AFRICAN GOVERNANCE AND DEVELOPMENT INSTITUTE

A G D I Working Paper

WP/11/017

Population Growth and Forest Sustainability in Africa

Simplice A. Asongu
African Governance and Development Institute,
P.O. Box 18 SOA/ 1365 Yaoundé, Cameroon.
E-mail: asongusimplice@yahoo.com

Brian A. Jingwa
Center for Statistics, Hasselt University
Campus Diepenbeek
Agoralaan – Gebouw D
3590 Diepenbeek, Belgium

AGDI Working Paper

Research Department

Population Growth and Forest Sustainability in Africa

Simplice A. Asongu[1] & Brian A. Jingwa

December 2011

Abstract

Recent distressing trends in climate change, population explosion and deforestation inspired this paper, which completes existing literature by providing empirical justification to hypothetical initiatives on the impact of population growth on forest sustainability in Africa. Using three instruments of forest exploitation, the study shows how rural, agricultural and national population growths affect forest-area and agricultural-land. In this particular study the findings indicate that instruments of forest exploitation do not explain changes in forest-area and agricultural-land beyond population growth mechanisms. Hence, population growth channels are a driving force by which forest-area and agricultural-land are depleted and expanded respectively. As a policy implication in the process of deforestation, a balanced approach is needed to take account of the interests of both; a green economy promoting sustainable development and the growing population needs.

JEL Classification: J10; L73; N50; O13; Q23
Keywords: Demography; Forestry; Agriculture; Environment; Africa

[1] Simplice A. Asongu is Lead economist in the Research Department of the AGDI (asongus@afridev.org).

1. Introduction

Since the dawn of human history, the destiny of humans and trees has remained tightly bound. Forests have exerted a tremendous influence on the livelihood and economic development of many societies. One of the most important concerns of this age is the question of population growth and whether the earth's resources can sustain this rapid expansion of population in most parts of the world. This has reignited an extensive debate worldwide on the relationship between population growth, depletion of resources and environmental sustainability. The world population quadrupled from 1.6 billion to 6.1 billion during the period 1900 to 2000 (United Nations, 2001). According to the United Nation's estimates, the world's population was 4 billion in 1975, 5 billion in 1987, 6 billion in 1999 and just recently in 2011 the world counted its 7 billionth person. In the same progressive vein, the projected estimates for 2027 and 2046 are 8 and 9 billion respectively (United Nations, 2010). However, this rapid population growth and development has occurred unevenly throughout the world, with African countries continuing to experience higher rates with the consequences of increasing unsustainable utilization of the forest resources.

The rapid growth in human population has often been identified as one of the main factors of environmental degradation. Population and environment are closely connected in a complex and dynamic manner. This relationship depends on a number of socioeconomic, cultural, political and developmental aspects. Growth in population affects the environment, principally through changes in land-use and industrial activity. In this context the concern of how rapid population growth in the African continent is affecting forest sustainability is very relevant.

Being the heart and lungs of the world, forests act as barometers of the economy and the environment (Kumar, 2001). According to current estimates, the African forest concentrated in the Congo Basin represents a significant part of World forest reserves and the world's second largest rainforest. The Global Forest Resources Assessment (2005) of the Food and Agricultural Organization (FAO) estimates the area of forests is largest in the Russian federation (809 million hectares), followed by Brazil (478 million hectares), Canada (310 million hectares), the United States (303 million hectares), China (197 million hectares), Australia (164 million hectares) and the Democratic Republic of Congo (134 million hectares). With increasing population growth in less and least developed regions, there has been growing concern about the sustainability of forests (FAO, 2005).

Given rising temperatures, climate change, the alarming increase of the African population and the importance of sustainably managing Africa's main limited forest resources, this paper seeks to assess how the increase in population in countries of the Congo Basin affects forest resources. Findings could be relevant to global policy makers, governments and local policy institutions in their quest to project the loss in forest-area based on demographic changes, as well as device measures aimed to sustain forest resources. The emergence of Africa in the world as one of the continents with the highest demographic growth rates with the population projected to double by 2036 and a projected representation of 20% of the world by 2050 (UN Worlds Population Prospects, 2009) presents a paramount geo-economic concern to policy-makers, researchers and social scientists (Asongu, 2011ab).

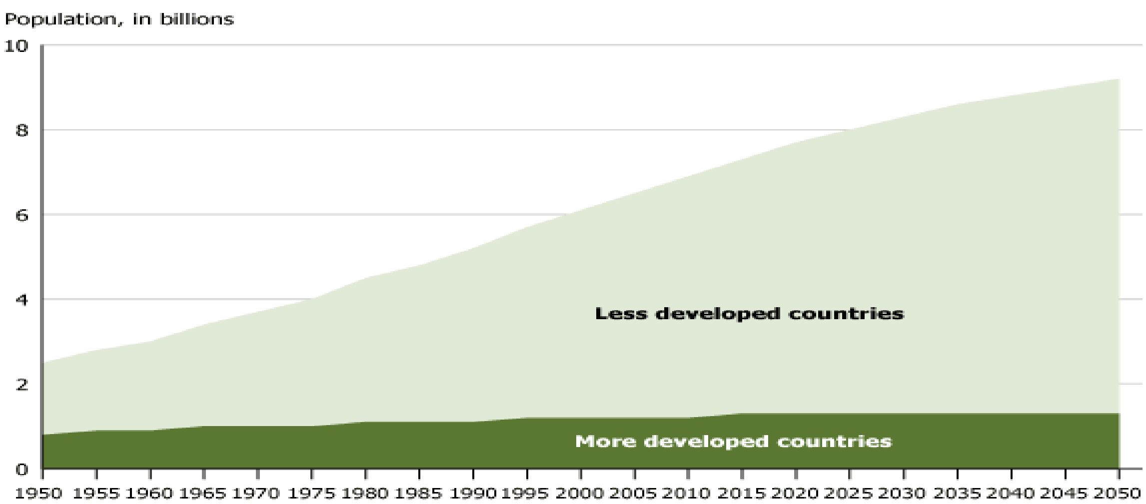
The rest of the paper is organized in the following manner; the authors complete the introductory part by presenting the story on population growth and forest degradation in pictures. Section 2 reviews existing literature. Data is presented and the methodology outlined in Section

