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An analysis of dynamics of deforestation and agricultural productivity in Côte D'ivoire

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Abstract

The relationship between agriculture and forestry is a recurring theme in tropical regions where forest areas are replaced by agricultural land. In this study, the main objective is to analyze the relationship between deforestation and agricultural productivity in Côte d'Ivoire. In our methodological process, a formal theoretical framework is examined before specifying the empirical model. In the first step, an optimal control model is used to determine the optimal steady-state forest stock in Côte d'Ivoire. In the second step, an error correction model is used to analyze long run and short run relations between deforestation and agricultural productivity. Data for the empirical model were obtained from World Bank and FAO statistical database. The estimates showed that the agricultural yield responds significantly and negatively to deforestation. Indeed, a 1 per cent rise in deforestation rate will lead to about 5 per cent decline in agricultural yield. The fact that deforestation accelerates soil erosion and thus shifts agriculture to less suitable areas explains this result.

Key Words: Deforestation, Agricultural productivity, Dynamic Analysis, Côte d'Ivoire.

JEL: Q18; Q23; C22

INTRODUCTION

Côte d'Ivoire is losing rainforest at rate of 300,000 ha a year, of the original 16 million hectares of rainforest only 3.4 million hectares remain (FAO, 2008). The loss of forest in Côte d'Ivoire is due mainly to conversion of forest land to farmlands which is driven by a rising population and poor definition of property rights over forest land (Ehui and Hertel, 1989). The deforestation in Côte d'Ivoire is one of the examples of forest management problem in African countries. The rainforests represent a valuable store of biodiversity, reduce the frequency of local flooding, sink for carbon and prevention of soil erosion. Their destruction is irreversible and the local and global environmental damage due to their destruction may, in the long run, be catastrophic.

The major parts of the population in Côte d'Ivoire obtain their means of subsistence from agriculture. Consequently land is used for agriculture and areas of rainforest are replaced by agricultural land. In these situations the forest is being exploited as a non renewable resource.

The area of managed forest in a country depends upon the relative value of land in forestry compared with its alternative uses. In Côte d'Ivoire, land is used mainly for agriculture. If the profitability of agriculture is increased then this may lead to a reduction in the area of forestry. The competitive equilibrium between forestry and agriculture exists where the rate of return on the last hectare employed in agriculture equals the rate of return on forestry given by Faustmann model The problem of interest in seeking this equilibrium is to take account of the interaction effects between deforestation and agricultural productivity. The determination of effects of deforestation on agricultural productivity can be used to establish incentives which will lead to preserve forest resources. The main objective of

this study is to analyze the interaction between the dynamic of forest resources and that of agricultural productivity in Côte d'Ivoire. Specific objectives are:
- (i) determine a sustainable equilibrium between forest resources and agricultural land using an optimal control model;
- (ii) estimate long and short run relationships between deforestation rate and agricultural yield during 1962-2010;
- (iii) Give policy implications for an optimal exploitation of forest resources in Côte d'Ivoire.

The paper is organized as follow: Section 2 presents forest resources and the forest policy framework in Côte d'Ivoire. A review of studies on deforestation dynamics is presented in Section 3. Section 4describes an optimal control model used to determine a relationship between the optimal deforestation rate and the returns in agriculture. Section 5 gives an econometric model which links deforestation to agricultural productivity in Côte d'Ivoire. Section 6 presents the emprical results and section 7 concludes.

Forest resources and forest policy framework in Côte d'Ivoire

Côte d'Ivoire's forest resources

Côte d'Ivoire, which is situated on the Gulf of Guinea, has a total land area of 32.2 million hectares and an estimated 20.8 million people in 2010 (PND, 2012). The tropical moist forest belt extends inland from the coast in the southwest and southeast for more than 250 km; beyond the tropical forest belt lies extensive savanna. Estimates of forest cover vary from 5.12 million hectares (19 % of the land area) to 6.7 million hectares (Food and Agriculture Organization (FAO), 2008).

FAO (2008) estimated the deforestation rate at 265,000 hectares per year in the period 1990-2000, which as a percentage of remaining forest cover was higher than in most other sub-Saharan tropical African country. One of the reasons for deforestation is rural poverty and the need for subsistence agriculture. Timber theft and illegal logging are widespread and are the primary reasons for the degradation of natural forests. Forests of both wet evergreen and semi-deciduous forests types outside protected areas are heavily degraded or in an early secondary stage. Bushfires are widespread in the savanna and the transitional forest-savanna, especially in the north at the end of the dry season. With an annual rate of depletion estimated at 3.1%, Côte d'Ivoire has one of the highest rates of deforestation in West Africa (See Table 1 below).

