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# Urban Growth and Deforestation by Remote Sensing in the Humid Tropical Forest of Congo Bassin: Case of Impfondo in Republic of Congo

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## Abstract

Urban growth is identified as one of the main deforestation drivers and land degradation in tropical region. Very few data exist to quantify the impact of this drivers. The aims of this study were: (i) estimating the activity data of the growth of the city's Impfondo in the period between 1986 to 2016; (ii) determining the indirect drivers of that urban growth. This study is carried out in Impfondo. The remote sensing and GIS techniques were used to assess urban growth and its impact on deforestation and degradation of the forest around and in Impfondo the period between 1986 and 2016. Landsat images were used; specially 2 images Thematic Mapper (TM) of 1986 and Operational Land Imager (OLI) of 2016. ERDAS 2014 software was for images classification, classification and calculation of forest lost area during this growth. Additional field survey was made to collect truth GPS ground points. As result, the urban tram area growth from 267.86 ha in the year 1986 to 859.68 ha in the year 2016. This study showed the impact of urban growth on deforestation on the one hand and on the other hand stress considering this factor in mitigating the effects of climate change.

## Keywords

Forests, Deforestation, Remote Sensing, Urban Growth, Impfondo, Republic of the Congo

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## 1. Introduction

The forests of the Congo Basin extend over nearly 200 million hectares and 90% of the forest consists of dense tropical forests. More than 99% of the forest surface consists of primary or naturally regenerated forests, as opposed to plantations. These tropical forests are characterized by significant biodiversity [1, 2, 3]. However, these forests suffer from both quantitative and qualitative loss of biodiversity resulting. However, these forests suffer a loss both quantitatively and qualitatively because of deforestation and forest degradation [4]. with significant impacts on the sustainability of tropical forest ecosystem. Although some authors [5, 4] consider that the Congo basin forest are relatively well preserved, the deforestation rate (0.17%) is far below in comparison with one observed in the others tropical regions e.g Amazonian forest. The rate of deforestation in Amazonian forest reached 0.4% per year annum [6]. in the past decades. Deforestation and degradation have significant impacts on plant biodiversity [1] and contribute approximately to almost 18% of global greenhouse gas emissions [7-10]. Several authors have reviewed the causes of deforestation and degradation in the tropics [11, 12], and shown that agriculture, logging activities were identified as

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the main drivers.

In the Republic of Congo (RoC), the annual deforestation rate growth from 0.02% in 1990-2000 to 0.03% in 2000-2010 [13]. This deforestation is unevenly distributed throughout the national territory of RoC. It has been noted in some departments of RoC that the rates of deforestation were much higher than the national average rate. For 2000-2010: The department of Kouilou had a deforestation rate of 1.78%, while in the other departments (Lekoumou, Niari and Pool) the rate of deforestation was 1.06%, 1.35%, 0.91% respectively). Several factors were identified as the source of forest losses in the Republic of the Congo, including: agriculture, infrastructure development, wood energy collection and urban growth, etc [24]. Urban growth also explains the significant losses of forest due to the consumption of building materials and the land use for house building and rural activities developments.

Urban land expansion is placing a formidable challenge in many countries around the globe, especially in terms of their link with deforestation and land degradation in intertropical region where many cities were developed inner deep tropical [14, 13]. According to a report submitted by the REDD + MDDEF-GAF pilot project "Monitoring National Forest cover" in the Republic of the Congo, the second major drivers of Deforestation is the expansion of residential areas (including logging roads), causing 14% of the changes in forest cover in the Republic of the Congo in the period of 2000-2010. This study had shown the bond which existed between the zones of conflicts and the increase in the of the population in the localities having which had received the refugees of civil war come from bordering countries. Urban land expansion a universal phenomenon that has known and is currently experiencing a acceleration in Africa and mainly of the republic of Congo [15, 05]. As urban growth is concerned, several factors have been identified: the population increase, rural exodus, civil war and conflicts with migratory phenomena accompanying it in some Central Africa countries, Poverty stricken in the rural area, the development of social and economic of cities [16, 17, 13].

