

## GEOINFORMATION FOR SUSTAINABLE DEVELOPMENT

### SPATIAL AND STRUCTURAL ANALYSIS OF DEFORESTATION IN AN URBAN AREA SINCE 1950: THE POINTE-NOIRE CASE STUDY (R. OF CONGO)

Aline FABING\*, Marc SIMARD\*\*, Philippe MAYAUX\*\*\*

\*CEREG, University of Strasbourg, France

[fabing@geographie.u-strasbg.fr](mailto:fabing@geographie.u-strasbg.fr)

\*\*JPL, NASA, LOS ANGELES

[simard@innu.jpl.nasa.gov](mailto:simard@innu.jpl.nasa.gov)

\*\*\*Africa Coordinator - TREES Project

Global Vegetation Monitoring Unit - Space Applications Institute

DG Joint Research Centre - European Commission, Ispra (VA); Italy

[philippe.mayaux@jrc.it](mailto:philippe.mayaux@jrc.it)

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#### ABSTRACT

Nowadays several discussions exist about the dramatic expansion of environmental degradation and the solution considered is sustainable development. This requires a great knowledge of the ecosystem pattern, processes and predictability as well as information about the relationship between environmental and human factors. It needs to link spatial pattern and ecological processes at broad spatial and temporal scales. In this purpose, one way is to identify and quantify the environmental and anthropological factors in order to assess the relationship between population and natural forest resources, through the establishment of a physical as well as a human factor balance. The emphasis has been placed on a strategic method in order to improve environmental information and to provide a reliable support for natural resources management. This was done by establishing maps predicting deforestation risks. The predicted African urban expansion for the next decade as well as the emergency and renewed interest in the environmental problematic confer a real significance to this paper. The results permit us to know where natural forest transgresses and in what quantities in six characteristic training zones. How much of this forest has disappeared since 1950 under population and urban pressures and what is the nature of these human pressures? This analysis is required to extrapolate information across scales (temporal and spatial) in order to provide, through dynamic predictive modelling, deforestation predictability support for reasonable landscape management.

#### RESUME

L'étude dont il est question ici est étroitement liée, à l'échelle globale, au problème de dégradation de l'environnement et de gestion durable. Elle répond à un besoin important de connaissances à l'échelle actuelle du fonctionnement des écosystèmes ainsi que des processus qui lui sont inhérents. Les objectifs de ce travail ont été d'identifier et de mesurer les différents facteurs environnementaux et anthropiques pour pouvoir dresser un bilan des interrelations entre la population et la ressource forestière naturelle. En établissant, d'une part, le bilan spatial des formations naturelles et, d'autre part, le bilan des facteurs anthropiques. Il s'agit d'une approche stratégique pour améliorer l'analyse des informations environnementales et proposer un support fiable pour une meilleure gestion du milieu forestier. Elle consiste en l'occurrence à l'établissement d'une carte des risques de dégradation forestière. Pour cela, on a mis à contribution l'outil télédétection (traitement d'images radars (JERS) et de photographies aériennes), système d'information géographique, modélisation, enquêtes et vérification terrain. Les résultats obtenus nous permettent de localiser et de quantifier la transgression forestière ainsi que la déforestation dans six zones tests sur le littoral congolais dans le but fournir un modèle dynamique de prédiction des risques de déforestation.

## INTRODUCTION

Nowadays several discussions about the dramatic expansion of environmental degradation guide to a solution of sustainable development. This concept, developed at the Rio conference (1992), has as purpose (through a dextrous natural resources management) the protection of the future generations and, to ensure the sustainability of natural resources. Furthermore, this kind of objective needs a great knowledge of ecosystem patterns, processes and predictability as well as information about the relationship between environmental and human factors. It needs to link spatial pattern and ecological processes at broad spatial and temporal scales.

It also has to be realized that recent past change might be identified and measured in a descriptive way while future change can only be modelled in a predictive manner. In this framework, this work deals with deforestation risks in a representative urban expansion area, which is the south Congo littoral. This area is subject to population pressures on the forest environment. Therefore we have chosen six training zones where different patterns have been isolated since 1951.

The first step consisted of the identification and the quantification of the environmental and anthropological factors that occur in this area. Photogrammetric and remote sensing procedure were used in combination with ground truth inquiries to assess the relationship between population and natural forest resources, through the establishment of physical as well as human factor balance.