Forest management in Côte d'Ivoire

The Ministry of Water and Forests is exclusively responsible for the protection and sustainable management of water, forest, wildlife and flora.Ten regional offices are in charge of forest protection and law enforcement. Field services are placed under the Society for Forest Development (SODEFOR - *Société de Développement des Forêts*), a government corporation created in 1966 and entrusted with the management of the forest reserves and with technical advisory functions for planted forests and social forestry.

Forest management in the rural area is exclusively conducted by the private sector. Forest industry is organized in syndicates and is quite effective in defending its interests in the forest sector. A number of national and international Non Governmental Organization (NGOs) are engaged in forest conservation and agro forestry activities.

Two forest management systems are employed in Côte d'Ivoire: forest reserve and rural forest area. In forest reserves, management is carried out by the state enterprise SODEFOR while in the permanent forest of the "rural area" it is carried out by private concession-holders. Until 2005, forest harvesting in the "rural area" was based on a licence system called the PTE (Permis de Transformation et d'Exploitation) system, which allocated areas of up to, 2,500 hectares to a large number of concession-holders.

With the new forest policy of 2006 the PTE system was abolished and replaced by a system based on PEFs "Périmètres d'Exploitation Forestières". By law, a "Périmètre d'Exploitation Forestière (PEF)" is at least 25,000 hectares and is allocated for 15-20 years; it can be renewed if management by the concession-holder is satisfactory. Concession-holders are obliged to present a forest management plan that includes a reforestation scheme and social investments for rural population living in or adjacent to the PEF. Management plans for PEFs must also include prescriptions for sustained-yield harvesting.

In the past, timber was mainly harvested in reserved forest areas, but excessive extraction over the past 30 years has led to their depletion. Management plans including prescriptions for sustained-yield are required.

Socioeconomic impacts of deforestation in Côte d'Ivoire

Many forests related problems currently impact on development in Côte d'Ivoire. For example, rapid deforestation is an acute problem that affects the daily lives of Ivorians. Although some corrective actions such as halting illicit harvesting, reforestation and reformation in logging activities have been taken by the government, expansion of agricultural lands at the expense of forests remain the fundamental contributor to deforestation in Côte d'Ivoire. Other factors include: high natural rate of population growth (3.9 percent annually) and flexible

Table 1: Rate of deforestation in West African countries

Country	Total Land Area (1000 ha)	Total forest 2007 (1000 ha)	Forest % of land area 2007	Forest change 1990-2007	Annual rate of change 1990-2007
Benin	11062	2221.4	20.08	-1100.6	-2.33
Burkina Faso	27360	6746.4	24.65	-407.8	-0.34
Côte d'Ivoire	**31800**	**5984**	**18.81**	**-4238**	**-3.1**
Ghana	22754	5286.2	23.23	-2161.8	-1.99
Guinea	24572	6652.2	27.07	-755.8	-0.63
Liberia	11137	3033.6	31.49	-1024.4	-1.69
Mali	122019	12371.5	10.13	-1700	-0.75
Niger	126670	1241.1	0.97	-703.9	-2.6
Nigeria	91077	10269.8	11.27	-6964.2	-2.99
Senegal	19253	8583.2	44.58	-765	-0.5
Sierra-Leone	7162	2812.4	39.26	-231.9	-0.46
Sudan	237600	66367.7	27.93	-10013.7	-0.82
Togo	5439	346	6.35	-339	-3.93

Source: FAO, 2008

immigration policies which create land use pressures (Gome, 1998).

The continuous destruction of forestlands is one of the most unfortunate and dramatic events in Côte d'Ivoire. It is estimated that Côte d'Ivoire has lost almost 83 percent of the 16 million hectares of tropical forests that existed in 1960 and is currently losing 450,000 hectares (1.1 million acres) of its tropical forests annually (Gome, 1998). Although tropical forest ecosystems are often used as a source of commercial timber and fuelwood, they also play a much larger and significant social and economic role in rural as well as in urban and national economies.