3. Empirical analysis and discussion are covered in Section 4, followed by a conclusion in Section 5.

1.1 Population growth trends

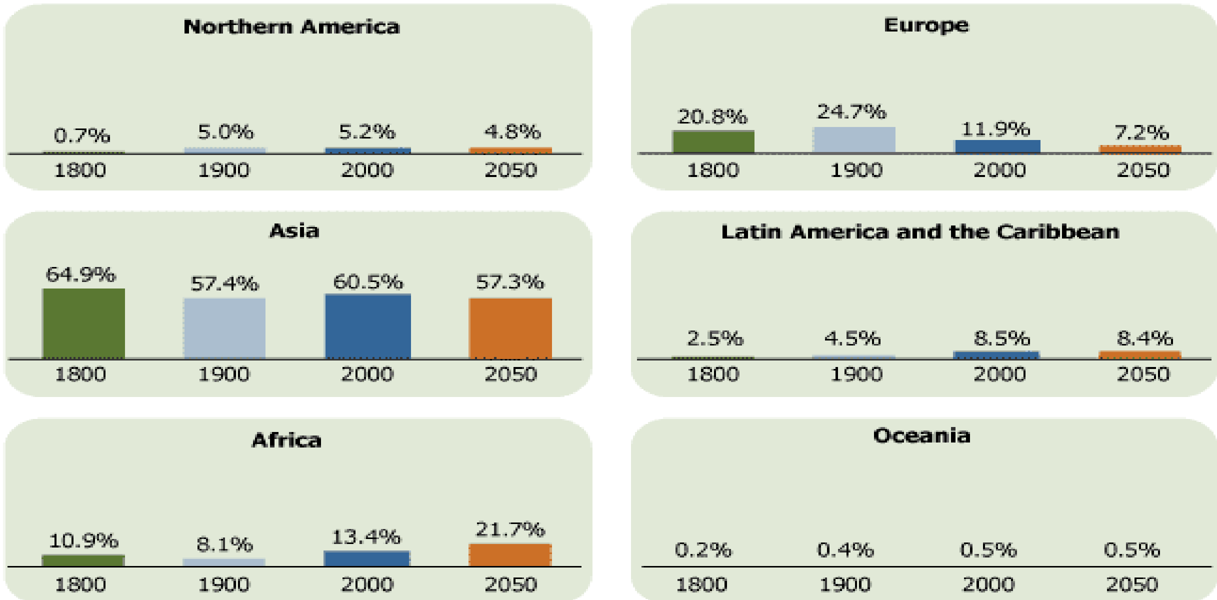
For over five decades, the world population has multiplied more rapidly than ever before and more rapidly than it is projected to grow in the future. For instance in 1950 the world had 2.5 billion people, a population which reached 6.5 billion in 2005 and projected to rise to more than 9 billion by 2050 (see Figure 1 below). To fully come to grasp the importance of Africa in the growth dynamics, it is worthwhile to present the population trends by region (see Figure 2)

Figure 1: World population growth trends



Source: United Nations Population Division, *World Population Prospects, the 2008 Revision*.

Figure 2: World population distribution by region: 1980-2050



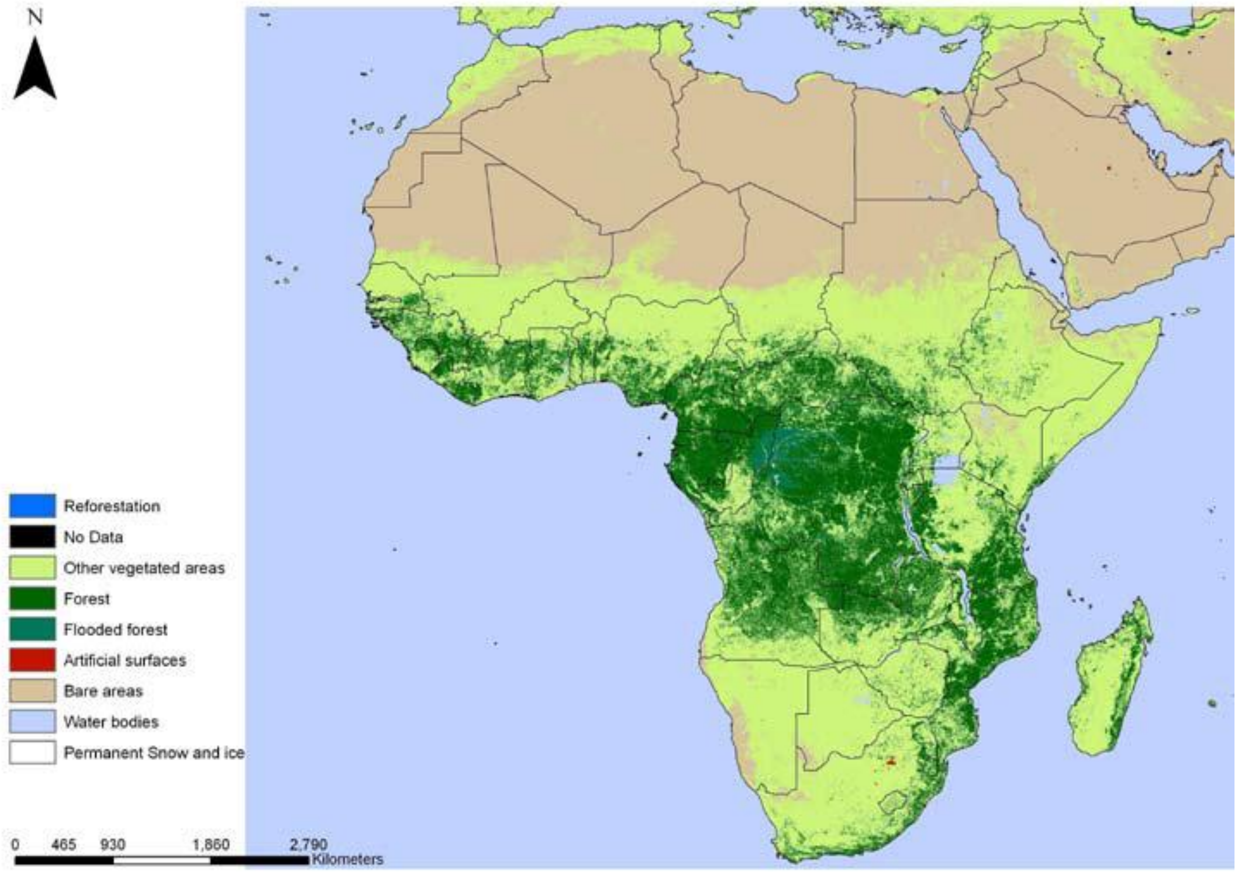
Source: United Nations Population Division, Briefing Packet, 1998 Revision of World Population Prospects; and *World Population Prospects, the 2006 Revision.*

As illustrated in Figure 2, in 1800, the great majority of the world's population (about 85 percent) resided in Asia and Europe with 65% in Asia. By 1900, Europe's share of the world population almost hit 25%, magnified by the population increase that accompanied the Industrial Revolution. Some of this growth spilled-over to the American continent, increasing their share of the world total. The world population also accelerated in the aftermath of World War II, when the population of less developed countries began to increase dramatically. After centuries of extremely slow growth, the human population indeed grew unprecedentedly and explosively; a billion people were added between 1960 and 1975; another billion between 1975 and 1987. Throughout the 20th century each additional billion has been attained in a relatively shorter time interval. At the dawn of the 20th century, human population stood at 1.6 billion and at the turn of the century, it had increased to 6.1 billion. Africa has played a substantial role in this growth and the overall effects on the environment and sustainable forest-use will continue to change the world landscape long after.