Observations in some countries of the Congo basin revealed that African cities are spreading and taking over natural spaces. In the Republic of the Congo, a recent study highlights the causes of urban sprawl: population growth, land-use planning, accelerated municipalization and residential sprawl have participated to the transformation of the landscape from south of Country until the North of territory. This study also showed how urban sprawl in a forest town, the city of Ouesso, has resulted in significant forest losses [15]. Other regions of the Republic of the Congo experienced in the years 1990 and 2000 to 2010 an important development of urban space due to the large flow of refugees from neighbouring countries, such is the case of the urban community of Impfondo.

The Impfondo city was created on December 12$^{th}$, 1920 and is the head quarter of the Likouala region. Historical data collected in the field revealed that this urban community was originally a camp of fisherman settled on the Ubangi River. In addition, this camp was plunged into a forested area. This urban community has widened with time attracting the populations of the villages scattered around. Also, the arrival of the first catholic missionaries help in promoting the administrative organization of this locality.

The present study aimed at quantifying the areas of forest loss because of the development of this local urban community. To date, starting from the official date of the creation of the Impfondo city, how much was the evolution of the urban community? What factors contributed to its development?

The following assumptions were made: the growth of the urban community of Impfondo and its related would be the main cause of forest loss in that community; Population growth, migratory population flows would justify this urban expansion and thus deforestation in the study area. The objectives of this study were to assess the impact of urban growth on the forest and to determine its immediate and structural drivers.

## 2. Materials and Methods

### 2.1. Presentation of the Study Area

The study was carried out within the tropical rainforest of the North of Congo Brazzaville in the department of Likouala (Figure 1). The zone of study covers a total surface of 155274 ha. It lies between 1∘ 27’ 52.85” and 2∘ 6’55.76” of northern latitude and between 17∘ 52’ 35.04” and 18∘ 04’32.65” of longitude. The climate of the study area was of equatorial type. Mean rainfall is of 1760 mm $y^{-1}$, with a dry season from December to January and a long-wet season from March to November (Figure 2). In the Dongou district, the soil cover is of tertiary clay sandy formation and a quaternary alluvial formation to the east.

The soils derived from there are impoverished ferrilitic brown-red clay-sand soils on the Western plateau, ferralitic/hydromorphic alluvial soils on alluvial terraces, and waterlogged peat soils in flooded areas. This area has one of the very low densities of human population (0.93 $km^2$) of the Republic of Congo.

The forest of Likouala contains a high diversity of trees and plants [1]. In the Dongou district, the forests of the study area are rainforest. The principal vegetation types are partially

deciduous dense rainforests of Ulmaceae and Sterculiaceae, swampy flooded forest of *Uapaca heudelotii* Baill., and forest of *Guibourtia demeusei* (Harms) J. Léonard [1]. Tree canopy closure of the forest varies from 93% to 100%