Unfortunately, government corrective actions such as increase the protected areas (forest reserves and national parks) and encourage private investments in forestry, have not addressed the fundamental factors leading to forest depletion, which are the increasing population growth rate; flexible immigration policies and the expansion of agricultural lands.

In essence, the government has transitioned from a policy of offering harvesting concessions, to an interim policy of timber export quotas, to an outright total ban of timber exports. These policies did not serve to aggressively combat forest depletion and stimulate forest management and wood product production. They simply shifted export products from logs to semi finished products. The conversion from sustainable utilization of forests to unsustainable agricultural cultivation has produced only short term productivity gains at the expense of long term socio-economic benefits (African Development Bank, 1990).

In Côte d'Ivoire, deforestation leads to plant or soil nutrient loss, accelerates soil erosion, declines in soil productivity and agricultural yields (Office of Technology Assessment (OTA), 1984). The loss of forest in Côte d'Ivoire is due mainly to conversion of forest to farmlands which is driven by a rising population. What policy of forestry exploitation may lead to an optimal equilibrium between forestry and agricultural land for the rural area in Ivory-Coast?

Deforestation dynamics : a review

Recent attempts to theorize forest land use changes have yielded some noticeable contributions on the field of deforestation. One such contribution referred to as "forest transition theory" has been put forward by Mather, Grainger and Needle since the early 1990 (Grainger, 1995; Red, Tomich et al., 2006).

According to this theoretical perspective, an overview of forest land use changes in the long run, provides firm evidence that while initially forest land areas retreat at a high speed, at same point, depletion starts slowing down. There is even a critical point over which the process of depletion reverses and forest land recovers by expanding into new areas. Prosperity level seems to have a key role in the whole process. During the course of development increased pressure is put on forest land due to higher demand for land and forest related products (Koop and Tole, 1999; Ehrardt-Martinez, Crenshaw et al., 2002). As a spatial unit moves to higher stages of development, pressure on forest land retreats because technological innovations allow for increased productivity in the primary sector, limiting the needs for expansion on forest land.

Empirical evidence systematically suggests that in as much as forests contribute to greater agricultural productivity in the short term, forest depletion reduces agricultural productivity in the long run. The reason is the protective role of the forest (Kaimowitz D and Angelsen

A, 1998). The forest helps to speed up the formation of top soils, creation of favorable soil structure and storage of nutrients that are useful for crop production by retarding erosion and silting and regulating stream flows.

There is an abundant literature on deforestation in developing countries while there is far less literature specific on 's deforestation. Allen and Bernes (1995) review the estimates in developing countries and analyze the relationship between deforestation and its probable causes. They found that in the short term, deforestation is due to population growth and agricultural expansion, aggravated over the long term by wood haversting for fuel and export.

Bawa and Dayanandan (1997) examine the correlation between deforestation in the tropics and 14 socioeconomic variables using data from 70 countries. Economic variables (per capita agricultural value added and par capita traditional fuel consumption) were among the most significant variables.

Ehui and Hertel (1990) used an optimal control model to determine the optimal steady-state forest stock in the . This stock is shown to increase with increases in the forestry returns relative to those in agriculture.

Analytical framework

An optimal control model is used to determine the optimal steady-state forest stock in Ivory-coast (Ehui et al., 1990). This stock is shown to increase with an increase in the forestry returns relative to those in agriculture.

The social objective is to maximize the utility derived from aggregate profit subject to changes in forest stocks over time. Both forested and deforested lands are considered as sources of future profits.

The following notations are adopted :

q : rate of deforestation in hectares;

z : quantity of purchased inputs used in production;

x: the forest area;

P_x: the price of forest production;

P_c: the crop price and P_z is the input price;

Public benefit of forest represented by $\pi(x)$.

Agricultural revenues are given as a production function per hectare multiplied by the crop price P_c and the area in agriculture $(\bar{x}-x)$ as the total area $\bar{x}$ less the forest area x. The production function $f(.)$ gives crop yield as a function of the current rate of deforestation. The cumulative loss of forest area $(\bar{x}-x)$ and variable inputs z.

The assumptions about the function are as follows. The utility function U is twice differentiable and is increasing in the net benefit from forestry $U^{'}>0$, but marginal utility is diminishing $U^{"}<0$.