1.2 African forest and woodland

From Figure 3, it could be observed that in the heart of Africa lies the world's second largest tropical forest: the Congo Basin. It is a mosaic of rivers, forests, swamps, savannas and flooded forests. This basin, which covers 500 million acres of land, makes up one of the most important wild areas left on earth with very rich biodiversity. It spans across six countries, namely: Cameroon, Central African Republic, Democratic Republic of Congo, Republic of Congo, Equatorial Guinea and Gabon. The rainforest there-in provides many benefits including: socio-economic value to local communities, regional climate regulation and water flow, water quality protection, a home for most of Africa's remaining forest elephants and great apes, many minerals used to create consumer electronics, gold and diamonds etc. One of the major economic activities of the Congo basin is timber production. The FAO (2001) estimated that the total timber production in six countries of the Congo Basin increased by 47% between 1993 and 2001. Ndoye and Tieguhong (2004) suggest that 61% of these timber species extracted from forests in Cameroon have important non-timber values that contribute to the livelihoods of local communities. This attests to the importance of population growth in the sustainability of forest resources; which is the object of this paper.

Figure 3: Forest and woodland cover in Africa



Source: ESA / ESA Glob Cover Project, led by MEDIAS-France

2. Existing Literature

2.1 Theoretical highlights

From Adam Smith and Karl Marx to present day political and neoclassical economists, there is consistent emphasis on the roles of markets and production forces in shaping and adjusting economic relations of production and social institutions. Both Smith and Marx asserted that capitalist economic expansion through trade and investment would inevitably transform pre-capitalist social productive relations. Thus according to them, depletion of forest-areas is due to market pressures on forest resources. By the same token, some theorists link demographic changes to shifts in relative prices and suggest that the two may move in tandem and there-by affect the development of market patterns of resources use (North & Thomas, 1973).

Cropper and Griffins (1994) re-characterized Malthus' theory of population growth based on environmental quality measured by the absence of air and water pollution or the stock of forests. In many developed and less developed regions, the effect of population growth on deforestation and environmental degradation has been buffered to a large extend, because the higher GDPs, growing economies and sufficient awareness in these regions enable the development and use of clean energy. On the contrary, population growth in the least developed countries puts a strain on resources and consequently increases pressure on the forests.

2.2 Strands in the literature

2.2.1 The overpopulation thesis and market pressure on resources

In the literature of deforestation, soil degradation, loss of biodiversity, food scarcity, underdevelopment and global warming, the concern with population pressure is ubiquitous. Scholars mostly focus on overpopulation when it comes to resource use (Wilson, 1992; Avise, 1994; Nimai & Debnarayan, 2001; Cochet, 2004). Two themes in the literature about overpopulation merit a critical view: the concern with population growth in the developing world and issues with activities of the numerous small producers that exploit land. The overpopulation thesis maybe summarized in the following statements. "*Exploding human populations are degrading the environment at an accelerating rate, especially in tropical countries*" (Wilson,1988), "*Many environmental problems including elimination of tropical rain forest and reductions in biodiversity are mostly clearly evident in the Third World*", (Bilsborrow & DeLargy, 1990), "*the most important thing the Chinese government can do to break the vicious circle of overpopulation and deforestation is to promote the practice of family planning and* *strictly control population growth*" (Li,1990), "*one view is that macro level socio-economic factors, especially demographic pressures, chiefly affect forest use and that population pressures have contributed to environment degradation*" (Nimai & Debnarayan, 2001).

Just as a vast literature asserts the importance of overpopulation in determining resource depletion, a powerful intellectual tradition ranging from Adam Smith and Karl Marx to present day political and neoclassical economists, emphasizes the roles of markets and production forces in shaping and adjusting economic relations of production and social institutions. Both Smith and Marx were confident that capitalist economic expansion via trade and investment, would inevitably transform pre-capitalist social productive relations. Some theorists link demographic changes to shifts in relative prices and suggest that the two may move in tandem and there-by affect the development of market patterns of resources use (North & Thomas, 1973). With respect to these theorists, lower prices that prevail in integrated markets, the constant revolutionizing of production and prices that come about as a result of greater specialization create an ever increasing demand and in-turn ever greater production. Thus, the integration of local resource systems into larger markets while providing for greater economies of scale also exposes them to demand from a larger system and hence creates greater harvesting and deteriorating pressures on a finite local resource system.

Within this context, the forest in the Congo Basin has become exposed to market pressures and thus local users (predominantly the rural and agricultural population) increase harvesting levels because, in addition to subsistence needs, they can further harvest cash crops for export purposes upon clearing the forest for cultivation. Subsistence agriculture and market pressures push users to extract forest products at increasing rates; rendering environmental degradation inevitable. Given the high rate of corruption in the countries making-up the Congo Basin, noncompliance with resources management rules could go unsanctioned.

2.2.2 The importance of local institutional arrangements

Literature pointing out the role of institutions, culture and technology in shaping the manner in which human action affects resource management is depicted here. While many resource management theorists and demographers assert that overpopulation and market pressure lead to overharvesting and the decrease in local resource management systems, an equally vehement group of scholars champion the positive role of local resource managers (Chetri & Pandey, 1992; McKean, 1992).

"Any theory of population and resources that overlooks cultural phenomena is likely to be deficient. Yet in much of the literature this is exactly what is done" (Davis, 1991). This implies most works often tend to ignore the manner in which the impact of population pressures and market forces on forests is mediated by local institutional arrangements. Institutions are human-devised constraints that affect human interaction (North, 1990). Therefore they do not only act as constraints but they also soften, mediate, structure, attenuate, mould, accentuate and create impacts that affect changes in the level of consumption. Scarcity in certain products could also result from modes of production and consumption.

Agrawal (1995) suggests that as market and demographic pressures rise, the condition of the resources deteriorates. Conversely, technological change increases efficiency and thereby reduces pressures on resources. At the same time greater efficiency resulting from technological improvements leads to lower prices, greater demand and thus exerts an indirect negative effect on the resource's condition. In the same vein scarcity can arise from the inability to reproduce a given mode of production that addresses consumption demands and thus "*society runs head log into 'nature' or natural constraints*" (Collins, 1992).

2.3 The Congo Basin

As presented in Table 1, the Congo Basin includes the second largest and most important tropical forest region in the world, with a coverage of over 227.6 (180.5) million hectares (FAO, 2001 and CBFP, 2006) respectively. These forests represent about 60% of the total land area of six countries of the central African region. However, the forests of this region are under increasing pressure, decreasing at an average annual rate of 0.35 % (FAO, 2001) as a result of population growth (which averages 2.3%), and other factors.