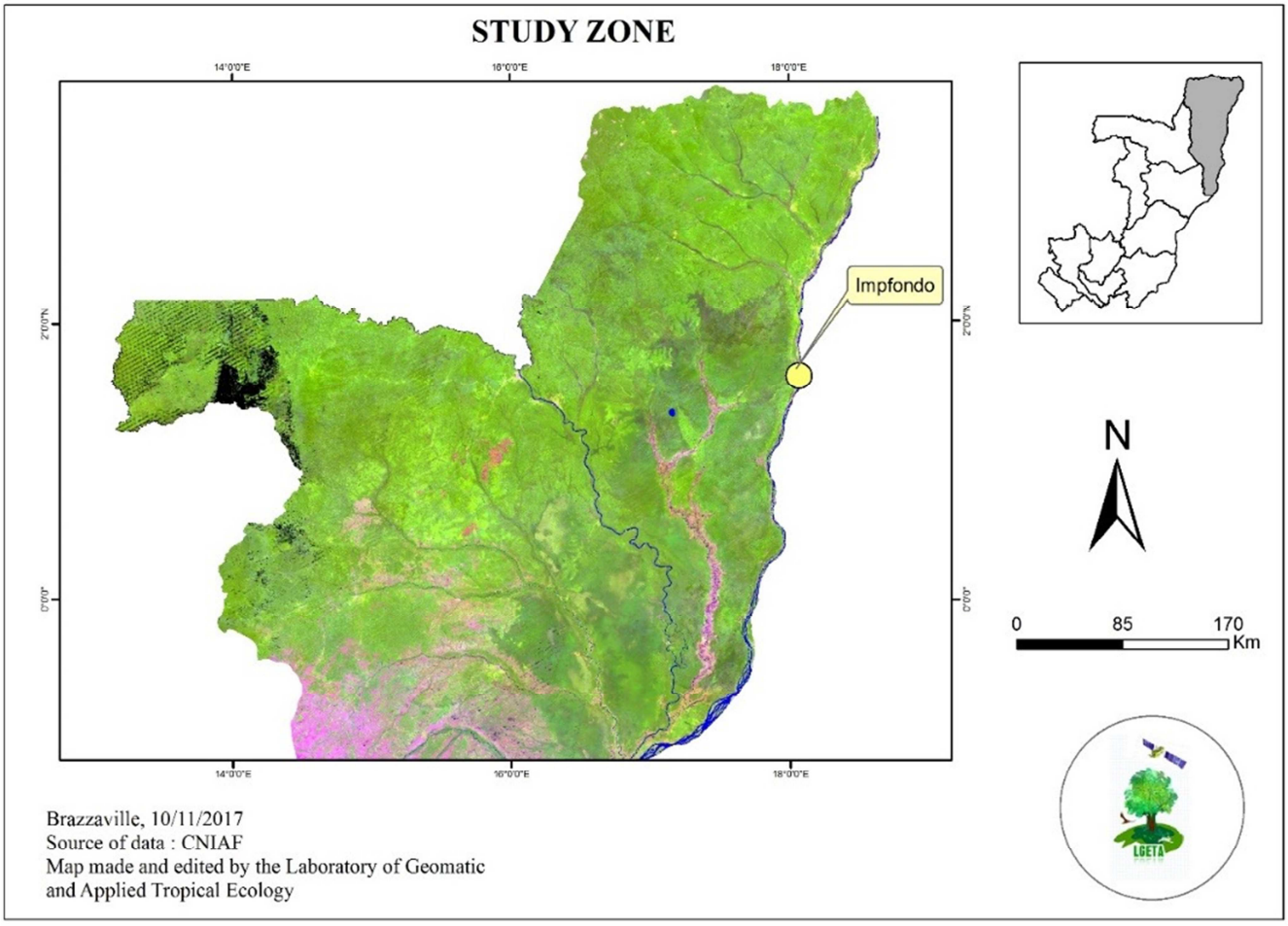


**Figure 1.** Locating the study area.

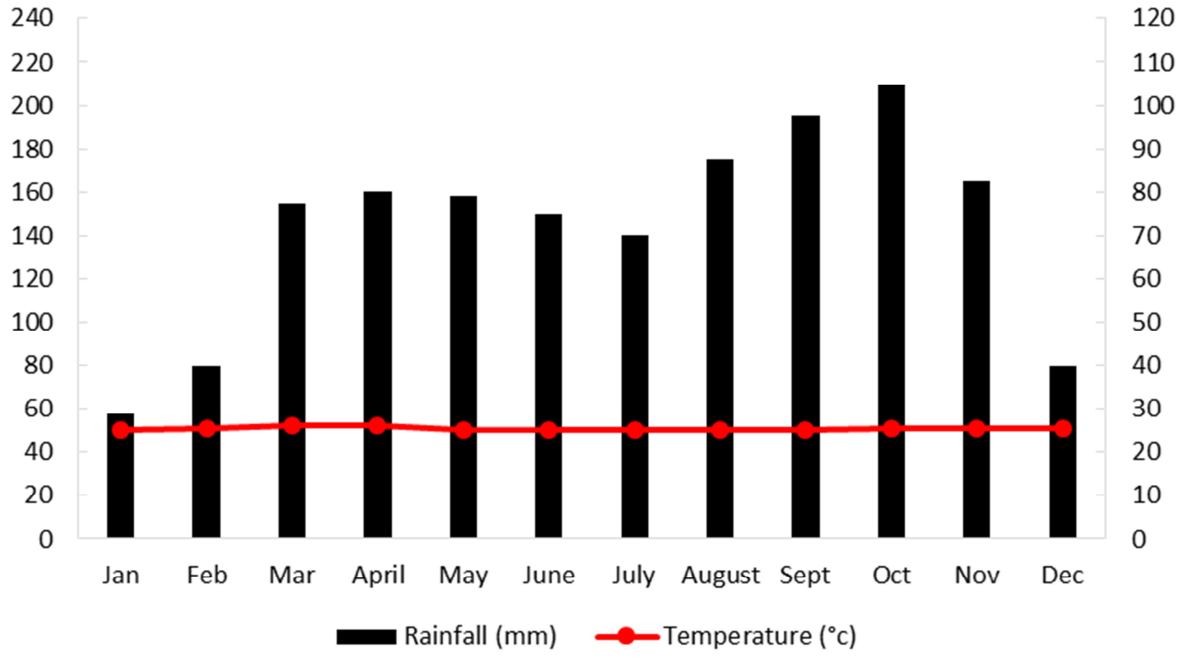


**Figure 2.** Ombrothermique diagram of the Likouala (mean of 1932-2015), ANAC Congo (2016).

## 2.2. Methods

The following steps were used to achieve the objectives of the study: Landsat images data collection from the website http://glovis.usgs.gov/ (2 scenes 181-59); image enhancement: During the image enhancement step, geometric and radiometric restitutions of the 2 sets of Landsat images were done; image classification, urban growth/land cover change analysis and deforestation assessment.

The image of the study area was extracted from the all scene using the subset image tool to facilitate this study (Figure 3: Color composition 7.4.2). The study area covers an area of 2940.4 ha.