We assume that average yield is increasing in purchased inputs and declines with increases in cumulative deforestation.

$$\max_{q,z,x}\int_0^{\infty} U(q(t),z(t),x(t)e^{-rt}dt$$

$$U\big(q(t),z(t),x(t)\big)=\pi(x)+P_x x+(\bar{x}-x)P_c f(q,(\bar{x}-x),z)-P_z z$$

$$\dot{x}=-q;X=(x_0-x)$$

Set up the Hamiltonian associated with the control problem described above:

$$H=e^{-rt}U\big(q(t),z(t),x(t)\big)-\lambda(t).q(t)$$

FOC

$$\frac{\delta H}{\delta q}=e^{-rt}U_q^{'}-\lambda=0 \quad (1)$$

$$\frac{\delta H}{\delta z}=e^{-rt}U_z^{'}=0 \quad (2)$$

$$-\frac{\delta H}{\delta x}=\dot{\lambda}\Leftrightarrow -e^{-rt}U_x^{'}=\dot{\lambda} \quad (3)$$

We want to eliminate (λ), in order to set a steady state relationship. Differentiate (1) with respect to time, we have:

$$-re^{-rt}U_q^{'}+U_q^{"}\dot{q}e^{-rt}-\dot{\lambda}=0\Leftrightarrow\dot{\lambda}=e^{-rt}\big(-rU_q^{'}+U_q^{"}\dot{q}\big) \quad (4)$$

Use equation (3) and (4) and rearranging gets

$$\dot{q}=-\frac{U_x^{'}}{U_q^{"}}+r\frac{U_q^{'}}{U_q^{"}}\Rightarrow\dot{q}=0\Leftrightarrow r=\frac{U_x^{'}(q^*,x^*,z^*)}{U_q^{'}(q^*,x^*,z^*)}$$

$$\dot{q}>0\Leftrightarrow r>\frac{U_x^{'}}{U_q^{'}}\text{ and }\dot{q}<0\Leftrightarrow r<\frac{U_x^{'}}{U_q^{'}} \quad (5)$$

The steady state occurs where the forest area is constant, and no incentive exists for deforestation. In this case, $\dot{x}=\dot{q}=0$. At the steady-state forest area, x^*, the following condition holds . $U_x^{'}(q^*,x^*,z^*)=rU_q^{'}(q^*,x^*,z^*)$.

It means that the present value of the marginal utility derived from holding foresting is equal to the marginal utility of deforestation.

$U_x^{'}(q,x,z)$ represents the "conservation motive", since it gives the marginal utility of forest stock. Intuitively $U_q^{'}(q,x,z)$ is the marginal utility of deforestation (deforestation motive) and a relatively high value for $U_q^{'}(q,x,z)$ indicates a large agricultural yield response from the deforestation.

Two outcomes would arise: either the conservation motive exceeds or equals the marginal return from deforestation thus the forest is preserved and the deforestation rate is lower in current period relatively to the future. Or the marginal returns from deforestation exceed the conservation motive thus the forest is mined to extinction.

To sum up, the optimal rate of growth of deforestation depends upon two motives: the return from deforestation