In the second step, the emphasis has been placed on a strategic method in order to improve environmental information and, to provide a reliable support for natural resources management via dynamic modelling prediction. This, by establishing maps predicting deforestation risks. The discussion will focus on the advantages and inconveniences of this procedure, on the actual human and environmental assessment and on the reliability of such aid to decision in environmental preservation in developing countries.

We will first be acquainted with the area of interest and the context, followed by the presentation of the materials and method and, finally the results and discussion on the matter.

## AREA OF INTEREST AND CONTEXT

### 1.1 The Congolese littoral

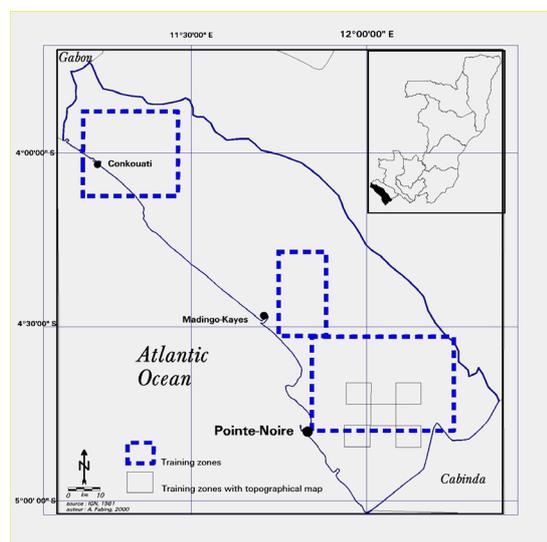


Figure 1. Study area localisation

The Congolese littoral area is located at the Southwest of the Republic of Congo (Figure 1). The study area covers roughly 170x60 km<sup>2</sup>, centred at longitude 11°45'00'' E and latitude 4°15'00'' S, respectively. The Gabon delimits it on the north, the Cabinda on the south, the Atlantic Ocean on the west and the Mayombe chain on the east.

The major features in this area are secondary littoral forest galleries, hydromorphic forest and savannah mosaic. Other land use present in this area for supporting local settlement and economic production are agricultural activities for bananas, oil palm, manioc, groundnut, pineapple, and eucalyptus plantations but also fuel wood consumption (Venetier, 1968).

### 1.2 Context

In the Congolese littoral study area, two opposed dynamics are confronted: a forest transgression which is known for a long time (about 100 meters per century) versus a human expansion irregular in time and space, this in a stable climatic context favourable to the forest transgression (Bigot, 1996).

Thus, the consequence of the demographic explosion (C.N.S.E.E, 1980, 1988; D.S.D.S., 1989; I.N.S.E.E., 1961) and the rural exodus, throughout disproportionate migration flows, is an urban concentration, which has environmental effects. These repercussions are the following:

Increase of human pressure on the rural fringe of about 100-km (Fabing in redaction). In these areas forests are frequently replaced by degraded formations, which have no time to develop into a secondary forest stage. This depends on many factors: shifting cultivation (reduced fallow time), fuel wood (firewood and charcoal exploitation to supply the Pointe-Noire agglomeration. Even along the road network, the human settlements and the associated agricultural extension impose constraints on the forest resource (degradation in a belt of 5 to 10 km around the villages.).

On the other hand, areas that are far away from the agglomeration became human deserts in which forest transgression is possible while only bush fire stops this expansion. Logging has an inconsequential effect on the forest degradation in the case where there is no agricultural continuum.

### 1.3 Objectives

In this context, we defined different objectives in order to develop the adequate procedure to improve the decision support for sustainable development. These objectives are the following.

First, to establish a spatial assessment of the antagonism between natural forest dynamics and population pressures (example of the urban expansion and its consequences on the environmental resources at a regional scale) through remote sensing treatment, GIS analysis and interpretation.

Second, to identify and quantify the effects of human organisation and activities on the forest resources through field researches and remote sensing analysis.

Third, to provide a reliable support for natural resources management by maps predicting deforestation risks via dynamic predictive modelling.

Fourth, to take into account political and individual solutions concerning the forest degradation problem.

## MATERIAL AND METHODS

### 1.4 Material

To meet these objectives, and to analyse the spatial and temporal changes in landscape patterns, photogrammetric and remote sensing data were used.

