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Optimal Forest Stock Determination in Côte d'Ivoire, in a Sustainable Development Perspective

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Abstract: For several decades, the forest sector in Cote d'Ivoire has undergone a drastic decrease of its forest coverage from 10,860,000 ha in 1960 to 1,500,000 ha in 2016. This situation brought about some climatic changes that affect farmers' traditional mode of production. The situation also has affected the wood industry through the lack of raw material (timber), forcing them fire workers. The objective of this study was, to determine the necessary size of the forest stock to preserve in order to maintain the ecological balance of the country. This equilibrium will allow the improvement of farming conditions (increased rainfall and climatic stability), revenue from farmers, the wood industry, and in return, the economy of the country. The results of this study indicate that, the forest stock for an ecological equilibrium in Cote d'Ivoire was estimated, at 8,343,000 ha but that equilibrium was disrupted since 1978. To rebuild the forest coverage capital, the size of the reforestation should be between 99,000 and 500,000 ha of forest per year compared with, the real reforestation by the government from 2,000 to 7,000 ha per year. Given the high cost of reforestation, our study suggested a paid community reforestation that is more efficient and less expensive. The determination of these references (optimum forest stock for an ecological equilibrium and optimum reforestation) would help the government adjust its resources for future forest recovery projects in order to significantly revitalize the agriculture and forest sector, which is the main pillar of the country's economy and the principal jobs provider. One advantage of this strategy will be to considerably reduce the rural exodus.

Keywords: Optimal Management, Optimal Forest Stock, Sustainable Economic Growth

1. Introduction

Recently, the management of natural resources has been the main issue in the environment concerns. A sustainable economy, compatible with long-term objectives on the environment protection, such as the preservation of natural resources for the next generations, suggests an efficient management of the resources. The policies on natural resource management are meant to enrich and save the natural heritage, especially leisure sites provided by the protected natural regions [1]. A rational use of the resources allows not only a sustainable production of the specific resource but also its continuation without any negative externalities. This explains why the analysis of the problem regarding natural resources and the economic incentives are supported by the idea that the optimal social use of the resources is a key factor of a viable economic development process [2]. Therefore, this is the main idea on which our study of forestlands in Côte d'Ivoire is based.

The problem of the forest sector in Côte d'Ivoire has been no less than extremely preoccupying lately. In fact, the demographic expansion and the substantial economic development that the country has witnessed from 1960 to 2016, specifically in the agriculture sector, have as consequence an increasing pressure on the forestry sector. The size of the forest in Côte d'Ivoire has considerably decreased, from 10,860,000 ha in 1960 to about 1.500.000 ha in 2016, corresponding to a degree of reforestation of about 2.6% for that period, leading the country to an ecological deadlock (climatic changes and reduction of the rainfall) with the effects being already perceptible. Given the complexity of the problems related to the decrease of the forest coverage and considering the importance of agricultural and forest use in the country's economy (33% of the GDP), we think that the answers to these problems should include a planning of an efficient use of the forestlands. Doing so, leads us to ask the following questions:

- What is the forest stock for an ecological balance?
- What is the level of reforestation that can help to achieve this balance stock?
- Which strategies to restore the ecological balance?

The objective of this study is to analyze the optimal management conditions for a sustainable development of the forest coverage in Côte d'Ivoire. Specifically this will imply:

a) Determining the optimal areas of forestland that should be allocated to forest related activities;
b) Explaining the difference between optimal forestland areas and the situation observed in the field;
c) Proposing a strategy to achieve this optimal allocation (new balance) in case that the observed areas were different than those determined.
d) choosing the economic approach underpinned by a mathematical method of dynamic optimization, namely linear programming Model,

2. Literature Review

Several tools in the context of the rational management of resources are used to help policy makers to take good decision. These tools can be presented as mentioned below.

The analysis of the effects of inappropriate use of the resources is made possible [1]., by the use of two related concepts that are: the Collective Cost of Opportunity (CCO) of resource use which is bound with the optimal rate in which a resource should be used. It includes three elements which are: the direct costs of extraction or harvesting (Ch), the costs that the user imposes to the future users (Cu) and, the external costs (Ce) bound to the resource use. What summarizes as: CCO = Ch + Cu + Ce; and, the Total Economic Value (TEV), which refers to the components of sustainable resource conservation; and includes: the consumption value (Bc), the value for future users or option value (Bo), and the value that the resource takes in sustainable preservation condition or the existence value (Be), which is summarized as follows: TEV = Bc + Bo + Be.

The CCO highlights the profit-cost analytical method in the management of natural resources [1]. Indeed, the inclusion of environment-related costs in the national accounts as well as the assessment and the monitoring of natural resources are management tools of natural resources according to reference [3].

There is a strong demand for forest products. Unlike the vast array of goods produced by the economy, private markets mechanisms have failed to solve the allocation problem with regard to multiple use services. Whatever the demand, multiple use evaluation is as much a matter of institutional form as economic method. Among the methods which may be used within a given institutional framework are: Money (Dollar) value reference points, opportunity cost, shadow prices, interagency bargaining, artificial markets and programming [4].

The mathematical models contributed to the management of natural resources and have been applied in several studies particularly on econometric models, in determining the causes of deforestation. These models have two gaps in the inability to overcome explicitly and implicitly the definition of forest and deforestation on the one hand; and secondly, to highlight the explanatory variables and the burden of responsibility in deforestation. That is why, according to these same authors, econometrics loses its relevance in favor of general equilibrium models and optimization models [5].