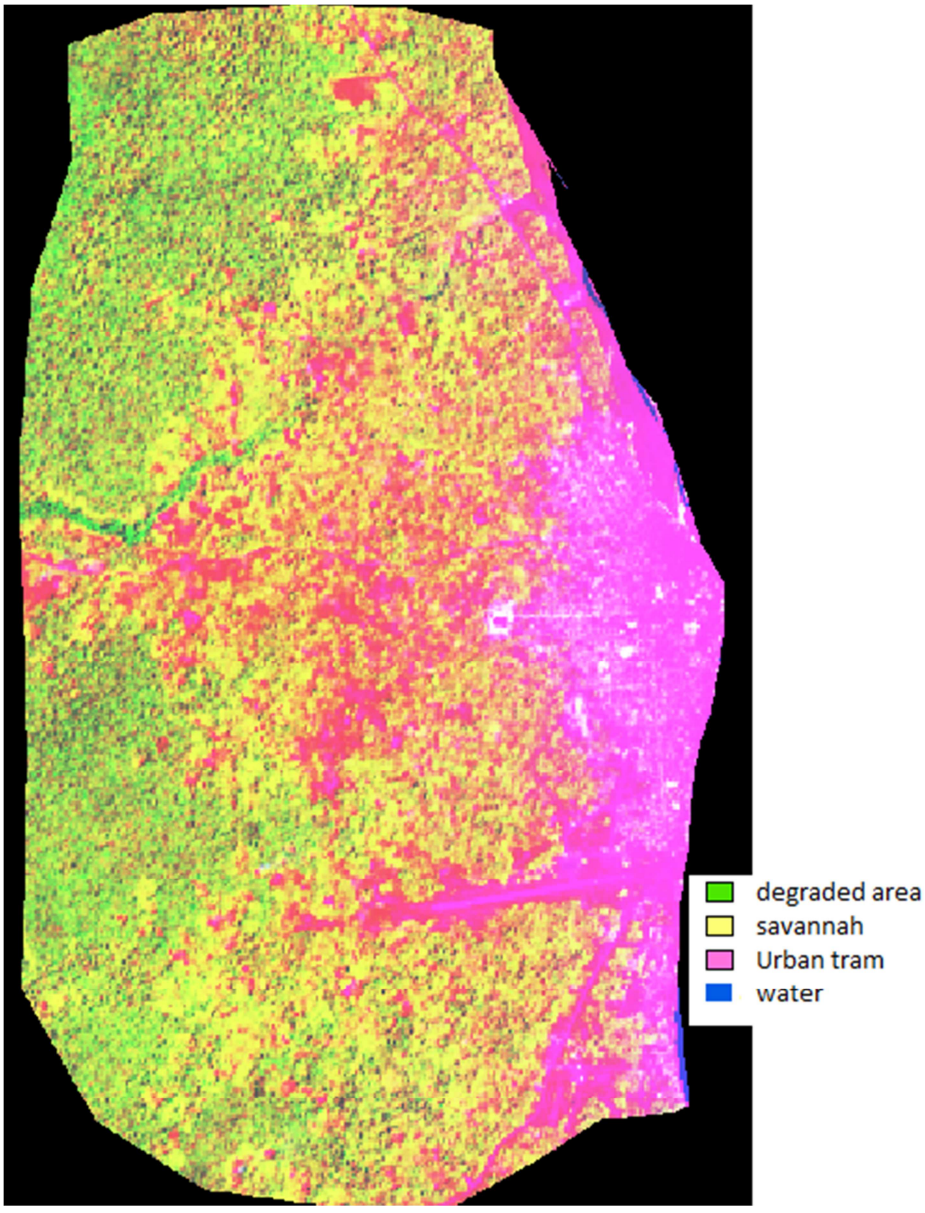


**Figure 3.** Landsat OLI Image with 7.4.2 bands.

## 2.3. Characteristics of the Images Used to Carry out This Study

Two types of images were used for this study: the Landsat image for 1986 and the OLI image for 2016. These two images which had the path and row number 181-059, were captured on different dates, in December for image of 1986 and February for the image of 2016, having both a resolution of 30m. The color composition of the 5-4-3 bands was applied for the 1986 image and the 7-4-2 bands for the 2016 image.

Image supervised classification was done using maximum likelihood algorithm. In the urban growth/land cover change analyses phase, post classification comparisons and analyses were performed to reveal the urban growth/land cover change pattern in the study area between the two dates. As well as deforestation assessment is concerned, image re-classification and cross-tabulation analysis were performed to

assess the extent of deforestation in the Impfondo area.

The bands selection was made by considering the bands that allow us to discriminate urban plot, forest and non-forest vegetation. The pretreatment of Images proceeded by a separate band visualization of the study area to determine which bands were reflective of the development information of the urban area compared to the vegetation. For Thematic Mapper (TM) of 1986, we used the colored composition 5-4-3; While for Operational Land Imager (OLI) of 2016, we used the colored composition 7-4-2.

After obtaining the first map of land cover type of the study area, a field visit was carried out to correct the errors due to the confusion of the pixels during the selection of the region of interest in laboratory. For this, 100 checkpoints scattered over the entire map produced had been selected in the laboratory, saved in the GPS map 60CSx of Garmin to perform class checking on the using of Garmin tools. To assess the accuracy of the map products, the confusion matrix was produced, and the overall classification accuracy was calculated.

### 2.4. Field Data Collection

Other data were collected as part of this study on the ground towards the local authorities of the administrative entities, data: on the demographics characteristics of this urban community from 1986 to 2016; on Likouala population poverty; on civil war refugees from neighbouring countries (obtained from to the National Refugee Assistance Committee - CNAR); on accelerated Municipalization (a government program intends to develop the administrative structures of cities by building infrastructure) in the Likouala Prefecture; on the causes of deforestation from local officials and authorities.

## 3. Results

### 3.1. Occupation of the Soil in the Study Area

Land cover type of the study area shows us that forest is the most important class in 1986. Overall classification accuracy is 86.84%. Producer's accuracy of urban plot class is 98, 08% and non-forest class is 62.50%.

The land use map of the study area in 2016 shows an extent of each class in the study area between the two periods (Figure 4). In 1986, the forest class was more important than the other two classes: the urban plot class and the non-forest class. In 1986, urban plot accounted for 9.11% compared to 29.23% in 2016. Forest accounts for 74% of the study area in 1986, while it increases to 42.74% in 2016. We also noticed an increase of 16.23% to 28.01% between 1986 and 2016 of non-forest item (Table 1).

Producers accuracy of the different land use type were of 75.00% for urban plot, 94.44% for the *forest* and of 96.43% for the non-forest when users' accuracy was 100%, 94.44% and 87.10% respectively.