#### 1.4.1 Data choice.

The aerial photographs have been chosen since they are the only data that exist and, give information fifty years ago. The resolution is about 5 meters. For the SAR data, the potential and capability for mapping and monitoring natural resources is already widely known, particularly in the persistent cloud-covered humid tropic region like Congo. JERS-1 data may provide appropriate metrics (pixel of 12.50 meters) for a meso-scale study and the L-band data are useful for regional vegetation changes and as an information source for tropical environment monitoring. We have three multi-date images from one area. The study concerns restricted zones appropriate for the understanding of most typical cases (figure 1).

The ground work has been defined on socio-economic inquiries (fuel wood consumption, agricultural practise, environmental perception) and, physical inquiries like carbon 13 sampling along 100 meters transects for each case complemented with botanical investigations. Also this work was supplied with bibliographical researches (literatures and administrative documentation).

### 1.5 Methods

Two methods were used: descriptive methods, which may allow to assess accurately past change (1951-1996) but are dependant on the availability of recent data or information, and predictive method, which may use historical data to estimate past and present changes when recent data are not available, as well as future change, through the use of

model. The main advantages of such methods are the richness of the thematic content and the possibility to describe the field processes. But the main limitations are related to the difficulty to quantify the reliability of the information.

### 1.5.1 The spatial indicators of forest cover change

The criteria we chose were population change (i.e., migration, increase, location), accessibility schemes (i.e. road network), the land use practices (i.e. logging, agriculture (i.e. shifting cultivation, fuel wood production)), socio-economic, political and cultural information i.e. (environmental perceptions) for the human factor (Thumerelle, 1996); physical and climatic information for the natural factors.

The in-depth analysis of such criteria allows the definition of spatial indicators of forest cover change, which were used as input in the spatial model. These indicators might be direct and indirect and have to be obtained through remote sensing and photogrammetric data as well as through ground research and inquiries. Multivariate analysis requires the input of these factors, which consists in selecting those spatial variables that are most correlated with the observed changes. The methodology for the identification and analysis of these factors is adapted from a hierarchical structure approach in order to compare these results with other researchs (FAO, 1997, TREES, 1998). The figure 2 resumes the approach we followed.