Table 1: Population and forestry in the Congo Basin

Countries	Area(Km²)	Population	Growth(%)	Forest (Million of H)	PF (Hectare)	PF(% of Total)
Cameroon	475 440	17 340 702	2.47	19.6	12	61
Central .African Republic	622 980	4 303 356	1.53	6.3	3.5	56
Congo Republic	342 000	3 702 314	2.6	22.3	13	58
D. R. of Congo	2 345 410	62 660 551	3.07	108.3	98	83
Equatorial Guinea	28 051	540 109	2.05	1.5	1.5	79
Gabon	267 667	1 424 906	2.13	22.1	17	77
Total	4 081 548	89 971 938	2.30*	180.5	137	76
Source: CIA,2007				Source: CBFP, 2006		

Km²: Kilometers square. D.R: Democratic Republic. PF: Production Forest. CIA: Central Intelligence Agency. CBFP: Congo Basin Forest Partnership.*: Average growth rate.

Lying on the equator, the Congo Basin harbours one of the richest concentrations of terrestrial biodiversity in the world. It is known to home 10 000 species of plant of which 80% are academic. The region also supports the world's largest assemblage of tropical forest vertebrates which include 23 threatened species, such as western and eastern gorillas, forest elephants, bonobos (pygmy chimpanzees) and chimpanzees (WWF, 2002). The Congo River in the Basin is the world's second richest river system for fish (700 species) and is distinguished by exceptional levels of mollusks and fish. The Congo Basin forest also provides valuable global ecological services by absorbing and storing carbon dioxide, thus helping to slow the rate of global climate change.

To the best of knowledge, literature assessing the impact of human activity on deforestation in the Congo Basin has been based on theoretical initiatives without empirical validity or justification (Ndoye, 1995; CARPE, 2001; Ndoye, 2003; Ndoye & Tieguhong, 2004). Thus, this paper adds to the literature by providing an empirical investigation of how demographic changes affect forest sustainability.

3. Data and Methodology

3.1 Data

A sample of six countries making up the Congo Basin in Africa (Central African Republic, Cameroon, Congo Republic, Gabon, Equatorial Guinea and Congo Democratic Republic) is examined with data from African Development Indicators (ADI) of the World Bank (WB). Due to data constraints and in a bid to obtain more updated policy implications the sample period is restricted to 1990-2007. A synthesis of selected variables is covered in Appendix 1.

3.1.1 Dependent variables

The paper uses "*forest-area in percentage of total land-area"* and *"agricultural land in Km²"* as endogenous variables to capture the effects on deforestation.

3.1.2 Endogenous independent variables

Endogenous independent variables are "*rural population growth rate*" and "*agricultural population*". The choice of these variables is based on the reality that their activities are predominantly forest related. In other words they depend on the forests in one way or the other for a livelihood.

3.1.3 Instrumental variables

Instrumental variables include: "*forest product exports*", "*total agricultural exports*" and "*the ratio of rural population to total population*". These variables are moment conditions of forest exploitation; implying the instruments explain forest exploitation in one way or the other.

3.1.4 Control variables (first-stage regressions)

"*GDP growth*", "*GDP per capita growth*", "*agricultural GDP growth*" and "*agricultural GDP per capita growth*" rates constitute control variables. Therefore we control both for national and agricultural growths at overall and household levels.

3.1.5 Control variables (second-stage regressions)

The choice of an endogenous variable of control at the second-stage of the IV process is very crucial for goodness of fit and model specification. This control variable must be endogenous (explainable) to (by) the moment conditions (instruments). Owing to issues of multicolinearity and limited degrees of freedom in moment conditions for the OIR test, the paper adopts "*population growth rate*" at national level as the endogenous control variable at the second-stage of the IV procedure.

3.1.6 Descriptive statistics and correlation analysis

Descriptive statistics and correlation analysis are represented in Appendix 1 and Appendix 2 respectively. Firstly, from the descriptive statistics, it could be inferred that the variables have distributions that are comparable if used in an empirical model.

With regard to correlation analysis, it aims at two main objectives; On the one hand, it guides the analysis to avoid issues related to multicolinearity and overparametization. On the other hand, it provides the work with a foresight on possible links between variables of interest (forest measurements) and other variables (endogenous independent and control variables).

3.2 Methodology

3.2.1 Endogeneity

Although population growth affects forest exploitation, there is the imperative of recognizing the reverse effect as well. The location and nature of forest and accompanying plants, animals and birds there-in also influence the character and size of the population that exploits it. For instance forest settlement will be more likely in one (forest) with many rivers and streams, than in one where water sources are not abundant. Failure to take account of this reverse causality could seriously lead to bias in estimated coefficients because the population variables of the paper are correlated with the noise (error) terms in the equation of interest.

3.2.2 Estimation techniques

In accordance with Beck et al. (2003) Instrumental Variables (IV) estimation technique is employed. As pointed-out earlier, the analysis requires an estimation technique that takes account of endogeneity. The IV estimator can avoid the bias that Ordinary Least Square (OLS) estimates suffer-from (absence of consistency) when independent variables in the regression are correlated with the error term in the main equation. Another important aspect worth pointing-out is the close relation between exports (from forest and agriculture) and deforestation; which provides another justification for the use of "*forest exports"* and *"total agricultural exports*" as instruments. Thus from another dimension the IV model investigates how forest (agricultural) exports affect forest areas through population growth dynamics. In line with Asongu (2011cd) IV process involves the following steps:

-justification of the use of an IV over an OLS estimation technique via the Hausman-test for endogeneity;

-showing that instrumental variables (forest exports) are exogenous to the endogenous components of explaining variables (population growth), conditional on other covariates (control variables);

-verifying if the instruments are valid and not correlated with the error-term of the main equation through an Over-identifying Restrictions (OIR) test.

Thus our IV methodology will include the following models:

First-stage regression:

$$Population\,Channel_{it} = \gamma_0 + \gamma_1 (FPExp)_{it} + \gamma_2 (TAExp)_{it} + \gamma_3 (RpTp)_{it} + \alpha_i X_{it} + \upsilon \quad (1)$$

Second-stage regression:

$$Forest_{it} = \gamma_0 + \gamma_1 (Population\,Channel)_{it} + \beta_i X_{it} + \mu \quad (2)$$

In the two equations, *X* is a set of exogenous control variables. For the first and second equations, *v* and *u*, respectively represent the error terms. Instrumental variables are *"forest product exports"* (FPExp), *"total agricultural exports"* (TAExp), and *"the ratio rural population to total population"* (RpTp).

3.2.3 Robustness of results

Robustness of our results will be assessed in the following ways. (1) Usage of alternative IV estimation techniques. These include, the Two-Stage Least Squares (TSLS), Limited Information Maximum Likelihood (LIML), Two-Step Generalized Methods of Moments (GMM-2) and Iterated Generalized Methods of Moments (GMM-Ite). (2) Rural and agricultural population dynamics are controlled for at the second-stage of the IV approach with national population growth. (3) Deforestation from both, the changing percentages of forest- land and variations in agricultural-land, is assessed. This third robustness application is premised on the fact that deforested land is predominantly used for agricultural purposes.