As for the general equilibrium model used on 1996 [6], it also loses its acuteness because of the difficulty in modeling the behavior of actors across parameters as elasticities and the propensity to save. Thus, authors come to condemn the use of CGE models for policy evaluation.

While McConnell [7], reveals that the problem of effective and optimal use of resources can be solved as a profit maximization problem from different uses of this resource by the use of optimization mathematical models. Thus the author has developed a programming model to three types of land use (agriculture, urban planning, and forestry). It was followed by the study on forest land in Côte d'Ivoire through optimal control model [8]. Optimization models are presented generally as follows:

Max Z: $\Sigma \mathrm{bij.Xj}$, which is the objective function to be maximized;

Subject to constraints functions:

$$\Sigma \mathrm{aij.Xj} \leq \mathrm{Es}$$

$$\mathrm{Xj} \geq 0$$

In our study, we chose the last method (mathematical optimization model), including dynamic programming method for reasons of strength, which are presented in the following section.

3. Method

In order to suite to the objectives of this study, the methodology we used consisted in:

- Modeling the forestland use in a form of mathematic equation that included all variables needed for its resolution.
- Defining three groups of scenarios that depend on two parameters, the forest value and the social discount rate, in order to undertake a parameterization. The forest could have values of: 10 USD, 50 USD, 70 USD, and 112 USD per ha. The value represents the total fees and donations to possess a hectare of forestland, depending on the region and the relative functions. The social discount rates were: 3%, 5%, 7%, and 10% (values of the international and the Central Bank of West African States- BCEAO loan interest rates). The scenario 1 (scenario maximum) results from the combination of maximum income and maximum social discount rate; the scenario 2 (scenario intermediary) results from the combination of average income and intermediary social discount rate; and the scenario 3 (scenario minimum) results from the combination of minimum

revenue and minimum social discount rate.

- Estimating the agricultural and forest average incomes per ha of land from 1960 to 2016, which were previously deflated compared to the consumer price index (1985 basis).
- Running the models with the General Algebraic Modeling System (GAMS) software.

Our primary and secondary data were collected from surveys conducted with farmers, administrative and political officials, State departments (Agriculture and rural development, Animals and Fisheries Production, Environment, Economic and Finance) research, National Agronomy Research Center (CNRA) and development structures (Ivorian State Company for Forest Development, National Bureau of Technical and Development Studies) institutes, and/or World Bank institutes. The study area is the forest region of the country represented in green in Figure 1.

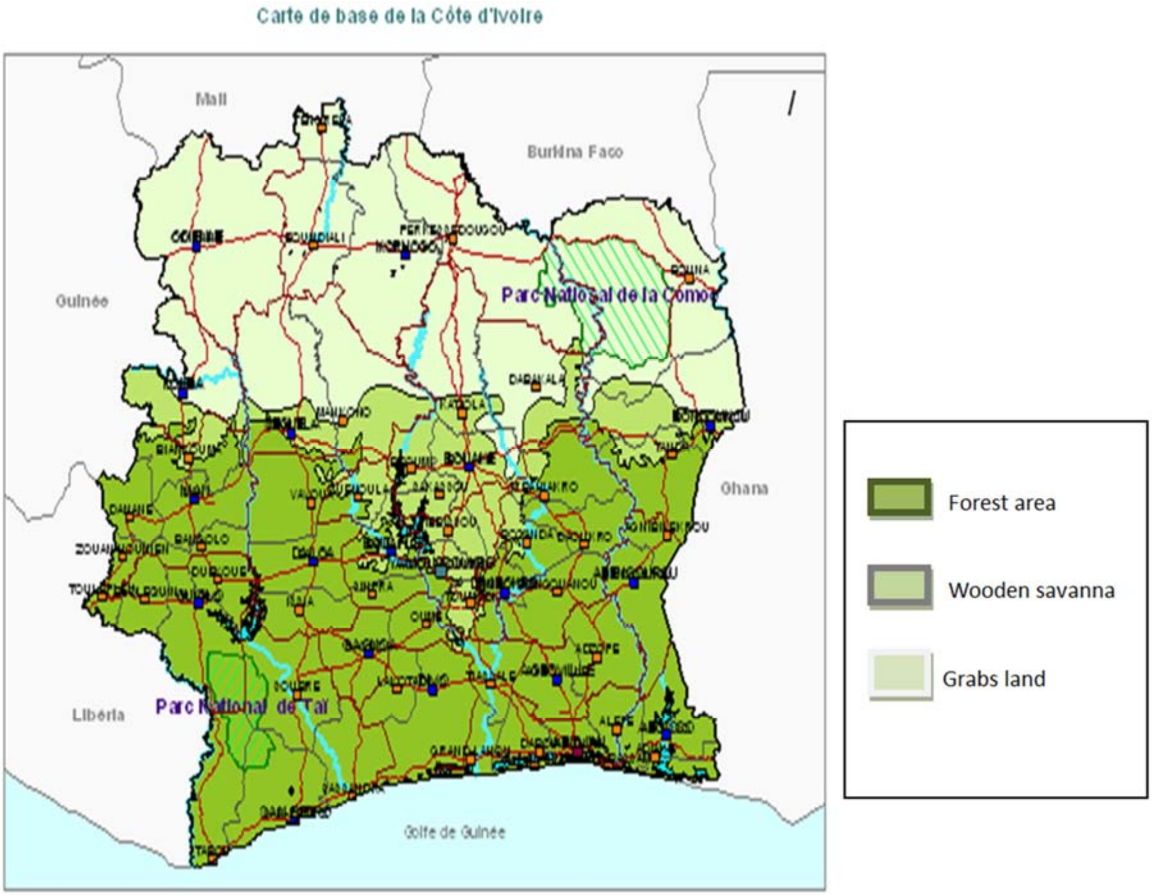


Figure 1. *Forest situation in Côte d'Ivoire, 1900 [9].*

The model is written as follows:

$$\text{Max } Z = \sum_{T}^{1960-2016}((1/(1+R0)T) * (RF(T) * D(T) + RA(T) * SA(T) - 0.30 * RF(T) * SR(T) + Fv * FO(T) * (1+R0)T) \quad (1)$$

