griffiths, 1994; Shafik, 1994, Koop and Tole, 1999). The importance of this definition is that it takes into account a larger variety of ways of measuring the different types of forests (Wooded land, wooded Savannahs, plantations, fallow forests etc.), in an intuitive manner that covers most of the country (Allen and Barnes, 1985; Koop and Tole, 1999; Nguyen Van and Azomahou, 2003)[5].

Like Bhattarai and Hammig (2001), we used the production volume of cereals as a measurement of agricultural productivity. The data were extracted from the World Bank Development Indicators (World Bank, 2022).

The literature review on the determinants of deforestation indicates that there is no consensus that would allow us to know which variables to include in the empirical model.[6] The identified factors that could have an impact on the rate of deforestation could be regrouped around three major elements of a demographic, economic and political nature (Duval and Wolff, 2009).

The empirical relationship between per capita gross domestic product (GDP) and deforestation has been discussed greatly over the past few years. In the literature, the debate is summarized into a discussion on the existence of the "environmental Kuznet's curve" (EKC). This curve indicates that at the macroeconomic level, environmental degradation increases at low-income levels and thereafter diminishes from a certain threshold of income. EKC was confirmed as an environmental index related to quality of air and quality of water (Selden and Song, 1994; Shafik, 1994; Grossman and Krueger, 1995). The results obtained for deforestation were contradictory. Studies by several authors have demonstrated a EKC linking per capita GDP to the deforestation rate (Cropper and Griffiths, 1994; Bhattarai and Hammig, 2001; Duval and Wolff, 2009; Combes et al., 2009). However, Shafik (1994) and Koop and Tole (1999) did not find any inverted U relationship between per capita GDP and deforestation. Nguyen Van and Azamahou (2003) even found a U-shape curve between per capita income and deforestation. The quasi-totality of these studies use per capita GDP as an indicator of economic growth. In order to verify the existence of an inverted U shape between economic growth and deforestation in Central Africa, we retained per capita GDP expressed in constant dollars and using 2015 as the year of reference, as the indicator of economic growth.

Various variables are used in empirical studies to measure the impact of demographic factors: the size of the total population, increase in the total population, the density of the population and the percentage share of the total rural population. Kaimowitz and Angelsen (1998) described the manner in which demographic pressure could affect the rate of deforestation. They demonstrated that theoretically, the population could affect the deforestation rate by increasing the number of families that use the forest to search for arable land and wood for domestic use of construction. In order to measure the impact of demographic factors, we retained the rate of population growth measured through the annual percentage increase of the total population (*cpop*) and the population density (*dpop*) measured as the number of people per hectare. These data were extracted from the *World Development Indicators*.

Various researchers have stated that the deforestation rate increases in countries where democracy is weak and political institutions are of poor quality. (Deacon, 1994; Didia, 1997; Bhattarai and Hammig, 2001). Indeed, the poor quality of institutions could lead to poor financial governance. In that case, there is a risk that investors may procure land at lower prices, which could easily lead to deforestation. In order to capture this variable, we chose the most commonly used democracy indicators (Freedom House and Polity IV) because of their historical coverage and also their widespread use in empirical studies. Freedom House has published an indicator of democracy since the 1970s (using expert opinions) bringing together measures of political rights, elections (the right to vote, free elections of representatives that have power over public policy) and civil rights (freedom of association, freedom of opinion, personal freedom without State intervention). We also constructed an indicator of democracy (Fhouse) from the two variables that focus on political rights and civil liberties. These two dimensions are measured on a scale going from 1 to 7, level 1 corresponding to a high quality of democracy and level 7 corresponding to a low quality. Like Bhattarai and Hammig (2001), we then calculated the sum of the two variables in order to obtain a sole indicator (going from 2–14).[7] The Polity IV democracy indicator (named Polity 2), measures constraints for the executive, competition and openness in the recruitment of the executive, the regulations and the competition in participating in political life. The scale ranges from -10 (highly autocratic) to 10 (highly democratic). The comparison of the respective content of the two indicators proves to be complex. But because both try to measure the level of democracy it would be interesting to compare the results of both assessments. The data are derived from the Penn World Table 4.0 and Polity IV.