4. Empirical Analysis

This section presents results from cross-country regressions to assess the importance of forest (agricultural) exports or moment conditions in explaining cross-country variances in forest –area (agricultural-land), the ability of moment condition (instruments) to explain cross-country differences in the endogenous explaining variables or population growth (rural, agricultural and national) and the ability of the exogenous components of population growth dynamics to account for cross-country differences in forest-area (agricultural-land).

4.1 Forest sustainability and moment conditions

In Table 2, forest-area and agricultural-land on moment conditions (instruments or forest exploitation variables) is regressed. The results indicate that distinguishing countries in the Congo Basin by moment conditions of forest exploitation helps explain cross-country differences in forest-area and agricultural-land. Almost all moment conditions and control variables are significant with the right signs. It follows that: (1) agricultural exports and rural population growth related activities decrease forest-area and increase agricultural-land; (2) as countries (agricultural population) and citizens (per capita agricultural household income) grow wealthier, they exert a negative impact on forest-area and agricultural-land. In order words, wealth increases forest exploitation but decreases the percentage of land allocated to agriculture. This is evident as wealth (at national and agricultural levels) comes with rural exodus and correspondingly less population to engage in agricultural activities.

Table 2: Forest, agricultural land and moment conditions

		Forest Area (% of Land)			Agricultural Land (Km²)		
Instruments or Moment Conditions (Forest Exploitation)	Constant	-4.482 (-0.178)	**142.45***** **(10.03)**	**84.792**** **(2.422)**	**3.674***** **(5.756)**	**3.240***** **(2.826)**	**4.565***** **(4.726)**
	Forest Product Ex.	**22.248***** **(7.518)**	---	**8.469*** **(1.797)**	**-0.166**** **(-2.213)**	0.164 (1.287)	**-0.321**** **(-2.471)**
	Total Agricultural Ex.	**-14.856***** **(-7.096)**	**-6.779***** **(-3.556)**	**-9.372***** **(-3.956)**	**0.341***** **(6.399)**	---	**0.406***** **(6.221)**
	Rural Pop./ Total Pop.	---	**-0.628***** **(-9.071)**	**-0.449***** **(-3.728)**	---	**0.007**** **(2.321)**	-0.005 (-1.565)
Control Variables	GDPg	**-0.334**** **(-2.266)**	---	---	**-0.021***** **(-5.770)**	**-0.030***** **(-7.098)**	---
	GDPpcg	---	-0.133 (-0.973)	-0.212 (-1.498)	---	---	**-0.020***** **(-5.297)**
	AGDPg(agricultural)	**-0.890**** **(-2.340)**	---	---	**-0.026***** **(-2.689)**	**-0.025**** **(-2.100)**	---
	AGDPpcg(agricultural)	---	**-0.693**** **(-1.998)**	**-0.881**** **(-2.464)**	---	---	**-0.026***** **(-2.676)**
Adjusted R²		0.522	0.604	0.616	0.608	0.433	0.630
Fisher		**22.330*****	**30.837*****	**26.058*****	**31.346*****	**15.926*****	**27.635*****
Observations		79	79	79	79	79	79

GDP: Gross Domestic Product. GDPg: GDP Growth Rate. GDPpcg: GDP Per Capita Growth Rate. AGDPg: Agricultural GDP Growth Rate. AGDPpcg: Agricultural GDP Growth Rate. Pop: Population. Ex: Exports. Km²: Kilometer Square. *, **, ***: significance levels of 10%, 5% and 1% respectively.

4.2 Population growth and instruments

Table 3 assesses whether moment conditions of forest exploitation explain population growth at rural, agricultural and national levels. While rural and agricultural population growth dynamics represent our main endogenous variables (forest exploitation depend on their activities), the national population growth rate is the control endogenous variable. The choice in this control variable is crucial because, prior to usage at the second-stage of the IV approach, it must be empirically endogenous (explained) to (by) moment conditions.

Table 3: First-stage regressions

		Endogenous Explaining Variables (EEV)						Control EEV	
		Rural Population growth			Agricultural Population			Population growth rate	
	Constant	**17.700*** **	**-2.004*** **	-1.226	**5.640*** **	**1.673*** **	**2.263** **	**3.563*** **	2.389
		(8.551)	**(-3.124)**	(-0.776)	**(7.791)**	**(3.860)**	**(2.085)**	**(5.857)**	(1.528)
Instruments or	Forest Product Ex.	**-2.943*** **	---	-0.070	**-0.673*** **	---	---	--	0.175
Moment		**(-12.05)**		(-0.339)	**(-7.550)**				(0.815)
Conditions	Total Agricultural Ex.	**0.877*** **	**-0.207** **	**-0.239** **	**0.821*** **	**0.493*** **	**0.520*** **	**-0.209** **	**-0.266** **
(Forest		**(5.079)**	**(-2.410)**	**(-2.423)**	**(13.04)**	**(8.469)**	**(7.001)**	**(-2.566)**	**(-2.473)**
Exploitation)	Rural Pop./ Total Pop.	---	**0.089*** **	**0.087*** **	---	**0.022*** **	**0.021*** **	**0.011*** **	**0.015*** **
			(28.53)	**(16.35)**		**(10.82)**	**(5.529)**	**(3.765)**	**(2.782)**
	GDPg	**0.041*** **	---	---	**-0.009*** **	**-0.015*** **	**-0.014*** **	---	---
		(3.394)			**(-2.863)**	**(-3.846)**	**(-3.440)**		
	GDPpcg	---	**0.010***	---	---	---	---	0.001	-0.0003
Control			**(1.781)**					(0.237)	(-0.059)
Variables	AGDPg(agricultural)	**0.092*** **	---	**0.041** **	---	**-0.028*** **	**-0.027** **	---	---
		(2.947)		**(2.552)**		**(-2.802)**	**(-2.471)**		
	AGDPpcg(agricultural)	---	**0.027***	---	---	---	---	---	---
			(1.738)						
	Adjusted R^2	0.654	0.914	0.913	0.692	0.794	0.792	0.135	0.132
	Fisher	**37.997*** **	**209.57*** **	**206.99*** **	**81.217*** **	**76.169*** **	**60.472*** **	**6.570*** **	**5.077*** **
	Observations	79	79	79	108	79	79	108	108

GDP: Gross Domestic Product. GDPg: GDP Growth Rate. GDPpcg: GDP Per Capita Growth Rate. AGDPg: Agricultural GDP Growth Rate. AGDPpcg: Agricultural GDP Growth Rate. Pop: Population. Ex: Exports. Km²: Kilometer Square. *, **, ***: significance levels of 10%, 5% and 1% respectively.