Subject to:

$$D(T) + SA(T) + SR(T) + FO(T) = W*(1 / (1 + 0.005)\ T) \quad (2)$$

$$FO(T) + SR(T) >= 0.20*W(T) \quad (3)$$

$$SA(T) >= 0.8SA(T-1) + 0.40D(T-1) \quad (4)$$

$$FO(T) >= 0.15D(T-1) + SR(T-1) + FO(T-1) \quad (5)$$

$$D(T) >= D(T-1) * (1 + R7(T))T \quad (6)$$

$$D(T), SA(T), SR(T), FO(T) >= 0 \quad (7)$$

Where:

- Z is the sum of income from different land use
- SA(T) is the agricultural area at each instant.
- D(T) is the forestry (forest activities) area at each instant.
- SR(T) is the reforested area at each instant.
- FO(T) is the stock of forest area at each instant.
- R7(T) is the annual deforestation growth rate.
- R_0 is the social discount rate (the interest rate of the society).
- Fv is the value of the forest.
- RF(T) is the income per ha of used forest.
- RA(T) is the agricultural income per ha.
- T indicates that the parameters are function of time.

The equation (1) represented the total value or the sum of instant values from different uses of the land, from 1960 to 2016, where:

- $(1/(1+R_0))^T$ represents the factor of discount values.
- RF(T)*D(T) represents the instant income from forestry areas (harvest timber).
- RA(T)*SA(T) represents the instant income from agricultural activities.
- 0.30*RF(T)*SR(T) represents the estimated cost of instant reforestation activities, according to our surveys, considering the lack of transparence around the real values of these activities. In fact the unit cost of the reforestation is estimated at 1200 to 1600 USD per ha, according to the "Department in charge of Forest development in Côte d'Ivoire" (SODEFOR). This cost was overestimated because its setting took in account many factors that had no direct link to reforestation. To avoid this ambiguity, we used a survey to estimate the cost based on the income from one hectare of private forest.
- $Fv*FO*(1/(1+R_0))^T$ is the instant value capitalized with the social discount rate.

The other remaining equations are restrictions factors that are interpreted as follows:

Equation (2) stipulated that the sum of land allocated to different activities (agriculture, forest use or timber harvest, reforestation, forest stock) should always equal the total quantity of forest available at a given time. According to reference [10], 0.5% of lands are lost each year in the form of soil erosion or as urbanization effect.

Equation (3) indicated that the forest stock at a given time must be at least greater than 20% of the initial quantity of land forests, and this in order to preserve the amount of biophysical environment [11]. This supports the idea that a country must have as objective at least a 20% of forest coverage from its territory.

Equation (4) indicated that the cultivated forest area each year, is at least equal 80% of the previous year forest area cultivated increased with 40% as the current year deforested surfaces. In fact, our surveys indicated that each year farmers reuse 80% of their lands and seek new naturally fertile forestlands estimated to be 40%. This is what is translated in our equation (4).

Equation (5) indicated the level of forest stock represented by the regeneration of 15% of the previous year harvested areas in the previous year, plus the reforested areas in the current year, plus the forest stock from the previous year. From our interviews with SODEFOR, about 15% of forest-harvested lands become forest again, increasing the forest stock.

Equation (6) stipulated that forestland increases at a rate of $R_7(T)$ compared to the previous year surface. The intensity of forestland harvested has considerably varied in the past. Indeed, it has been intensive in the period of 1960-1970 with an average yearly increase rate of 16% before decreasing to 4% in the years 1971-1980; then it became negative from 1981 to1990. Since 1991, it's been a slow increase in the deforestation due a lack of timber. We estimated the forestland harvest rate at zero from 1996 until the end of our study.

Equations (7) are the conditions of non-negativity. They represent the boundaries allowing the modeling to run in the positive range.

The limit of this model is that it does not include the dynamic of a natural forest due to the lack of scientific data in Côte d'Ivoire. The model also considered as forest a recently reforested area.

4. Results and Discussions

4.1. Comparison of Optimal and Real Area of the Forest Stock

Optimum surface data obtained from our model relative to scenarios 1, 2, and 3 are compiled in table 1 below. The same data used in figure 2, reveal more the differences between real and optimum sizes of forestland.