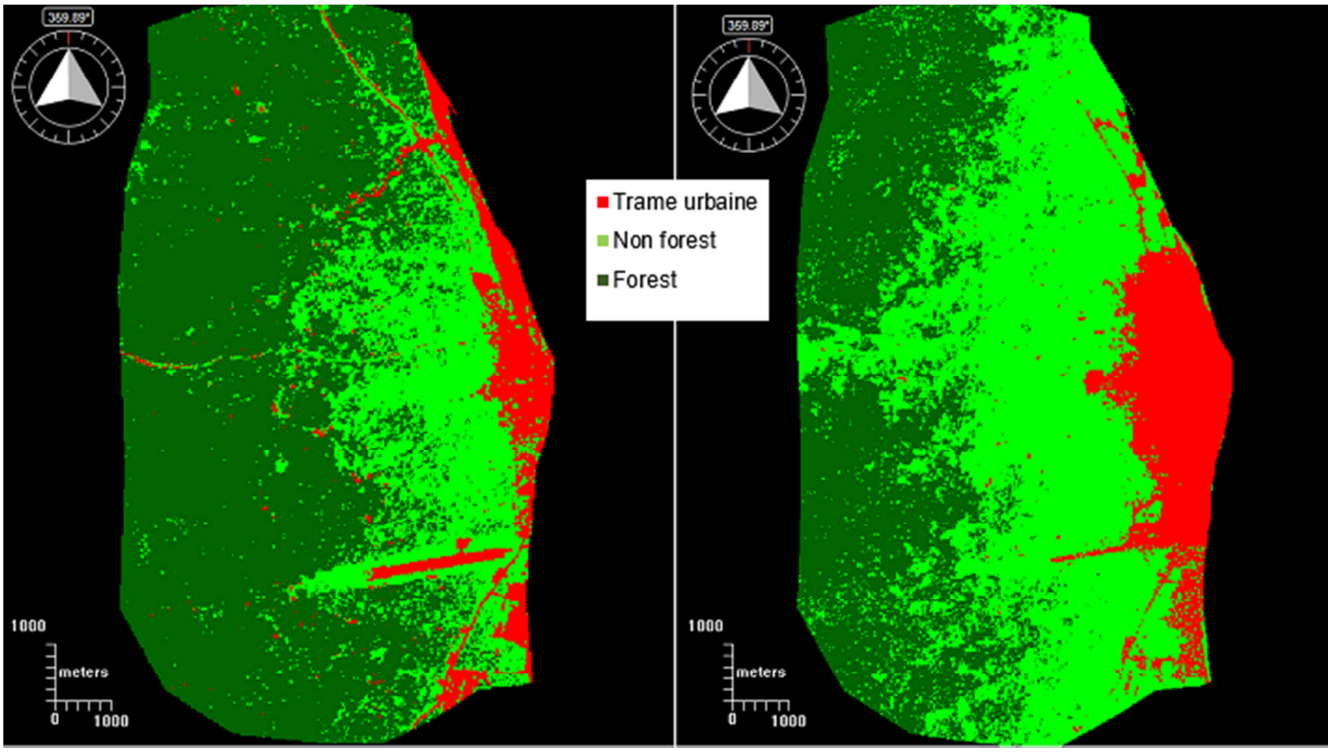


**Figure 4.** Land use maps in 1986 (left) and 2016 (right).

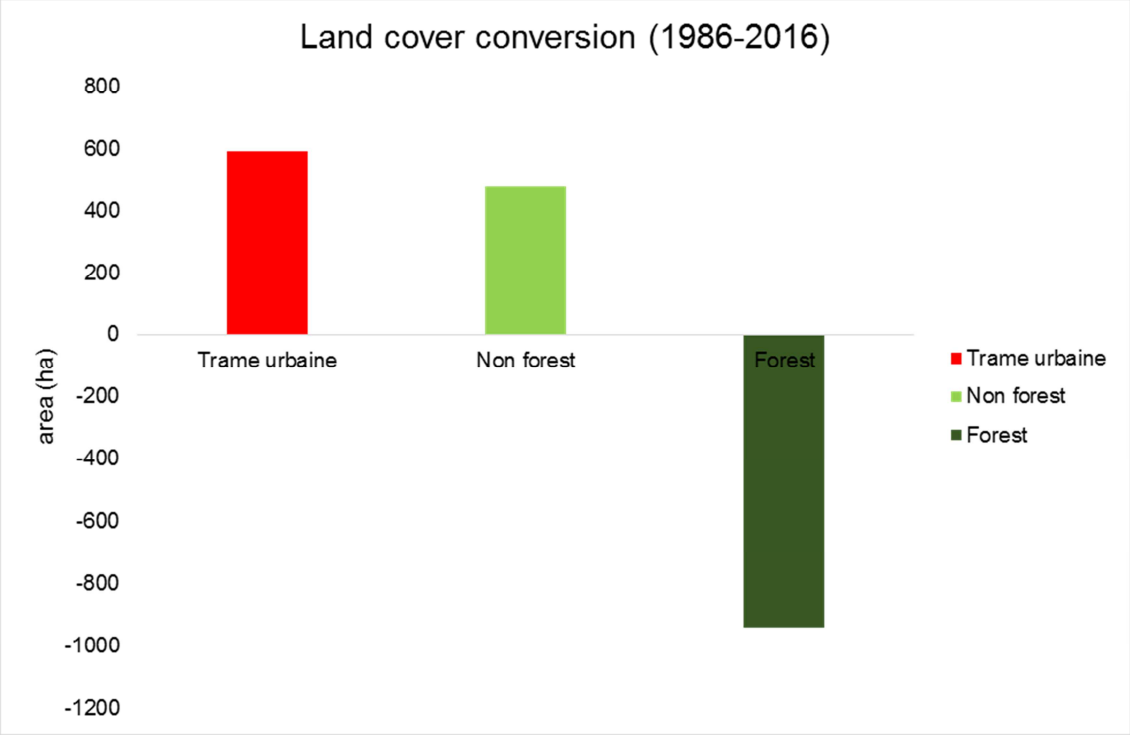


**Figure 5.** Land cover conversion between 1986 and 2016.

**Table 1.** Area of the different classes of land use between 1986 and 2016.

| Land use | 1986 | | 2016 | |
|---|---|---|---|---|
| | Area (ha) | % | Area (ha) | % |
| Uban plot | 267.86133 | 9.11 | 859.68 | 29.23 |
| Non-forest | 477.21069 | 16.23 | 823.68 | 28.01 |
| Forest | 2195.22798 | 74.66 | 1256.94 | 42.74 |

### 3.2. Deforestation and Urban Growth

At a time, difference of 30 years, urban growth caused a forest loss of 592 ha. The results obtained shows that the Impfondo city is sprawling Eastwards (river Ubangi with flooded forest) to Westwards (remained dense tropical forest ecosystem).

### 3.3. Drivers of Deforestation

Data collected in the field revealed that both direct and indirect drivers explains the deforestation around the Impfondo city. The main cause of deforestation is urban growth, followed by agriculture, new house buildings. The indirect causes of deforestation in the study area are population growth, poverty, migration of people in the last 15 years coming from Democratic Republic of Congo (DRC), Rwanda and Central Africa Republic (CAR).

## 4. Discussion

Urban growth is the direct cause of deforestation and degradation of forest in the North of the republic of Congo. This present study has shown that the development of urban tram has a direct impact on the sustainability of the dense tropical forest of this region.

Urban growth has been identified as a direct cause of deforestation by many researchers [5, 4]. As we observed in the land use map, a large forest area has been replaced by non-forest land with the development of the Impfondo urban plot from 1986 to 2016. During this period of study, the urban tram area growth from 267.86 ha to 859.68 ha a loss of the forest area of 591.82 ha. Several factors could explain this urban growth in the municipality of Impfondo: population growth, residential sprawl, land-use planning and the development of peri urban agriculture. These same factors were identified by several authors in the literature having worked in other cities around the world [14, 13, 19, 20]

### 4.1. Population Explosion

According to the Congo report [5], urban expansion is mainly motivated by the population explosion in large cities. Factors such as rural exodus, economic reasons, displacement and the arrival of refugees have been identified as structural causes that would explain population expansion in different communities both forested and non-forested. Looking at the results of data collected during field truth ground, the survey with the local administrative authorities of the urban community of Impfondo revealed that the “accelerated municipalization,” the construction of the modern administrative infrastructures in this city in 2004 and 2005

did not contribute significantly to the loss of the forests, because it took place on mostly marshy areas while our research concerns already-subdivided areas. Thus, infrastructure construction has not been undertaken on primary forest.