It is worth noting that Table 3 captures the first-step of the IV approach where-in, the instruments must be exogenous to the endogenous components of the population channels, conditional on other covariates (control variables). We also investigate whether the moment conditions taken together explain the endogenous components of the independent variables. Clearly, the moment conditions help in explaining population growth dynamics. The signs of estimated control variables are broadly consistent with the population growth nexus. That is, wealth (at national and per capita levels) comes with increase in population growth through higher living standards, life expectancy and low infant mortality. In the same vein the percentage of population relying on agriculture for subsistence decreases with improvements in national and household wealth.

The Fisher-test of whether the forest exploitation moment conditions taken together significantly explain population growth dynamics is also reported. Clearly, the instruments explain demographic changes at national, rural and agricultural levels as the F-test for the joint significant of the moment conditions is significant at the 1% level is all regressions.

4.3 Forest sustainability and population growth

Table 4 addresses two main concerns: (1) the issue of whether the exogenous components of population channels explain changes in forest-area and agricultural-land, conditional on moment conditions of forest exploitation and; (2) whether moment conditions (instruments) of forest exploitation affect changes in forest-area and agricultural-land beyond population channels. To make these assessments we use the IV regressions with forest exploitation instrumental variables (moment conditions). Therefore we integrate the Equation (2) into the first-stage regressions: Equation (1).

Table 4: Instrumental Variable regressions

Panel A: With Rural Population growth rate as main endogenous regressor								
	Forest Area (% of Land)				**Agricultural Land (Km²)**			
	TSLS	LIML	GMM(2)	GMM(Ite)	TSLS	LIML	GMM(2)	GMM(Ite)
Constant	-75.637	-77.162	**-74.66***	**-74.75***	**12.32****	**12.548*****	**12.100*****	**12.064*****
	(-1.419)	(-1.421)	**(-1.694)**	**(-1.695)**	**(3.789)**	**(3.696)**	**(4.740)**	**(4.749)**
Rural Population growth rate	**-15.32*****	**-15.41*****	**-15.24*****	**-15.24*****	**0.375***	**0.388***	**0.374***	**0.373***
	(-4.177)	**(-4.134)**	**(-4.096)**	**(-4.094)**	**(1.677)**	**(1.670)**	**(1.687)**	**(1.689)**
Population growth rate	**59.16*****	**59.79*****	**58.68*****	**58.72*****	**-3.090****	**-3.181****	**-3.003*****	**-2.988*****
	(2.706)	**(2.686)**	**(3.136)**	**(3.136)**	**(-2.317)**	**(-2.285)**	**(-2.772)**	**(-2.771)**
Hausman test	**81.623*****	---	---	---	**65.057*****	---	---	---
GMM Q-Criterion	---	---	0.0011	0.0011	---	---	0.0031	0.0034
OIR (Sargan/LR /Hansen) test	**0.072**	**0.0718**	**0.124**	**0.123**	**0.169**	**0.165**	**0.341**	**0.373**
P-value	**[0.787]**	**[0.788]**	**[0.724]**	**[0.725]**	**[0.680]**	**[0.684]**	**[0.559]**	**[0.541]**
Cragg-Donald	1.794	---	---	---	1.794	---	---	---
Adjusted R²	0.382	---	---	---	0.037	---	---	---
F-Statistics	**10.293*****	---	---	---	**2.884***	---	---	---
Observations	108	108	108	108	108	108	108	108
Instruments(Moments)	Constant; Forest product exports; Total Agricultural exports; Rural population on Total population							

Panel B: With Agricultural Population as main endogenous regressor								
	Forest Area (% of Land)				**Agricultural Land (Km²)**			
	TSLS	LIML	GMM(2)	GMM(Ite)	TSLS	LIML	GMM(2)	GMM(Ite)
Constant	**228.65*****	**228.82*****	**229.12*****	**229.13*****	**4.896*****	**5.106*****	**4.719*****	**4.666*****
	(7.200)	**(7.194)**	**(7.568)**	**(7.569)**	**(5.159)**	**(5.005)**	**(5.379)**	**(5.606)**
Agricultural Population	**-18.08*****	**-18.09*****	**-18.23*****	**-18.23*****	**0.439*****	**0.435*****	**0.420*****	**0.406*****
	(-5.329)	**(-5.324)**	**(-5.947)**	**(-5.948)**	**(4.331)**	**(4.061)**	**(4.460)**	**(4.538)**
Population growth rate	**-20.69****	**-20.74****	**-20.54*****	**-20.54*****	**-1.133*****	**-1.205*****	**-1.014*****	**-0.956*****
	(-2.382)	**(-2.383)**	**(-3.158)**	**(-3.158)**	**(-4.367)**	**(-4.258)**	**(-5.095)**	**(-5.034)**
Hausman test	**305.72*****	---	---	---	**248.36*****	---	---	---
GMM Q-Criterion	---	---	0.0004	0.0004	---	---	0.0277	0.0312
OIR(Sargan/LR /Hansen) test	**0.036**	**0.036**	**0.049**	**0.049**	**1.430**	**1.366**	3.000*	3.371*
P-value	**[0.848]**	**[0.848]**	**[0.824]**	**[0.824]**	**[0.231]**	**[0.242]**	[0.083]	[0.066]
Cragg-Donald	6.833	---	---	---	6.833	---	---	---
Adjusted R²	0.017	---	---	---	0.317	---	---	---
F-Statistics	**16.742*****	---	---	---	**19.371*****	---	---	---
Observations	108	108	108	108	108	108	108	108
Instruments(Moments)	Constant; Forest product exports; Total Agricultural exports; Rural population on Total population							

TSLS: Two-Stage Least Squares. LIML: Limited Information Maximum Likelihood. GMM(2): Two-Step Generalized Method of Moments. GMM(Ite): Iterated Generalized Method of Moments. (): z-statistics. Chi-square statistics for Hausman test.OIR: Overidentifying Restrictions Test. LM statistics for Sargan test. Chi-Square statistics for LR OIR-test. Chi-Square statistics for J OIR test. [ ]:p-values. Cragg-Donald Weak Instrument test. *, **, ***: significance levels of 10%, 5% and 1% respectively.

Whereas the first concern is addressed by the significance of estimated coefficients, the second is assessed by the Overidentifying Restrictions (OIR) test, whose null hypothesis is the position that the instruments are not correlated with the error term in the main regression (Equation 2). Thus a rejection of the null hypothesis of the OIR test is a rejection of the position that forest exploitation moment conditions explain changes in forest-area and agricultural-land only through population growth channels. For robustness purposes we apply four IV techniques with Sargan, Likelihood Ratio (LR) and Hansen OIR tests for the TSLS, LIML and GMM regressions respectively.