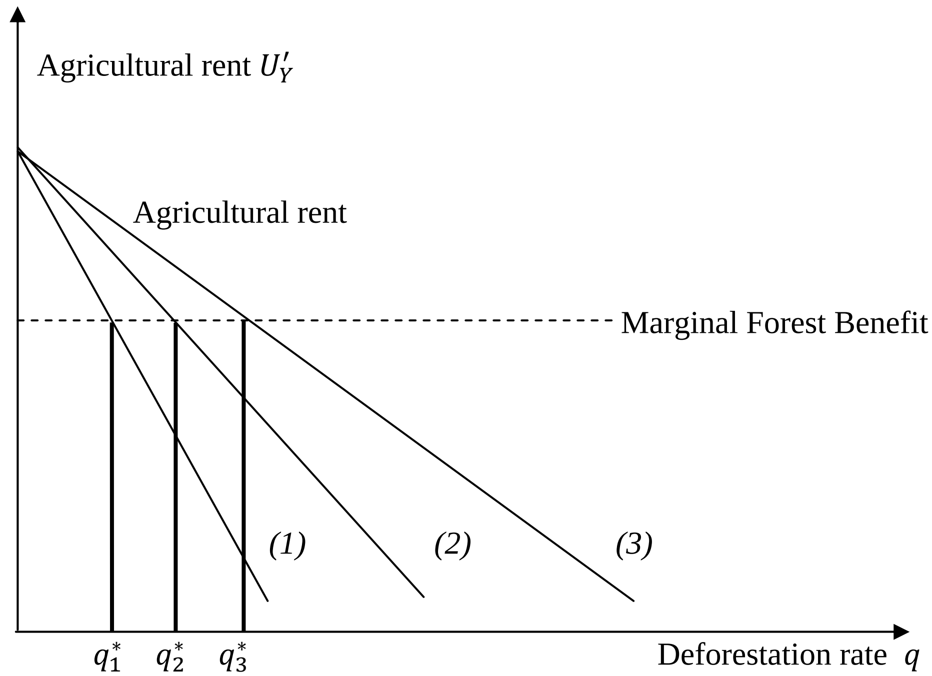

Figure 1: Relationship between the optimal deforestation rate and the decline in agricultural productivity

and the conservation motive.The optimal deforestation rate in current period will be high if the conservation motive is relatively weaker than the deforestation motive. In Côte d'Ivoire, the deforestation motive is essentially the agricultural productivity response from deforestation.

The optimal rate of deforestation is even lower than the decline in agriculturalproductivity is accelerated ($q_1^* < q_2^* < q_3^*$).

Given the role of agricultural productivity in the dynamic of forest resources changes, it would be helpful for policymakers to have information on short run and long run relations between agricultural productivity and deforestation.

Empirical model and method of estimation

An empirical model can be used to analyze the long-term relation among deforestation, climate changes and agricultural productivity in Côte d'Ivoire. The models include unit root tests, cointegration and error correction mechanism.

The rate of deforestation in hectare, the agricultural yield in constant dollar per hectare and the average rainfull in millimeter are the variables chosen to analyze the long run dynamic between deforestation, agricultural productivity and climate changes.

The impact of deforestation on agricultural yields could not be rigorously analyzed without considering the changes in climate. According to Fischer et al. (2002), the deforestation issue is global, long term and involves complex interaction between climatic, environmental and socioeconomic factors.

In the past several years, Africa has experienced the most adverse effects on agricultural production caused by drought, floods and unpredictability of climate (Intergovernmental Panel on Climate Change (IPCC), 2007). Agricultural productivity has been severely compromised by climate variability and change caused partly by deforestation. Particularly agricultural losses due to climate change could be as high as 4 % of the GDP in Central and West Africa. Furthermore, the impacts of climate changes on Africa's ecosystem include a loss of around 5 million hectares of forest per year (IPCC, 2007).

Climate change is thus, an important factor, while considering the issue of deforestation.

Hence, analyzing the long term relationship between deforestation and agricultural yield and neglecting the climate change can lead to biased results which in turn lead to false policy recommendation.

The Vector Error Correction Model (or VECM) representation is as follows:

$$\begin{pmatrix}\Delta y_t\\ \Delta x_t\\ \Delta z_t\end{pmatrix} = \begin{pmatrix}\mu_1\\ \mu_2\\ \mu_3\end{pmatrix} + \begin{pmatrix}\alpha_1\\ \alpha_2\\ \alpha_3\end{pmatrix}\left(y_{t-1} - \beta_1 x_{t-1} - \beta_2 z_{t-1}\right) + A_2\begin{pmatrix}\Delta y_{t-1}\\ \Delta x_{t-1}\\ \Delta z_{t-1}\end{pmatrix} + \cdots + A_k\begin{pmatrix}\Delta y_{t-k}\\ \Delta x_{t-k}\\ \Delta z_{t-k}\end{pmatrix} + \begin{pmatrix}v_{1t}\\ v_{2t}\\ v_{3t}\end{pmatrix} \quad (6)$$

where
y_t= agricultural yield in constant dollar per hectare;
x_t= rate of deforestation in hectare;
z_t= average rainfall in millimeter.

v_{1t}, v_{2t} and v_{3t} are iid disturbances with zero mean and constant and finite variance, the operator Δ denotes that the I(1) variables have been differentiated. Parameters contained in matrices $A_2 \dots A_k$, measure the short run effects, while β_1 and β_2 are the cointegrating parameters that characterize the long run equilibrium relationship between the agricultural yield, the deforestation and the average rainfall.