Timber harvesting, which is a significant activity in the Central Africa, should appear among the explanatory variables. Unfortunately, data on the number of logging licences issued per year that would have served as proxies, are practically non-existent.

Descriptive Statistics

Table 1 gives descriptive statistics of the explanatory variables and the dependent variables. The average rate of deforestation of the sampled countries over the period studied (1990–2020), is 0.42%; the minimal average value for the rate of deforestation is recorded in Rwanda (-2.6%) and the maximum is in Burundi (4.48%). In relation to indicators of economic growth, the per capita GDP for the all the countries studied is a sum equivalent to US$3,492.81. Equatorial Guinea had the highest level of per capita GDP US$21,459.55 in 2016, which is certainly due to the export of raw materials, notably oil and gas. The Democratic Republic of Congo experienced the lowest level of per capita GDP ($82.66 in 2001). Furthermore, the volume of production of cereals is at 1132.731 kg per hectare. As pertains to demographic variables, population density was 95 people per hectare for the entire sample, and the rate of population growth was 3% per year for the sampled countries. Finally, the quality of institutions in the entire subregion is rated at 11.33 by Freedom House and -2.14 for Polity IV.

Table 1: Description of the sample

Variables	Observations	Average	Standard errors	Min	max
Rate of deforestation	279	0.004218	0.012344	-0.02597	0.047630
GDP (dollars)	279	3.492383	5.398455	0.8266	21.45955
Agricultural productivity	279	1132.731	376.7411	501	1987.52
Population density (per hectare)	279	95.386	152.496	4.778	492.396
Population growth (as a percentage)	279	3.0473	0.892724	-7.533	10.984
Freedom House	279	11.3292	1.89721	6	14
Polity2	279	-2.14312	3.87321	-8	6

Source: author from data derived from FAO, World Bank, the Penn World Table 4.0 and from Polity IV.

C) Unit root tests and cointegration

This sub-section covers the integration order of the variables used in the study.

Unit root tests

The existence of a relationship of cointegration (or long term) translates to the idea that a linear combination of non-stationary variables could be stationary. Unit root tests are a prerequisite for any analysis of a cointegration relationship.

The results of the verification of stationarity (table 2) clearly show that all the variables used are integrated to the order of zero (1(0)) and that they are stationary at level without transformation at first difference.

Table 2: Results of the panel unit root test

Variables	Im, Pesaran and Shin (IPS 2003)		Fisher chi-squared (Dickey-Fuller Augmentés (ADF))		I(.)
	Stat de test	P-value	Stat de test	P-value	
Rate of deforestation	-1.74	0.000	22.45	0.000	I(0)
GDP	-2.70	0.002	3.99	0.001	I(0)
Agricultural productivity	-1.22	0.003	64.22	0.000	I(0)
Population density	-4.33	0.000	8.76	0.000	I(0)
Population growth	-2.13	0.000	99.38	0.000	I(0)
Freedom House	-3.90	0.000	52.21	0.000	I(0)
Polity2	-4.59	0.000	37.54	0.000	I(0)

Note: H0: the series comprises a unit root.

Source: Estimations by the author.

Cointegration tests

Once the stationary order has been defined, the next step is to examine the cointegration tests of the model in order to determine whether there is a long-term relationship between the set of integrated variables. We carried out three cointegration tests: Kao (1999), Pedroni (2004) and Westerlund (2005) on all the panel data. All the tests have a common null hypothesis on absence of cointegration. In regard to the alternative hypothesis which permits heterogeneity, the Kao and Pedroni tests check whether the variables are cointegrated for all the panels. However, the Westerlund statistics examine the assumption that the variables are integrated in certain panels.