Table 4 reveals the second-stage IV regressions. The choice of the IV estimation method is first justified with the Hausman test for endogeneity. The null hypothesis of this test is the perspective that estimated coefficients by OLS are consistent; indicating they do not suffer from endogeneity. In the event where the Hausman test fails to reject the null hypothesis (absence of endogeneity) we do not consider the IV estimation method appropriate because estimates by OLS are efficient and consistent. With OLS strong evidence of endogeneity are found in the four set of regressions. The effects of rural population growth (Panel A) are assessed independently from those of agricultural population growth owing to limited degrees of freedom in the moment conditions. Since the unrestricted second-stage regressions have three endogenous regressors, the instruments (moment conditions) must exceed the endogenous independent variables by at least one degree of freedom for the OIR test to be possible.

In Panel A of Table 4, the first issue is addressed by the significance of estimated coefficients and could be summarized as follows. (1) Rural population growth decreases forest-area but increases agricultural-land. (2) The effect of population growth is positive on forest-area, but negative for agricultural-land because population growth is often associated with massive rural exodus. The second issue is addressed by the OIR test which fails to reject the null hypothesis in all eight regressions. This implies forest exploitation moment conditions explain changes forest-area and agricultural-land through no other mechanisms than population channels. In other words rural population changes consistently explain variations in forest-area and agricultural-land conditional on the instruments (forest exploitation moment conditions). Results of Panel B confirm those of Panel A as agricultural-population growth decreases forest-area but increases agricultural-land: consistent with the effects of rural population growth. Also national population growth negatively affects forest-area while the effect on agricultural-land is consistent with the rural exodus explanation highlighted above. The all regressions, failure to reject the null hypothesis of the OIR test confirms earlier findings that moments conditions of forest exploitation explain changes in forest-area and agricultural-land via no other mechanisms than population channels.

Overall, findings are broadly consistent with the literature. Earlier results by Ndoye & Tieguhong (2004) that forests of the Congo Basin are exploited a great deal by rural and agricultural communities are confirmed. Evidence that not only timber exports are a concern for deforestation in the Congo Basin has been provided. Human activity, particularly agricultural and rural projects (owing to increasing demographic changes) also significantly affect the sustainability of the second largest and most important tropical forest region in the world. Borrowing from Ndoye & Tieguhong (2004), the forest in the Congo Basin is exploited by rural communities and timber companies at different scales to meet various conflicting interests. While the impact of timber exploitation on deforestation is evident from common-sense, the contribution of forests to the livelihoods of agricultural (rural) population and corresponding effects on deforestation had been hitherto simply based on theoretical initiatives without empirical validity. To the best knowledge, this is the first paper which empirically assesses how demographic changes in the Congo Basin are affecting forest-area using updated data.

5. Conclusion

Recent distressing trends in climate change, population explosion and deforestation inspired this paper, which completes existing literature by providing empirical justification to hypothetical initiatives on the impact of population growth on forest sustainability in Africa. Using three instruments of forest exploitation the study has shown how rural, agricultural and national population growths affect forest-area and agricultural-land. In this particular study the findings indicate that instruments of forest exploitation do not explain changes in forest-area and agricultural-land beyond population growth mechanisms. Hence, population growth channels are a driving force by which forest-area and agricultural-land are depleted and expanded respectively.

Deforestation, while hampering the global ecosystem, represents an important source of livelihood to local communities. With such a divergence in interests, there is need for a well-defined mutually beneficial partnership between local communities, logging companies and international norms in forest sustainability. Hence, policies need to be established through a balanced approach that takes account of the interest of all parties concerned. For example the integration of social, cultural, economic, ecological and legal aspects in timber and non timber forest products could be a step to better policy formulation and improved forest management. This could involve the exclusion of certain timber species of local and ecological importance from exploitation and providing compensation to timber companies for compliance. It could also be interesting if timber companies were to sign social responsibility agreements with local communities to this effect. Governments would have to monitor and legally enforce adherence to these agreements by ensuring that companies tendering for timber cutting permits are examined in terms of how they adhere to social and environmental regulations. Illegal logging must also be checked by government agents to mitigate the vulnerability of local communities to clandestine logging practices. These could be based on a fairly simple, cost-effective, accountable system that supports sustainable and socially friendly logging. Most importantly, based on the findings, introduction of mechanized farming could increase farming productivity and deter the need for mass clearing of forest for cultivation purposes. The extra-time and energy gained from mechanization could be used in reforestation of areas exploited by timber companies.

Appendices

Appendix 1: Variable definitions

Variable	Sign	Variable Definitions	Sources
Forest Area	Forest	Forest Area(% of Land)	World Bank (WDI)
Agricultural Land	AgriL(Km^2)	Log. of Agricultural Land(Km^2)	World Bank (WDI)
Rural Population Growth	Ruralpop	Rural Population Growth rate(Annual %)	World Bank (WDI)
Agricultural Population Growth	Agripop	Log. Agricultural Population (FAO Numbers)	World Bank (WDI)
Population Growth	Popg	Population Growth Rate(Annual %)	World Bank (WDI)
Forest Product Exports	FPExp.	Log. Forest Product Exports(FAO, Current US Dollars)	World Bank (WDI)
Total Agricultural Exports	TAExp	Log. Total Agricultural Exports(FAO, Current US Dollars	World Bank (WDI)
Rural Population Ratio	RpTp	Rural Population on Total Population	World Bank (WDI)
GDP Growth	GDPg	GDP Growth Rate(Annual %)	World Bank (WDI)
GDP Per Capita Growth	GDPpcg	GDP Per Capita Growth Rate(Annual %)	World Bank (WDI)
Agricultural GDP Growth	AGGDPg	Agricultural GDP Growth Rate(Annual %)	World Bank (WDI)
Agricultural GDP Per Capita Growth Rate	AGDPpcg	Agricultural GDP Per Capita Growth Rate(Annual %)	World Bank (WDI)

Km^2: Kilometer Square. Log: Logarithm. %: Percentage. WDI: World Development Indicators. GDP: Gross Domestic Product. FAO: Food and Agricultural Organization. US: United States.

Appendix 2: Summary Statistics

Variables	Mean	S.D	Min.	Max.	Skewness	Kurtosis	Obser.
Forest Area	59.715	14.970	36.430	85.097	0.127	-0.670	108
Agricultural Land	4.713	0.579	3.510	5.359	-1.206	0.335	108
Rural Population Growth	1.277	1.503	-2.266	3.673	-0.801	-0.152	108
Agricultural Pop. Growth	6.344	0.706	5.404	7.563	0.332	-1.155	108
Population Growth	2.618	0.568	1.555	3.914	0.118	-0.664	108
Forest Product Exports	8.024	0.448	6.855	8.767	-0.308	-0.802	108
Total Agricultural Exports	7.491	0.672	6.428	8.904	0.509	-0.599	108
Rural Population Ratio	1.277	1.503	-2.266	3.673	-0.801	-0.152	108
GDP Growth	4.503	11.798	-13.469	71.188	3.286	13.912	108
GDP Per Capita Growth	1.828	11.366	-16.683	65.772	3.236	13.771	108
Agricultural GDP Growth	2.574	3.707	-11.700	11.605	-0.402	2.156	79
Agricultural GDPpcg	-0.018	3.632	-13.741	8.274	-0.386	1.726	79

S.D: Standard Deviation. Min : Minimum. Max : Maximum. Obser : Number of observations. GDP: Gross Domestic Product. GDPpcg: GDP Per Capita Growth.