$(y_{t-1} - \beta_1 x_{t-1} - \beta_2 z_{t-1})$ reflects the error or any divergence from the equilibrium. The vector $\begin{pmatrix}\alpha_1\\ \alpha_2\\ \alpha_3\end{pmatrix}$ contains parameters, usually, ; $0 </ \ ʹ \ /< 1, \ = 1,2,3$; commonly called error correction coefficients, that measure the extent of corrections of the errors.

Johansen's procedure for cointegration analysis

Before testing for cointegration, it is important to ascertain that the relevant variables are integrated of order 1 (abbreviated as I (1)). For this one needs to carry out unit root tests for each of the variables.

For the purpose of testing the cointegrating relationship, we adopt here the procedure suggested by Johansen and Juselius (1990) which provides a suitable framework to examine the question of cointegration in a multivariate setting. Their approach yields a maximum likelihood estimate of the unconstrained cointegrating vectors and the test is free from arbitrary normalization restriction.

Johansen's test examines the following multivariate system:

$$\Delta X_t = \Gamma_1 \Delta X_{t-1} + \cdots + \Gamma_{k-1}\Delta X_{t-k-1} - \Pi X_{t-k} + \varepsilon_t$$

X_t is a (□ × 1) vector of variables and $□_□$ is a (□ × 1) vector of innovations drawn from a Gaussian distribution.

Johansen's procedure essentially tests for zero rank of the matrix Π. If the rank of the matrix Π is zero, the null hypothesis of no cointegration is not rejected; if the rank of the matrix Π lies between 0 and □, there exists at least one cointegrating vector. Johansen suggested two tests: (a) the trace test and (b) the maximum eigenvalue test.The actual implementation of these tests involves the following steps:

1. Specify a multivariate autoregressive model of order □ for (□ × 1) vector $□_□$.
2. Regress $\Delta □_□$ on $\Delta □_{□-1}, \Delta □_{□-2}, \dots, \Delta □_{□-□+1}$. Keep the residual vector as $\hat{□}_□$.
3. Regress $□_{□-1}$ on the same set of regressors as in step (2). Keep the residual vector as $\hat{□}_□$.
4. Compute the □ squared canonical correlations ($□^2_□$; □ = 1,2, … , □) between the vectors $\hat{□}_□$ and $\hat{□}_□$. Order the squared canonical correlations as $□^2_1 > □^2_2 > \dots > □^2_□$.
5. For the trace test the null hypothesis is that these are h cointegrating relation against the alternative of □ cointegrating relations. The likelihood ratio test statistic is: $-□ \sum_{□=h+1}^{□} \ln(1 = □^2_□)$. For the maximum eigenvalue test, the null hypothesis is that there are h cointegrating relations against an alternative of $h + 1$ cointegrating relations. The test statistic in this case is: $-□□n\,(1 - □^2_{h+1})$. Both tests are asymptotically equivalent.

Data source and variables' measurement

In order to carry out our analysis, we considered the following variables relating to 48 years period (1962-2010):
□: Agricultural yield expresses in real agriculture value added per hectare;
□: Harvested forest areas expressed in Ha;
□: Rainfall expressed in millimeter.

Our series result from three principal sources: The World Bank regarding the productivity of agricultural sector, the FAO statistical database regarding the forest areas and SODEXAM regarding the average rainfall.

EMPIRICAL RESULTS

Unit root test

In order to ascertain that the relevant variables are integrated of order 1 and test for cointegration, we carry out unit root tests for each variables. The augmented Dickey-Fuller (ADF) and Phillips-perron (PP) statistics for the logarithm of the three series are presented in Table 2. Unlike the Augmented Dickey-Fuller test, the Phillips-Perron test allows the disturbances to be heterogeneously distributed. A linear trend term is added in the ADF and PP regressions because otherwise the root of the process shows an explosive pattern.

The results show that all the ADF statistics as well as PP statistics for level are greater than the 95 per cent critical value, which clearly indicates that a unit root is present in all three series. On the other hands, for the first differences, the results of the ADF and PP tests show that the two price series are I (1).