In Table 3, the results of the cointegration tests reject the null hypothesis of the absence of cointegration in a significant manner.

Table 3: Results of the cointegration tests

	Kao cointegration test	
	Stat of test	**P-value**
Modified Dickey–Fuller t	0.673	0.2343
Dickey–Fuller t	0.721	0.4510
Augmented Dickey–Fuller t	0.932	0.1737
Unadjusted modified Dickey–Fuller t	0.452	0.4329
	Pedroni cointegration test	
	Stat of test	P-value
Modified Phillips–Perron t	0.412	0.265
Phillips–Perron t	-0.539	0.486
Augmented Dickey–Fuller t	-0.867	0.136
	Westerlund cointegration test	
	Stat de test	P-value
Variance ratio	– 0.2427	0.3921

Note: Kao, Pedroni, Westerlund: H0 : absence of cointegration.

d) Econometric specification

The study sought to estimate the parameters of the following econometric specification:

$$DF_{it} = \alpha_0 + \beta PA_{it} + \gamma X_{it} + \varepsilon_{it} \quad (1)$$

with DF_{it} the rate of deforestation of country i over year t. PA is the agricultural productivity and X is the matrix of control variables comprised of per capita GDP and its quadratic terms of population density ($dpop$), population growth ($cpop$) and the institutional variable (FreeHouse or Polity2).

Whereby, the differences β are the parameters of interest to be estimated; the indexes i and t indicate the country under consideration and the year of observation respectively; and α_0 represents the constant and ε = the error term.

Contrary to the studies undertaken by Marchand (2012) that examined the effect of agricultural productivity on deforestation by examining technical efficiency based on microeconomic data from Brazil, our study adopted the use of panel data models. This is because our study focused on several periods and covered a number of countries. Like Koop and Tole (1999), we used the random and fixed effects models. The underlying assumption of the random effects model is that the explanatory factors are not correlated to terms specific to each country. It is, however, possible that there may be some characteristics that are specific to each country, which may not have been taken into account in the regression, that are correlated with the retained explanatory factors. In such a case, the appropriate method would be the fixed effects model. In the classical sense, we implemented the Breusch-Pagan (1980) and Hausman (1978) multiplier tests so as to verify the most appropriate specification for the data we used. In order to verify the robustness of the results, we referred to the years in which FAO carried out surveys (in intervals of five to 10 years). The six reference years we used are: 1990, 2000, 2005, 2010, 2015 and 2020.

Results of the estimations

The results are presented in Table 4. The Hauman test refutes the hypothesis of the absence of a correlationship between the random term ε_{it} and the explanatory variables of the model (P-value ≤5% regardless of the sample used[8]). The estimators of the component errors model are biased. Econometric literature also suggests the parameters estimated from the fixed effects models are more appropriate for this type of analysis because they take into account the historical and structural differences between countries (Greene, 1997).

Given the variances in size between the sampled countries, the fixed effects models are estimated through Feasible Generalized Least Squares (FGLS). Contrary to the Ordinary Least Squares (OLS) that gives equal weight to each observation, GLS corrects some aberrant values and measurement errors by giving less weight to their aberrant values. Econometric literature suggests that FGLS is equivalent to MLE estimations (Greene, 1997).

Whichever the model used, the results indicate the failure in the appearance of an environmental Kuznet's curve for deforestation in our model, thus agreeing with the conclusions in the studies undertaken by other researchers (Koop and Tole, 1999; Azomahou and Nguyen Van, 2007; Tanner and Johnson, 2017). However, contrary to a Kuznet's curve, the model only taking into account the years in which surveys were undertaken (model 2) shows that the relationship between the rate of deforestation and per capita income is in the U form. This result had already been arrived at by Nguyen Van and Azomahou (2003) using annual data from 85 developing countries over the period 1961 to 1994.