Table 1. *Evolution of Real and Optimum Forest land areas according to scenarios 1, 2, 3 (x 1000 ha).*

Year	Real Forest area	Optimal Forest area Scenario1	Optimal Forest area Scenario 2	Optimal Forest area Scenario 3
1960	10680	2800	2800	2800
1961	10400	2821	2821	2821
1962	10120	2845	2845	2845
1963	9840	2874	2874	2874
1964	9560	2906	2906	2906
1965	9280	2944	2944	2944
1966	8985	2989	2989	2989
1967	8535	3040	3040	3040
1968	8100	3099	3099	3099
1969	7650	3168	3168	3168
1970	7200	3248	3248	3248
1971	6750	3340	3340	3340
1972	6300	3448	3448	3448
1973	5500	3560	3560	3560
1974	5400	3676	3676	3676
1975	5100	3797	3797	3797
1976	4800	3922	3922	3922
1977	4500	4053	4067	4053
1978	4200	4189	4217	4189

Year	Real Forest area	Optimal Forest area Scenario1	Optimal Forest area Scenario 2	Optimal Forest area Scenario 3
1979	3900	4979	4373	4331
1980	3800	5126	4536	4478
1981	3600	5279	4705	4631
1982	3300	5438	4881	4790
1983	3000	5589	5048	4941
1984	2700	5733	5206	5084
1985	2500	5869	5357	5221
1986	2200	5999	5500	5350
1987	2000	6122	5636	5473
1988	1900	6239	5766	5590
1989	1850	6350	5888	5701
1990	1800	6456	6005	5807
1991	1700	6556	6116	5907
1992	1650	6651	6221	6002
1993	1600	6747	6327	6099
1994	1500	6844	6435	6196
1995	1500	6943	6543	6294
1996	1500	7042	6653	6393
1997	1500	7142	6763	6493
1998	1500	7242	6874	6593
1999	1500	7342	6984	6712
2000	1500	7442	7095	6831
2001	1500	7542	7206	6949
2002	1500	7642	7316	7068
2003	1500	7742	7427	7186
2004	1500	7842	7537	7305
2005	1500	7943	7648	7424
2006	1500	8043	7759	7542
2007	1500	8143	7869	7661
2008	1500	8243	7980	7780
2009	1500	8343	8091	7898
2010	1500	8343	8091	7898
2011	1500	8343	8091	7898
2012	1500	8343	8091	7898
2013	1500	8343	8091	7898
2014	1500	8343	8091	7898
2015	1500	8343	8091	7898
2016	1500	8343	8091	7898

Source: Reference [9.] and author's calculation from the model

The results in figure 1 indicated that optimal surfaces from years 1960 to 1978 were considerably less than the real forest stock.

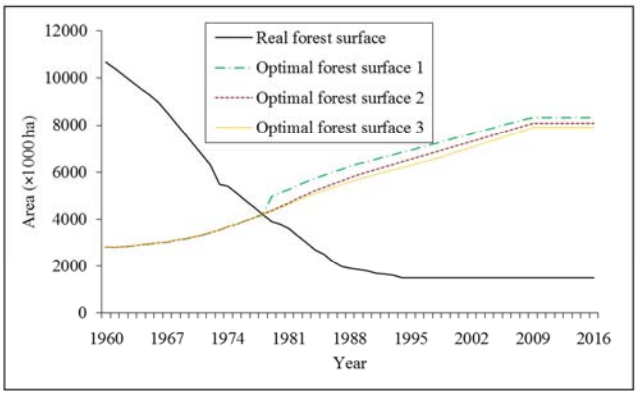


Figure 2. *Evolution of Real and Optimum Forest land areas according to scenarios 1, 2, 3 (x 1000 ha).*

As can be showed, that optimal solutions (optimal forest area) from 1960 to 2016, for all scenarios, have an increasing trend with a low slope. According to all scenarios, the optimal forest stock starts from 2,800,000 ha with a slow increase to between 7,898,000 and 8,343,000 ha.

The optimal forest stock increased slowly each year due to its capitalization (gains value). From 1960 to 1978, the optimal solutions were all identical expressing their total inelasticity with the incomes and social discount rates. After 1978, the optimal solutions seemed to become barely elastic with no significant difference.

Since 1960, the real stock of forest showed a sharp decrease to 1991 before stabilizing until 2016. For that period, the real forest stock decreased from 10,860,000 ha in 1960 to 1,500,000 ha in 2016 indicating the sharp decrease caused by demographic changes combined with the basic human needs (agriculture, firewood, charcoal), changes in forest use (use of qualified personnel, new technologies, increasing number of forestry companies), construction of specialized logging seaport (San Pedro), and the international timber price effect.

From 1960 to 1978, even with a sharp decrease, the real forest stock was greater than the optimal forest stock (amount of forest that should be kept, considering its economic value), indicating that the deforestation of forestlands, even without reforestation, was not damageable to the forest environment whatever the scenario.

In the other hand, since 1978, figure 1 showed that in all scenarios, the optimal forest stock was greater than the real forest stock. Since these forest entities (optimal and real forest stocks) were divergent in the negative way, we could suggest that the environmental balance has been interrupted because the level of the real forest stock in that period represented a harmful source to the environment. This discrepancy amplified increasingly until 2016. This observation indicated that the forestlands have not been allocated optimally and that their use was not efficient since 1978 (waste or abusive use of the forests). In fact, several factors could play in the explanation of the cause of this rapid disappearance of the real forest stock such as:

- *The lack of forestlands planning* for the multiple uses. In fact, during the colonial period, the Ivorian forests were so inhospitable that the colonists used them only as a means for financing the colony. Considering this inhospitable situation, the rural colonization of these forests was encouraged. After the country's independence, forestlands were considered as inexhaustible natural resources.
- *The failure of the forestry fiscal system* to induce good use practices from forest loggers. In fact, the forestry fiscal system should require good use practices during the issuance of harvest permits. In addition, the forestry fiscal system was under evaluated, encouraging overuse; it comprised numerous taxes that created difficulties for their collection by the government agencies due to insufficient funding. The increase of these taxes inclines to encourage overuse of forests as confirmed by reference [2, 12].
- *The low capacity of the Department in charge of the forestry to work* such as the weak qualification of the personnel, lack of new technology equipment for monitoring and control, complex and unrecognized political and institutional maps or framework, bad governance and law level of reforestation as confirmed by reference [13, 14].