However, an indirect cause of deforestation played a decisive role in the losses of forests not only in this city, but also throughout the Likouala' region. The massive arrival of refugees from neighbouring countries (CAR, DRC and Rwanda) greatly participated to the degradation and then the deforestation along the Ubangi river [21]. Indeed, in Impfondo in the recent year NGO Médecin d'Afrique have registered a total of 30600 refugees from the DRC. This was confirmed by previous studies which showed that from 2000 to 2010, large areas of forest were lost around the towns of Betou, Dongou and Impfondo, thus increasing the spatial size of these cities [22].

The displacement of civil war refugees is an indirect factor for deforestation and degradation of forest in the Republic of Congo, particularly in the north of RoC, in the Likouala region [15, 22].

Data collected from the government department dealing with the management of Refugees (CNAR) reported that from 2000 to 2014, 13809 refugees had been registered in their Impfondo' office. These people are embarked on agricultural activities significantly increasing the useful area of the urban community of Impfondo. Refugees developed the activities in the sector of agricultural inside the primary forest with a great impact on the structure and biodiversity of forest.

Data on the population collected at National Institute of Statistics, revealed that the population of Impfondo has risen from 33.911 to 40.389 habitants from 2007 to 2014.

As the population grows, demands for agricultural products increases as well as agricultural production. Around Impfondo a large part of the forests has been destroyed by local populations for the establishment of diverse crops such as: cassava, banana, maize, peanut, cocoyam and many others. These crops respond to a variety of demands from urban populations. But these activities are carried out by the populations not only for their food, but also for the income they serve to satisfy their needs; but this activity contributes enormously to the growth of this cities. The link between urban growth and population growth is confirmed by the numerous authors [19, 8, 22, 17, 13]

### 4.2. Agriculture

Data collected during fieldwork revealed that agriculture is the primary cause of deforestation. Around the Impfondo urban community, traditional or subsistence agriculture is the main cause of deforestation. Many studies have concluded that in the Congo Basin, agriculture will be the first cause of changes in forest cover observed. Geist and Lambin [11] identified the expansion of agriculture as one of the major groups responsible for deforestation and forest degradation in the intertropical zone. Similarly, the REDD + MDDEF-GAF pilot project "Monitoring National Forest cover" in the Republic of the Congo has come to the results that agricultural expansion has been the main driver of change representing 78% of changes in forest cover observed in the RoC [22]. This observation was confirmed by [24] who showed that peasant farming is the main cause of deforestation in tropical areas. It contributes 35% to the destruction of the forest in Africa.

The importance of agricultural areas around this city could be explained by the high population density and the increase demands for food as well as by the level of poverty. Agriculture comes in support of the fishery that is exercised by the local people and participates very weakly in regulating the local economy. It is indeed totally dependent on the collection of natural resources from forests, fishing, but also and above all from the sale of basic agricultural products such as cassava leaves, oil palm and the development of the banana plantation. When these farmlands became poor, they are abandoned for almost seven years for fallow sand such a situation could explain the large fallows around this forested community.

## 5. Conclusion

The study on deforestation due to urban growth in the Impfondo city using remote sensing data between 1986 and 2016, reveals that urban growth in forest areas is an important cause of deforestation and forest degradation in the RoC. The huge amount of forest loss obtained in this study allows us to consider urban sprawl as a threat on forest cover areas. Several causes have led to this situation: population growth, local spatial planning and the arrival of refugees from neighbouring countries. Nevertheless, it is necessary to extend the study to other small size town of RoC.

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Research highlights

1 the urban tram area growth from 267.86 ha in the year 1986 to 859.68 ha in the year 2016,

2 direct link between human activities and the lost of forest cover around this agglomeration,

3 population explosion and poverty are the drivers of deforestation

## Author's Contribution

Suspense Averti IFO, conceived and planned the experiments. Stoffenne BINSANGOU, Suspense Averti IFO, Lypsia IBOCKO, Lisa LOUVOUANDOU, carried out the experiments in the field. Ifo Suspense Averti, Stoffenne BINSANGOU and Mesmin TCHINDJANG contributed to the interpretation of the results. Suspense Averti IFO and Stoffenne BINSANGOU took the lead in writing the manuscript. Mesmin TCHINDJANG, Félix KOUBOUANA provided critical feedback.

## Competing Interest

The authors have declared that no competing interest exists.

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