Appendix 3: Correlation Analysis

Dependent Variables		Endogenous Explaining Variables			Instrumental Variables			Control Variables				
Forest(%)	AgriL(km²)	Ruralpop	Agripop	Popg	FPExp.	TAExp.	RpTp	GDPg	GDPpcg	AGDPg	AGDPpcg	
1.000	-0.053	-0.572	-0.456	0.219	0.365	-0.449	-0.690	0.039	0.029	-0.132	-0.172	Forest(%)
	1.000	-0.183	0.761	-0.277	0.129	0.575	-0.055	-0.617	-0.608	-0.239	-0.255	AgriL(km²)
		1.000	0.302	0.377	-0.667	-0.012	0.899	0.221	0.205	0.056	0.012	Ruralpop
			1.000	-0.024	-0.188	0.706	0.526	-0.417	-0.419	-0.119	-0.144	Agripop
				1.000	-0.281	-0.203	0.308	0.168	0.121	0.037	-0.105	Popg
					1.000	0.303	-0.712	-0.008	0.005	0.276	0.297	FPExp.
						1.000	0.150	-0.329	-0.321	0.142	0.155	TAExp.
							1.000	0.069	0.054	-0.016	-0.044	RpTp
								1.000	0.998	0.141	0.140	GDPg
									1.000	0.140	0.147	GDPpcg
										1.000	0.989	AGDPg
											1.000	AGDPpcg

Forest(%): Forest Area in % of Land. AgriL(km²): Agricultural Land in Km². Ruralpop: Rural Population Growth Rate. Agripop: Agricultural Population. Popg: Population Growth Rate. FPExp: Forest Product Exports. TAExp: Total Agricultural Exports. RpTp: Rural population on Total population. GDP: Gross Domestic Product. GDPg: GDP Growth Rate. GDPpcg: GDP Per Capita Growth Rate. AGDPg: Agricultural GDP Growth. AGDPpcg: Agricultural GDP Per Capita Growth Rate.

References

Agrawal, A. (1995). “Population pressure = forest degradation: an over simplistic equation?”, *Unasylva*, 46(181), pp.50-58.

Asongu, S. A. (2011a). “How would population growth affect investment in the future? Asymmetric panel causality evidence for Africa”, *MPRA 30124.*

Asongu, S. A. (2011b). “Long-term population growths on aggregate investment dynamics: selected country evidence for Africa”, *MPRA 30128*.

Asongu, S. A., (2011c). “Law, finance, economic growth and welfare: why does legal origin matter?”. *MPRA Paper* No.33868.

Asongu, S. A.,(2011d). “Financial determinants of human development in developing countries”. *MPRA Paper* No. 33949.

Avise, J. (1994), “The real message from Biosphere 2”. *Conservation . Biology*, 8(2), pp.327-9.

Bilshorrow, R. and DeLargy, P. (1990). “Landuse, migration and natural resource degradation: the experience of Guatemala and Sudan”, *Population and Development Review*, 16, pp. 125-147.

Central African Regional Programme for the Environment: CARPE (2001). Rich forests, poor countries: adaptingforest conservation to economic realities, *CARPE Information Series*, No. 10. USAID, Washington, DC.

Central Intelligence Agency (2007). *The World Fact book 2007.* Washington, DC, USA.

Chetri, R., and Pandey, T. (1992). *User group forestry in the far-western region of Nepal*. Kathmandu, ICIMOD.

Cochet, H. (2004). “Agrarian Dynamics, Population Growth and Resource Management: The Case of Burundi”, *GoeJournal*, 60(2), pp. 111-122.

Collins, J. (1992). Marxism confronts the environment: labor, ecology and environmental change. In S. Ortiz & S. Lees, eds. *Understanding economic processes*. Lanham, Md., USA, University Press of America.

Congo Basin Forest Partnership (2006). *The forests of the Congo Basin –state of the forest report*. http://www.cbfp.org/doc_en.html Accessed on 15/11/2011

Cropper, M., and Griffiths, C. (1994). "The Interaction of Population Growth and Environmental Quality", *The American Economic Review*, 84(2), pp. 250-254.

Davis, K. (1991). "Population and resources: fact and interpretation", *Population and Development Review*, 16, pp. 1-21.

F. A .O (2005). *"Global Forest Resources Assessment 2005, Main Report. Progress Towards Sustainable Rain Management",* FAO Forestry Paper 147, Rome.

F. A. O (2001). *State of the World's Forests*. FAO of the United Nation. Rome.

Kumar, H.D. (2001). " *Forest Resources: Conservation & Management",* Affiliated East-West

Li, J.(1990), "Comment; population effects on deforestation and soil erosion in China", *Population and Development Review*, 16, pp. 254-258.

McKean, M. (1992). "Success on the commons: a comparative examination of institutions for common property resource management". *Journal of Theoretical Politics*, 4(3), pp. 247-82.

Ndoye, O. and Tieguhong, J.C. (2004, May), "Forest Resources and Rural Livelihoods: The Conflict Between Timber and Non-timber Forest Products in the Congo Basin", *Scandinavian Journal of Forest Research*, 19 (Suppl.4), pp. 1-9.

Ndoye, O. (1995). " Markets for non-timber forest products in humid forest zone of Cameroon and its borders: structure, conduct, performance and policy implications", Unpublished CIFOR Report.

Ndoye, O. (2003). “Timber harvesting, non-timber forest products and rural livelihoods in Central Africa”, *Center for International Forestry Research*.

Nimai, D. and Debnarayan, S. (2001). “Population, Forest Degradation and Environment: A Nexus”, *MPRA 15161*.

North, D. & Thomas, R. (1973). *The rise of the western world*. Cambridge, UK, Cambridge University Press.

North, D. (1990). *Institutions, institutional change and economic performance*. Cambridge, UK, Cambridge University Press.

United Nations (2001). Population, Environment and Development: The Concise Report, New York.

United Nations (2009). “World Population Prospects: The 2008 Revision Highlights”, Department of Economic and Social Affairs.

United Nations (2010). “World Population Prospects: The 2010 Revision”, Department of Economic and Social Affairs.

Wilson, E. (1988). *Biodiversity* Washington, DC, National Academy Press.

Wilson, E. (1992). *The diversity of life*. New York, W.W. Norton.

World Wide Fund for Nature (WWF). 2002. *Strategic planning –Western Congo Basin Moist Forest Eco-region*. Eco-region Technical Report. Libreville, Gabon, WWF Central Africa Regional Programme Office (CARPO).