All these weaknesses have lead to an abusive use of forests [9, 14]. According to several studies, the forest destruction rate during harvesting was estimated at 4.3m^3 for each m^3 harvested [9]. The use of a resource for which the accessibility or extraction cost is lower than the real use cost will lead to waste and unsustainable use of that resource [1, 14]. This affirmation supports on their wastage assumption [11, 12]. Indeed, the annual financial loss due to the wastage of timber resources was estimated at 200 million USD before the devaluation of the local currency (Franc CFA) in 1994.

The Figure 1 [9] and Figure. 3 [15], Figure 4 [15], below, shows the photographic changes of forest land in Côte d'Ivoire from 1900, 1955, 1988 and 2013. The green colors represent the forest land. The light green in figure 1 represents wooded savanna areas and grassland; The yellow color represent the fallows in Figure 3; The red color in the Figure 4 Represent the amount of forest land that disappeared from 2000 to 2012 according to reference [9, 15]

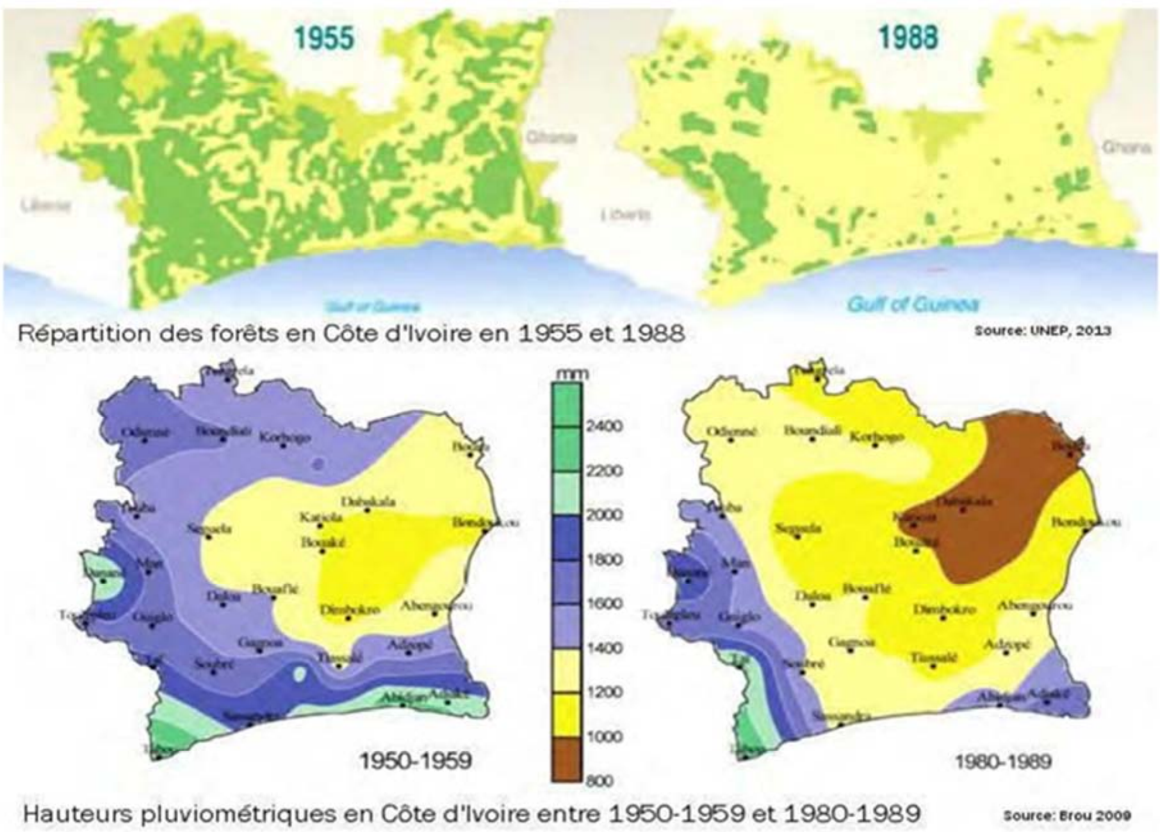
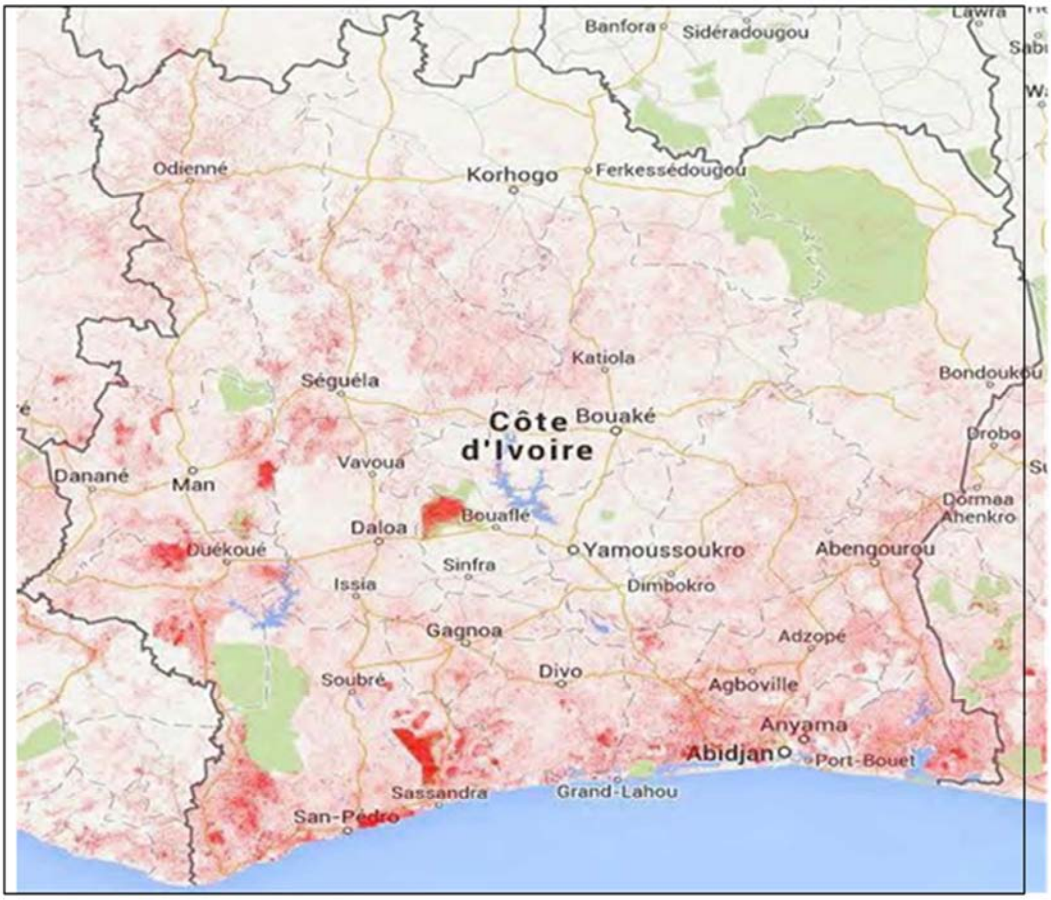