Cointegration analysis

The results of Johansen cointegration test are presented in Table 3 (below). In this table, starting with the null hypothesis that there is no cointegrating, the trace statistic is 49.495 which is well above the 95 per cent critical value, indicating that the null hypothesis of no

Table 2: Results of Unit root tests

	Level		First Difference	
Variables	ADF	PP	ADF	PP
Log (y)	-2.357	-2.813	-3.870*	-4.111*
	(-3.600)	(-3.600)	(-3.600)	(-3.600)
Log (x)	-2.890	-2.199	-4.264*	-6.615**
	(-3.600)	(-3.600)	(-3.600)	(-3.600)
Log (z)	-2.458	-3.346	-3.654*	-9.118**
	(-3.600)	(-3.600)	(-3.600)	(-3.600)

**, * Denotes significant at 1% and 5% level respectively. Numbers in parentheses are critical values at 5%.
Note: Log (y) = log of agricultural yield; log (x) = log of harvested forest areas, log(z)=log of rainfall.

Source: Author's computations.

Table 3: Johansen cointegration test for Log (y), Log (x) and log (z)

Hypothesized Number of Cointegrating equation(s)	Eigenvalue	Trace Statistic
None*	0.95118	49.495
		(29.68)
At most 1	0.32754	7.219
		(15.41)
At most 2	0.11209	1.664
		(3.76)

The Trace test indicates 1 cointegrating equation at the 0.05 level.
*Denotes rejection of the hypothesis at the 5 per cent level.
Numbers in parentheses are critical values at 5%.
Note: Log (y)=log of agricultural yield; log(x)=log of harvested forest areas, log(z)=log of rainfall.

Source: Author's computations.

cointegration is rejected at the 5 per cent level of significance.

If the null hypothesis: □ $= 0$ is rejected, one may then proceed sequentially and test the null hypothesis: □ ≤ 1 against □ $= 2$. It may be noted that the trace statistic is 7.219 which is well below the 95 per cent critical value indicating the presence of one cointegrating vector.

The cointegration test indicates that the agricultural yield, the rate of deforestation and the average rainfall have a common trend.

Error Correction model estimates of agricultural yield response to deforestation and rainfall

The error correction model allows deriving both the long run and short run elasticities.

Long run relationship among agricultural yield, deforestation and rainfall

The cointegrating equation defines the long run relationship. When agricultural yield is treated as the dependent variable and deforestation and rainfall as the independent variables, the long run equilibrium equation is:

$$\log(Y_t) = -5.37\log(X_t) + 3.73\log(Z_t) \qquad (8)$$
$$(-4.21) \qquad (4.79)$$

where the numbers in parentheses are the corresponding t-ratios.

The agricultural yield responds significantly to both deforestation and rainfall. The two elasticities have opposite signs in the long run. They indicate that a 1 per cent rise in deforestation rate will lead to about 5 per cent decline in agricultural yield, while a similar rise in average rainfall will give rise to about 3.7 per cent increase in agricultural yield in the long run. The estimates indicate that deforestation reduces agricultural yields. This result is explained by the fact that deforestation accelerates soil erosion and thus shifts agriculture to less suitable areas.

The short run dynamic

Cointegration is purely a long run phenomenon, however, one may still wonder about the short run dynamics of the

Table 4: Error Correction Estimates of agricultural yield response to deforestation and rainfall

Variable	Coefficient	Std-Error	t-value	P-value
$\Delta\log(Y_{t-1})$	-0.7198	0.5499	-1.31	0.191
$\Delta\log(X_{t-1})$	-0.0547	0.2551	-0.21	0.830
$\Delta\log(Z_{t-1})$	11.0544*	6.0103	1.84	0.066
Constant	0.0040	0.2571	0.02	0.988
ECM_{t-1}	-0.3117***	0.1125	-2.77	0.006
$R^2 = 0.7693$	AIC=-13.901	HQIC=-13.910	SBIC=-13.099	

***, **, * Denotes significant at 1%, 5% and 10% level respectively.

Δ denotes that the variables have been differentiated.

Note: Log (y) = log of agricultural yield; log (x) = log of harvested forest areas, log(z) = log of rainfall.

Source: Author's computations

variables. Table 4 reports the results of the short run dynamic and error correction model.

The results of the short run dynamic show that in the previous year, the rainfall was the most significant predictor of current agricultural yield. As expected, the error correction term (ECM_{t-1}) is significant and has the correct sign implying a short run adjustment of agricultural yield to the previous period's deviation from the long run relationship. Indeed, the speed of adjustment is 31 %, this means that 31 per cent of adjustment to long run equilibrium takes place in the next period after a deviation of agricultural yield from its equilibrium value.