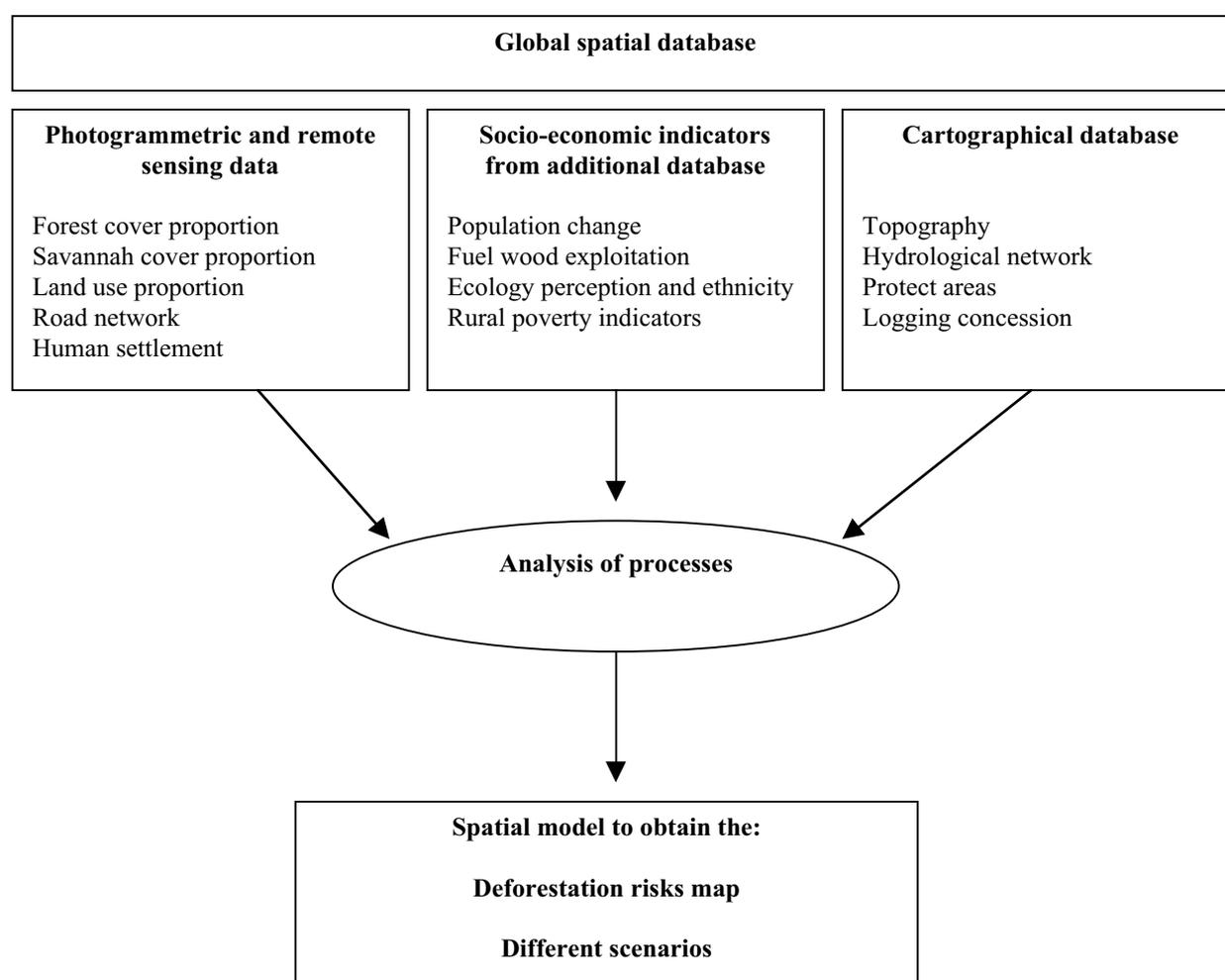


Figure 2: Theoretical approach for the establishment of the deforestation risks map.

## RESULTS AND DISCUSSION

As results we obtain maps where areas with recent deforestation indicate different speed of forest cover change (high, medium, low) and different forest status (dense, fragmented, low density). These results show where natural forest transgresses and in what quantities; how much of this forest has disappeared since 1950 under population and urban pressures. We verified these results with field research as physical sampling, inquiries about fuel wood and agricultural exploitation and the general perception of this problem.

## 1.6 General description

The region is actually relatively stable in terms of present deforestation, it is more suitable to talk about forest degradation (usually transformed in bushes). Land-use change particularly over the last 20-30 years has been largely responsible for the forest extent and conditions of its actual patterns.

In our area, gallery forests are accessible and are subject to strong pressure, on the other hand there are hydrological barriers (Kouilou and Loeme rivers) where forest is stable or transgresses. The annual rate of deforestation is estimated at 0.6 percent for Central Africa (FAO, 1997).

In our area, this rate depends on the location, the speed of forest cover change is variable. In the north, above the Kouilou river the forest transgression is about 0.03 % per year, 0.020 % per year at the east of the Loeme river. Close to Pointe-Noire, gallery forest is transformed in agricultural zones and disappears, it loses 0.023 % per year since 1951 while under intensive exploitation. On the other hand, the agricultural areas gained about 0.08 % per year.

### 1.6.1 Forest evolution since 1950, a contrasted assessment: Urbanisation and land desertification

The main observation and measure we could make was the imbalance between rural and urban areas, the first became a human desert and the other cumulated all human flows. This allows us to notice that deforestation and forest degradation are concentrated along the road network since the access to the forest is facilitated by the tracks opened by logging companies. But as soon as we go into the land, we can observe forest stagnation but also transgression without any human interference (fire bush). Likewise, if population pressure is not important and/or far away from Pointe-Noire, forest tracks can close in ten years of time. Anyway, the primary cause being the demand of food supplies for the Pointe-Noire City.

### 1.6.2 Structural balance: which interrelations?

The deforestation and land degradation are a combination of factors, the process of forest colonisation is the following: logging companies, exploiting government concessions open the forest with creating primary and secondary roads. With the increase of food products (manioc, bananas etc.) requirement in the city, people settle along the roads and initiate the trade of these products, which can generate a colonisation within the primary forest. With food products is also associated fuel wood production since urban people conserve the rural usage. This last factor is determinant on the amplitude and velocity of forest degradation. One new factor is growing up: civil war, which has driven several hundreds of thousands of people into the Pointe-Noire area, where they contribute to the pressure on the forest (1997) in order to subsist and to earn money, fuel wood production is their first activity.