Figure 3. *Forest situation in Côte d'Ivoire, 1955 and 1988 [15]*



NB: Red color indicate the quantity of forest disappeared from 2000 to 2012.

Figure 4. *Forest situation in Côte d'Ivoire, 2013 [15].*

4.2. Comparison of Optimal and Real Area of Reforestation

The data for this comparison, between real and optimal total reforested areas are compiled in Table 2 and illustrated by Figure 2.

Table 2. *Evolution of Real and Optimal according to scenarios reforestation areas (x 1000 ha).*

Year	Real area Reforested	Optimal area Reforested Scenario 1	Optimal area Reforested Scenario 2	Optimal area Reforested Scenario 3
1960	12,835	-7880	-7880	-7880
1961	13,685	-7579	-7579	-7579
1962	14,56	-7275	-7275	-7275
1963	15,46	-6966	-6966	-6966
1964	16,41	-6654	-6654	-6654
1965	17,46	-6336	-6336	-6336
1966	18,61	-5997	-5997	-5997
1967	19,81	-5495	-5495	-5495
1968	22,06	-5001	-5001	-5001
1969	24,31	-4482	-4482	-4482
1970	26,56	-3952	-3952	-3952
1971	28,81	-3410	-3410	-3410
1972	31,06	-2852	-2852	-2852
1973	33,31	-1940	-1940	-1940
1974	35,56	-1724	-1724	-1724
1975	37,81	-1303	-1303	-1303
1976	40,06	-878	-878	-878
1977	42,31	-447	-433	-447
1978	44,56	-11	17	-11
1979	46,81	1079	473	431
1980	49,06	1326	736	678
1981	51,31	1679	1105	1031

Year	Real area Reforested	Optimal area Reforested Scenario 1	Optimal area Reforested Scenario 2	Optimal area Reforested Scenario 3
1982	53,56	2138	1581	1490
1983	57,06	2589	2048	1941
1984	61,56	3033	2506	2384
1985	66,56	3369	2857	2721
1986	71,56	3799	3300	3150
1987	76,56	4122	3636	3473
1988	81,56	4339	3866	3690
1989	86,56	4500	4038	3851
1990	91,56	4656	4205	4007
1991	96,56	4856	4416	4207
1992	101,56	5001	4571	4352
1993	106,56	5147	4727	4499
1994	111,56	5294	4885	4646
1995	116,56	5393	4993	4744
1996	121,56	5492	5103	4843
1997	126,56	5592	5213	4943
1998	131,56	5692	5324	5043
1999	136,56	5792	5434	5162
2000	141,56	5892	5545	5281
2001	146,56	5992	5656	5399
2002	151,56	6092	5766	5518
2003	156,56	6192	5877	5636
2004	161,56	6292	5987	5755
2005	166,56	6393	6098	5874
2006	171,56	6493	6209	5992
2007	176,56	6593	6319	6111
2008	181,56	6693	6430	6230
2009	186,56	6793	6541	6348
2010	191,56	6793	6541	6348
2011	196,56	6793	6541	6348
2012	201,56	6793	6541	6348
2013	206,56	6793	6541	6348
2014	211,56	6793	6541	6348
2015	216,56	6793	6541	6348
2016	221,56	6793	6541	6348

Source: References [9, 17] and author's calculation from the model

Figure 2 below indicated that from 1960 to the reference date of 1978, economically the recommended deforestation rate related to forest and agricultural activities should have been at an annual optimal varying roughly from 300,000 to 430,000ha [9]. The optimal reforestation area from 1960 to 1978 did not vary according to the three scenarios, which means that the reforestation was totally inelastic to the financial forest value and the social discount rates. It seems that the annual deforestation rate estimated at 300,000 ha [9] was sustainable before 1978, but not after.