CONCLUSION

Any effort to combat deforestation must be based on a complete understanding of the agents of deforestation and what its direct and underlying causes are. The circumstances vary from country to country and from region to region.

Based on our estimates the impact of deforestation on agricultural productivity in Côte d'Ivoire is negative. The fact that deforestation accelerates soil erosion and thus shifts agriculture to less suitable areas explains this result.

Small farmers are the most important agents of deforestation in Côte d'Ivoire. The most important predisposing conditions that underlie deforestation are growing population and poverty. The rural poor in Côte d'Ivoire have very few alternative sources of income outside agriculture. With few alternatives available to them such as trade and transport, the rural poor look to the forests as a short term solution to their economic problems.

Options that could slow down considerably the rate of deforestation and its negative impacts are:

- The adoption of joint forest management: local people must be involved in the planning and implementation of programs to manage forests;
- The improvement of the productivity of subsistence agriculture: greater productivity from the existing farm will reduce the pressure to convert more forests to these uses;
- The promotion of agroforestry and non-timber forest products.

REFERENCES

African Development Bank (ADB), (1990). *Overview of environmental problems in regional member countries*, Abidjan, Côte d'Ivoire: Policy Paper.

Allen J, Barnes D (1995). "The causes of Deforestation in Developing Countries", *Annals of the Association of American Geographers*, vol. 75, pp. 163-184.

Barbier E, Burgess J (1997). "The Economics of Tropical Forest Land Use Options" *Land Economics* 73 (2): 174-195.

Bawa KS, Dayananda S (1997) "The Socioeconomic factors and tropical deforestation" *Nature*, vol. 386, pp. 562-563.

Ehui S, Hertel T (1989) "Deforestation and Agricultural Productivity in The Côte d'Ivoire" *American J. of Agric. Eco*, vol.71, pp. 703-711.

Ehui S, Hertel T. Prickel K (1990). "Forest Resource Depletion, Soil Dynamics, and Agricultural Productivity in the tropics" *Journal of environmental Economics and management*, vol.18, pp. 136-154.

Ehrhardt-Martinez, K., Crenshaw, E., and Craig, J. (2002). "Deforestation and the Environmental Kuznets Curve: A Cross-National Investigation of Intervening Mechanisms." Social Science Quarterly 83(1): 226-243.

Fischer G, Shah M, van Velthuizen H (2002) *Climate Change and Agricultural Vulnerability*. A special Report Prepared as a Contribution to the World Summit on Sustainable Development. Laxenburg, Austria.

Food and Agriculture Organization (FAO), (2008). *State of the worlds Forests*, Rome, Italy.

Gome G (1998). *Forêts sacrées, patrimoine écologique vital de* . Croix Verte de , Abidjan, 169p.

Grainger A (1995). "The Forest Transition: An Alternative Approach." Area 27(3): 242-251.

Hamilton J (1994). *Time Series Analysis*. Princeton: Princeton University Press.

Hanley, N., Shogren, J. and White, B. (1997). *Environmental Economics in theory and Practice*, Oxford University Press, USA.

Intergovernmental Panel on Climate Change (IPCC), (2007) *Assessment report on Climate Change*, Geneva: IPCC Publications.

Johansen S, Juselius K (1990). "Maximum Likelihood Estimation and Inference onCointegration with Application to the Demand for Money" *Oxford Bulletin of Economics and Statistics*, vol. 52, no. 2, pp. 169-209.

Office of Technology Assessment (OTA), (1984). *Technologies to Sustain Tropical Forest Resources*, Washington D.C., Office of Technology Assessment (U.S. Congress).

United Nations Environment Programme- World Conservation

Monitoring Centre
(UNEP-WCMC), (2004) *Spatial analysis of forests within protected areas in ITTO Countries*, Cambridge, UK.: Data prepared for ITTO.
Kaimowitz D, Angelsen A (1998) . Economic Models of Tropical Deforestation. A review (Center for International Forestry Research (CIFOR)).
Koop G, Tole L (1999). "Is there an environmental Kuznets curve for deforestation?" *Journal of Development Economics* 58(1): 231-244.
Reid, R., Tomich T, Xu J, Geist H, Mather A (2006). *Linking land-change science and policy: Current lessons and future integration. Land-use and Land-cover change: Local processes and global implication*. E. Lambin and H. Geist. Wurzburg, Springer: 157-176.