### 1.6.3 Particular case

The south Conkouati's particular case: an Asian logging company has acquired a concession in 1992 from the Congolese government. These concessions are nearby harbour facilities, which reduces considerably the transportation costs. The concession can then log less expensive species, since transportation costs represent up to 50% of the total timber cost. It means that there is danger of intensive logging in this location, and possibility of clear-cutting (TREES, 1997). Actually and with the civil war this company has disappeared while there is no trace of clear-cutting on the radar data but the inquiries on the ground confirm that fact.

## 1.7 Discussion

### 1.7.1 The main factors

#### 1.7.1.1 Growth of human pressure... risks...

Population growth is probably the main factor of deforestation, but the economic conditions of the region are considerably degraded since 15 years, what has led to a comeback of urban inhabitants to the rural areas. Natural resource exploitation is often the only way for rural and also urban people to ensure their subsistence, since other economic activities do not exist. A distinction of urban and rural people is necessary in order to describe the deforestation process. An increase of rural population leads to a reduction of the fallow duration and, in the midterm, to land degradation. It often takes place in the secondary forest but when the population pressure becomes stronger, primary forest can be attacked. An urban population growth (natural growth and migrations) increases the food demand and creates an economic market which initially is a subsistence system: in this way the impact on deforestation depends on the accessibility, and therefore on the road network quality.

### 1.7.1.2 Fuel wood extension

Deforestation is mainly associated with the supply in fuel wood for the city: it becomes an easy way to earn money, and is the principal activity of the migrants out of the civil war (refugees village where the main activity is the charcoal production). An interesting factor has to be specified, the eucalyptus plantations, which reduce the impact on the natural forest. The Eucalyptus of Congo decided to sell old plots in order to make them profitable: this wood quality was accepted by the population, therefore it is a positive factor.

### 1.7.1.3 Logging concessions

The logging concessions do not represent a major risk of deforestation, usually they exploit a few valuable species (Niove, Okoumé etc.) without drastically reducing the canopy cover. On an other hand, logging operations open new forest tracks for exploitation: cultivators use these new openings to penetrate into deep forest.

### 1.7.1.4 Fires

Burned areas are often found in secondary forests, since regular fires are important components of the shifting cultivation system, these fires are spatially limited by the forest-savannah boundary but can be amplified by the wind.

### 1.7.1.5 Transportation network

Two parameters are important: the quality and the delineation of the road for its contribution to deforestation, it helps to know where deforestation can occur. It is difficult for local people to find a car because of the expensive costs, people have to travel together to reduce their costs and to transport the agricultural and fuel wood production. In the eucalyptus plot cases, the company organised also this traffic. This is a natural way to interest the population on eucalyptus wood.

## 1.7.2 Prevision tools: the model predictable scenarios

We can classify the different scenarios in two categories: the positive and the negative evolutions. In the first case, two situations can be imagined: an extension of both protected area and eucalyptus plantations in which one secondary forest regrowth can be observed. The second solution is an ideal situation of a natural resource management without any need to protection.

In the second case, different factors can produce the increase of forest degradation: the continuum of the urban/rural imbalance; the development of secondary centres; an economical increase with logging and agricultural development and finally an economical decrease due to civil war. In these cases, the deforestation risks map has as purpose to determine at first where the deforestation hotspot could be located first; secondly to heighten people awareness of this problem and try to explain them which areas have to be taken as fallow and could be exploited.

The major problem that will appear is how to explain that 15 to 20 years are necessary for sustainable management to local population? But also, how to manage the land ownership if there is the owner, the tenant? Who has to be warned?

## CONCLUSION

Through the identification and the quantification of the environmental (forest/savannah cover, figure 2) and anthropological factors (settlement location, road network and population changes) it was possible to establish an assessment of their interrelations and to analyse the connected processes (development along logging road network, Pointe-Noire food and fuel wood supplies). The emphasis has been placed on a strategic method in order to improve environmental information and to provide a reliable support for natural resources management.

This procedure has as major advantage an exhaustive study of the factor combination that occurs in this theme, and provides a synthetic support for sustainable management as well as future changes. Other advantages are the limited costs (use of aerial photographs and radar images) and the easy use of this procedure in developing countries. The main inconveniences are the availability of recent information (civil war) and the non-spatial data acquiring (sporadic data).

The project to produce deforestation risks map, which identify the principal areas that could be deforested throughout the different scenarios is reliable. It has to add other studies such as inquiries about local population reactions in front of a 15 years fallow time, the old cultural and modern ownership procedures, and the knowledge of the psychological factors like the relationship with money.

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