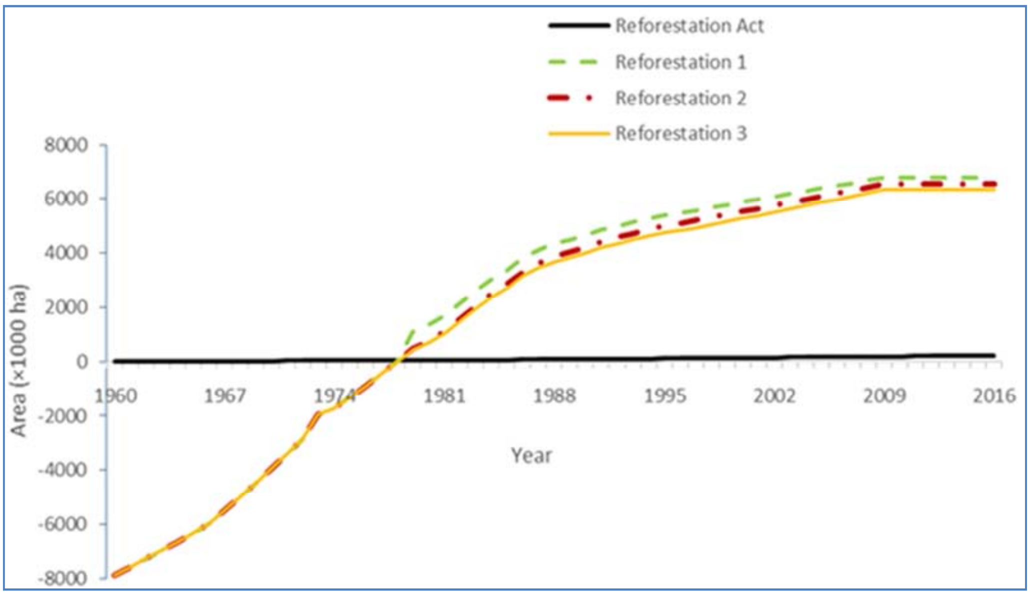


Figure 5. *Evolution of Real and Optimal according to scenarios reforestation areas (x 1000 ha).*

As the gap between the optimal forest area and the real forest stock since 1978 increased (Fig. 1), the need for a rapid reforestation of affected areas to reach a balance increased. Consequently, figure 5 indicated that economically the optimal recommended rate of reforestation to reach a balance should be varying roughly from 99 000 to 500 000 ha/year (Table 3). We also observed that the optimal reforestation rate was inelastic compared to the financial value of the forest and the social discount rates**.** As well, the cumulative areas to be optimally reforested increased slowly and became constant at 6,348,000 or 6,793,000 ha according to the scenarios. The reforestation achievements realized by the government since 1960 varying annually from between 2,000 and 3,500 ha to exceptionally 7,000 ha in 1997 and resulting in the reforestation of 180,000 ha since 1960 [14] compared to the annual optimums of reforestation (99,000 to 500,000 ha/ha) and the level of optimum reforestation (6,793,000 ha) respectively, reflected the insignificance reforestation operations undertaken by the government and subsequently the difficulties to reach an environmental balance.

Regarding the government's failure in the reforestation experiment through Ivorian State Company for Forest Development (SODEFOR), with a high cost of mechanized reforestation (1200 USD to 1600 USD according to this State Company) that limited reforestation areas to an average of 5,000 ha in contrast to the urgent need to reconstitute the forest stock of the country, the paid community reforestation in a form of civil education seems to be an alternative choice, which has been long used in western Canada. This alternative will encourage participants (villagers and students from primary school, high school, and universities and unemployed people) to join the experiment and will minimize the risk of failure experienced by the mechanized method of SODEFOR. This paid community and civil reforestation, in contrary to the industrial reforestation applied by SODEFOR, should be encouraged. In the past, the reforestation by villagers did not succeed in Côte d'Ivoire because of the following factors:

- The objective of that previous experiment was to encourage farmers to perform reforestation of their own lands, which was not part of their daily duty habits. In addition, these reforestation activities were in conflict with farming activities, which provided quicker income.
- The reforestation by farmers was perceived as a volunteer act and was not paid by the authorities.

Concretely, we could propose the following plan for the community and civil paid reforestation. With our survey indicating that the plant nursery was estimated at 16 cents a plant, by proposing 1 cents the planting of a tree (the equivalent of 18 cents for 250 plants per ha), the cost of the reforestation would be estimated at 75 USD the hectare which covers 35 USD for the salary and 40 USD for plant production at the nursery.

As the optimal cumulative reforestation was estimated at 6,793,000 ha for all scenarios, a reforestation on a 10-years plan would re-establish the forest stock to its optimal, starting from 2016 at a rate of 680,000 ha/year with an annual reforestation budget of 51 million USD. That budget would represent 0.5% of the GDP, which is less that the financial loss due to deforestation at 500 million USD representing 6% of the GDP [14]. Working 22 days each month per person, this reforestation operation should target students and pupils during the school holidays (July to August) and create 30,877 jobs with monthly income of 384 USD per person. The plant production by nurseries should be accomplished mainly by rural primary schools near reforestation sites as experimental gardening work using special technical manuals under the supervision of teachers and Waters and Forests Department agents (Ministry), Participants should include out-of-school people. Each nursery could produce plant to reforest 500 ha which could be estimated at 1360 nursery Centers receiving 20 000 USD each.