Furthermore, population growth only has a positive and significant effect on the rate of deforestation in model 2 (with a threshold of 5%) and is positive. This result could be explained by an increase in the demand for wood energy in tandem with population growth. However, the coefficient of population density is not significant statistically. Conversely, the results relative to the quality of institutions seem more robust, showing that the poor quality of institutions accelerates the rate of deforestation. This confirms the results arrived at in other studies (Deacon, 1994; Didia, 1997; Bhattarai and Hammig, 2001; Duval and Wolff, 2009).

Given that the level of financial governance remains mediocre in all the countries that are part of the Congo Basin, various investors purchase land at the lowest possible cost and thus expand their activities at a large scale while neglecting their social and environmental responsibilities. Governments should put in place solid policies in terms of future financial investments. Encouraging the involvement of communities through granting them access rights and strengthening their capacities to manage land could have a positive effect on the conservation of forests.

Table 4: Results of the estimations

Variables	**1**		**2**	
	All the years		**Years of the survey**	
Agricultural productivity	-0.103***	-0.112**	-0.234**	-0.347*
	(0.02)	(0.03)	(0.06)	(0.05)
GDP/1,000	0.014**	-0.08*	-0.345*	-0.385*
	(0.05)	(0.04)	(0.21)	(0.17)
$(GDP/1,000)^2$	-0.004	0.007	0.051*	0.054
	(0.00)	(0.00)	(0.01)	(0.01)
Population density	0.032	0.035	-0.043	0.035
	(0.00)	(0.00)	(0.01)	(0.01)
Population growth	0.008	0.012	0.031**	0.123**
	(0.08)	(0.08)	(0.15)	(0.14)

Freedom House	0.321		-0.248***	
	(0.06)		(0.05)	
Polity2		-0.164		-0.127**
		(0.04)		(0.04)
Adj.R2 (unweighted)	0.15	0.16	0.11	0.12
Number of observations	279		54	

Source: author using data from FAO, World Bank, Penn World Table 4.0 and Polity IV. *significant to 10%; ** significant to 5%; *** significant to 1%. The values in parentheses are standard deviations.

We now focus on the role of growth on agricultural productivity. Regardless of the model used, we found a negative and significant coefficient with a threshold of 5%. This result indicates that the process of deforestation is mitigated by an increase in value addition in the agriculture sector. This increase in agricultural productivity allows for attaining the given production goals in a smaller surface area. The result is contrary to that arrived at by Angelsen (1999). The author demonstrated theoretically how in an open economy with a model of free access where ownership rights are defined, such as is the case in the Amazon, an increase in productivity promotes the expansion of agriculture, and therefore deforestation. Our result could be explained by the fact that in Central Africa, agriculture is essentially a subsistence activity and commercial farming is not geared towards international markets, but more towards satisfying local and fixed demands. Thus, access to inputs and technologies that would allow for an increase in yields from agriculture reduces the demand for new arable land.

The coefficients associated with population growth and agricultural productivity show that two opposing forces are at play in the economic environment of Central Africa. An increase in agricultural productivity exerts pressure to lower the price of agricultural produce, whereas population growth exerts pressure to increase prices. If population growth becomes dominant and the prices experience a slight increase, the demand for more agricultural land could increase. It is also possible that the existing land could be cultivated more intensively through the use of fertilizer or by adopting modern farming techniques. In other words, the responses from farmers could lead to either an increase in the demand for agricultural land or an increase in production technologies. If productivity growth dominates over population growth (in other words if increase in supply is higher than that of demand), prices would then decline and the pressure on arable land would decrease.

In order to fight against deforestation, which could come as a result of population growth in Central Africa, the countries in the region should develop their agribusiness sector, which would then increase their agricultural productivity and support economic growth as well as structural transformation by freeing manpower from the agriculture sector to the benefit of the services and industrial sectors. This would only be possible if the States in the region improve governance and establish a regulatory and institutional framework that is favourable to investments in technology and in innovation so as to improve on land productivity, and in particular that of labour (improved seeds, new tools, fertilizers and control of water use).