The economic impact as recommended by references [9, 15, 16] of such a project will be considerable, as the income perceived by the students would alleviate school fees disbursed by parents at the beginning of each school year and the project being a tool to teach students how to be autonomous. Another advantage would be the migration of unemployed youths in cities towards the countryside at each school break, reducing insecurity and delinquency in cities. In addition, the reforestation activities will allow youths to acquire arboricultural knowledge and the usefulness of the environment. The 20 000 USD could cover the often-needed small material expenses such as chalk, rulers, school chairs and tables, notebooks, soccer balls, uniforms, etc. for schools and would represent employment, opportunities for small businesses, a disincentive to youth exodus to big cities, and the consideration for trees and the environment.

Table 3. *Annual Real and Optimum reforestation areas according to scenarios 1, 2, 3 (x 1000 ha).*

Year	Real area Reforested	Optimal area Reforested Scenario 1	Optimal area Reforested Scenario 2	Optimal area Reforested Scenario 3
1960	0,835	-301	-301	-301
1961	0,85	-301	-301	-301
1962	0,875	-304	-304	-304
1963	0,9	-309	-309	-309
1964	0,95	-312	-312	-312
1965	1,05	-318	-318	-318
1966	1,15	-339	-339	-339
1967	1,2	-502	-502	-502
1968	2,25	-494	-494	-494
1969	2,25	-519	-519	-519

Year	Real area Reforested	Optimal area Reforested Scenario 1	Optimal area Reforested Scenario 2	Optimal area Reforested Scenario 3
1970	2,25	-530	-530	-530
1971	2,25	-542	-542	-542
1972	2,25	-558	-558	-558
1973	2,25	-912	-912	-912
1974	2,25	-216	-216	-216
1975	2,25	-421	-421	-421
1976	2,25	-425	-425	-425
1977	2,25	-431	-431	-431
1978	2,25	-11	17	-11
1979	2,25	1090	456	442
1980	2,25	247	263	247
1981	2,25	363	369	353
1982	2,25	459	476	459
1983	3,5	451	467	451
1984	4,5	444	458	443
1985	5	336	351	37
1986	5	430	443	429
1987	5	323	336	323
1988	5	217	230	197
1989	5	175	172	165
1990	5	156	167	156
1991	5	200	211	200
1992	5	145	155	145
1993	5	146	156	147
1994	5	147	158	147
1995	5	99	108	98
1996	5	99	499	99
1997	7	100	110	100
1998	5	100	111	100
1999	5	100	110	119
2000	5	100	111	119
2001	5	100	111	118
2002	5	100	110	119
2003	5	100	111	118
2004	5	100	10	119
2005	5	101	111	119
2006	5	100	111	118
2007	5	100	110	119
2008	5	100	111	119
2009	5	100	111	118
2010	5	0	0	0
2011	5	0	0	0
2012	5	0	0	0
2013	5	0	0	0
2014	5	0	0	0
2015	5	0	0	0
2016	5	0	0	0

Source: Reference [11.] and author's calculation from the model.

5. Conclusion

We conclude from this study that:

- The level of real forest stock has decreased drastically from 10,860,000 in 1960 to 1,500,000 ha in 2016 while the optimal forest stock, when compared to the financial value and the interest society could confer to it (*social discount rates*) has increased from 2,800,000 to 8, 343,000 ha for the same period. The implementation of our model was used to estimate this value of 8343000 ha, which represents the forest stock necessary to ecological balance of the country. Compare this optimum value of ecological balance, in the current area of forest stock estimated to 1 500 000 ha nowadays, according to the Ministry of Agriculture, reflects the large deviation from the equilibrium point. This reference value also, illustrates the need for rehabilitation of Ivorian forest capital.
- From 1978, the optimal forest stock was greater than the real forest stock with an increasing gap each year, indicating the period of disruption of the ecological balance. This suggested a desperate need for reforestation, which annual optimal value varied from 99,000 to 500,000 ha, according our model, while the realizable annual reforestation rate, according the World Bank and the Ministry of Waters and Forests [17], varied yearly from 2,000 to 7,000 ha. This new reference which is the optimum value of reforestation, also shows a big gap with the reforestation practices of

the Government through the State Department for Forest Development (SODEFOR). Indeed SODEFOR reforestation practices are most costly and limits the chances of reaching the balance point. That is why, we proposed an alternative cheaper and faster.

- A paid community reforestation remain the best alternative and will encourage participants (village pupils, students, out of school youths, unemployed people) and minimize risks of failure of this model of reforestation in comparison to the expensive and off state capacity mechanized model used by Ivorian State Company for Forest Development (SODEFOR). For an estimated cost of USD 51 million, according to our estimate, it is possible to reconstitute the forest capital very quickly and easy, so to avoid losing $ 500 million every year as environmental cost due to drastic deforestation of the country.
- The determination of these references (optimum forest stock for an ecological equilibrium and optimum reforestation) would help the government adjust its resources for future forest recovery projects, as initiated by the references [15 and 16], in order to significantly revitalize the agriculture and forestry sector, which is the main pillar of the country's economy and the principal jobs provider. One advantage of this strategy will be to considerably decrease the rural exodus.

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