5. Conclusion and suggestions for economic policy

In this paper, we have discussed the role of improvement in agricultural productivity on the process of deforestation in the Central Africa. Although it is now evident that the improvement of agricultural productivity has major consequences in terms of food security and human well-being, the possible consequences of deforestation still remain a subject of debate. Using data from nine COMIFAC countries over the period 1990–2020, we highlighted a few major results.

First, our results show that there was no evidence of the appearance of an environmental Kuznet's curve for deforestation. Second, we demonstrated that population growth has a negative influence of the conservation of forests in Central Africa. Furthermore, the rate of deforestation decreases with an increase in agricultural productivity. These results indicate that the increase in agricultural productivity is imperative in Central Africa because it not only satisfies the increase in demand for wood products due to an increase in population, but it also has a positive effect on the conservation of forests. However, with the exception of Cameroon, research and development (R&D) capacity in Central Africa has been destroyed over the past few decades (Megevand et al., 2013). Our results call for a stimulation of research based notably on subsistence crops that are most common to the region, such as cassava, banana plantain and yams.

Beyond our overall recommendations, to be more specific, governments in Central Africa should invest in the improvement of the productivity of the main cash crops. Thus, the governments of Chad and Central African Republic must improve the production of cotton. The Government of Cameroon must place more emphasis on the production of bananas, cocoa, coffee, cotton and rubber. The Government of Burundi should focus more keenly on coffee; Congo and Equatorial Guinea should focus on yams; the Democratic Republic of Congo on maize; Rwanda on potatoes; and Gabon on bananas and yams.

Finally, the poor quality of institutions tends to increase the rate of deforestation. Given that financial governance remains mediocre in all the Central African countries, some investors buy land at low prices and could expand their activities to large areas while neglecting their social responsibilities towards forest conservation. Governments must put in place firm policies related to matters of future large-scale investments, insisting especially that the supply of land for agriculture be oriented towards non-forested areas and abandoned plantations.

In conclusion, this study had a few limitations. First, although this study focused on countries with similar economic structures, the number of sampled countries was relatively low (nine countries), which could cast doubt on our results. Also, our study focused on the period from 1990 to 2020, which does not allow us to take long-term elements into account in our analysis. Finally, the aggregated approach used in this study could not allow us to further explore the underlying mechanisms of the relationship. It is therefore very difficult to provide recommendations for countries based on macroeconomic data.

Notes

1 Deforestation is the long-term or permanent conversion of forest land to other uses not related to forestry (Megevand et al., 2013). The United Nations Framework Convention on Climate Change (UNFCCC) defines deforestation as “the direct human-induced conversion of forest land to other land use”.

2 Socapalm (palm oil plantation) and Hevecam (rubber), in the case of Cameroon, for example.

3 In this document and in conformity with the definition given by Miranda et al. (2010), the term “wood-energy” refers to both firewood and charcoal. Firewood is harvested for immediate use, without any form of conversion. Charcoal is produced from wood, through the process of pyrolysis (slow heating without oxygen).

4. As stated previously, Säo Tomé and Principe is excluded due to lack of data.

5 This definition nevertheless faces certain difficulties. For example, the data are sometimes subjective because they are furnished to FAO by governments. Furthermore, when the official or quasi-official data are not available, the estimations are of poor quality (see, for example, Allen and Barnes, 1985; Koop and Tole, 1999).

6 For a summary of the empirical literature on deforestation, see Angelsen and Kaimowitz (2001) and Barbier (2004).

7 The separate use of these two indicators could create a problem of collinearity. Indeed, a high level of political rights in a country is often accompanied by low levels of civil liberties (Azomahou and Nguyen Van, 2007).

8 The results of the test are available from the author.

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