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Quantifying Forest Loss in the Mbalmayo Forest Reserve (Center Region, Cameroon)

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Abstract

This study was carried out in the forest reserve of Mbalmayo, Center Region of Cameroon, with the aim to analyze the dynamics of land use/land cover (LULC) changes over the past 30 years. The databases used were made up of 3 Landsat satellite images (5TM of 1990, 7ETM+ of 2005 and 8OLI of 2020). The satellite images were processed using ArcGIS and Erdas Imagine software. Ethnobotanical surveys were conducted to investigate the relationships between the local population and the forest reserve. The Mbalmayo forest reserve is consisted of seven main land cover namely: mature secondary forest, young secondary forest, savanna, fallows and crops, built, bare soil and water surface. The dynamics of the forest cover undergoes more significant changes between the years 1990-2005 with losses estimate at 4762 ha compared to the years 2005-2020 (2231 ha), with a marked decrease in the area of dense forests. This regression is much more important in dense forest vegetation. The forest cover lost 6993 ha (26.92%) of its surface, which corresponds to an average rate of deforestation of 233.1 ha/year. The survey revealed the need for NTFPs for the Mbalmayo reserve forest populations. Indeed, all respondents agreed that they use non-timber forest products from the forest, mainly for medication (37%), wood (34%) and food (24%). Therefore, it becomes urgent to redefine a management plan for the Mbalmayo forest reserve which will define how the forest must be managed in order to avoid the loss of large areas of forests disappearing each year under the human action, which exerts pressure on forest species, thus leading to their possible disappearance.

Keywords

Mbalmayo Forest Reserve, Satellite Images, Ethnobotany, Land Use/Land

Cover Change

1. Introduction

Cameroon's forests are important locally, regionally and globally because of the various environmental services they provide. Despite their importance, these forests face several threats that impact their ability to produce goods and services (WRI, 2012). These changes within the forest which negatively affect the stand or site and, in particular, reduce productive capacity, are called forest degradation (FAO, 1998; Vasquez-Grandon et al., 2018). This is a process that takes different forms, especially in open forest formations, deriving mainly from human activities such as overgrazing, overharvesting (for firewood or logging), repeated fires, or due to attack by insects, disease, plant pests or other natural sources such as cyclones. In most cases, degradation does not manifest itself as a decrease in the area of woody vegetation but rather as a gradual reduction in biomass, changes in species composition and soil degradation (FAO, 1998; Modica et al., 2015). Between 2015 and 2020, the world-wide rate of deforestation was estimated at 10 million hectares per year, against 16 million hectares per year in the 1990. The global area of primary forests has shrunk by more than 80 million hectares since 1990 (FAO, 2020). This deforestation is leading to imminent extinctions of plant and animal species (Ricketts et al., 2005), making it urgent to monitor the dynamics of these ecosystems and their preservation, before their possible disappearance.

Land use changes are among the components of global change responsible for the erosion of biodiversity around the world (Loreau, 2005). Land cover changes information is useful to achieve a better perspective of landscape dynamics and is also proper for evaluating the sustainability of natural resources (Whittle et al., 2012; Aliani et al., 2019). Thus, ground cover monitoring and mapping are required to investigate spatial planning and environmental examination (Cheng & Wang, 2019; Tripathy & Kumar, 2019). Additionally, land cover and land use analysis will help in the reliable prediction of future circumstances. For example, future changes in forest cover can be predicted using the substance gained from historical data sets and remote sensing observations (Hamad et al., 2018). The assessment of land use and land cover changes and trajectories at the global, national, and local levels is, therefore, useful for sustainable development policies, monitoring food security, and climate change and environmental-related research (Wang et al., 2016).

Tropical African forests are threatened by a wide range of anthropogenic activities that imperil natural ecosystems and biodiversity. For instance, the few previous studies conducted in the threatened forest of the Koupa-Matapit Gallery Forest in West Cameroon (Momo et al., 2018), Melap Forest Reserve in West Cameroon (Temgoua et al., 2021), Ajei Community Forest in North West Region of Cameroon (Temgoua et al., 2018) and the greater Congo Basin (Laurance et al., 2015) identified deforestation as a major factor driving both forest loss and degradation (Hosonuma et al., 2012; Ordway et al., 2017; Aleman et al., 2018). To reduce deforestation, forests mapping and the monitoring of their evolution are very important. Mapping areas of forest cover change is essential for developing locally adapted strategies to better control these dynamics (de Wasseige et al., 2014). To carry out such monitoring, remote sensing is a less-expensive method that has proven its effectiveness for assessment of forest cover dynamics and degradation over several decades and at different scales (Loveland et al., 2012; Hansen et al., 2013; Nagendra et al., 2013; Wani et al., 2016; Mukete et al., 2017).

The Mbalmayo Forest Reserve is a peri-urban forest. The development of the city and the increase of its population have increased the pressure on the reserve for firewood and farmland. The forest was classified at a time when the population density was low, in areas of cultivation and hunting. The colonial decree No. 269 of July 29, 1947 establishing the forest reserve of Mbalmayo stipulates, in its article 2, that: "The cocoa plantations cultivated and in good condition will be maintained, and new plantations will only take place replacing the old ones". Article 3 specifies that: "The natives, customary owners of the land, are authorized to establish their food crops within the classified perimeter at the condition that they respect the trees which will be indicated by the Water and Forestry Service". This has generated a "logic of clearing and the race for land" to constitute a "land heritage". Then, gradually, the peasants associated fruit trees such as mango trees, avocado trees, African plum trees (*Dacryodes edulis*) and cola trees with food crops. These trees serve as land markers and traditional title deeds (Owona et al., 2009). Hence there is a need for a land use management plan. In fact, recent studies show that even classified forests are facing many anthropogenic pressures that lead to their degradation and deforestation (Zekeng et al., 2019; Djiongo et al., 2020; Fokeng et al., 2020; Temgoua et al., 2021). Therefore, the aim of this study is to present the changes in forest cover in the Mbalmayo forest reserve over the past 30 years, based on GIS analysis of satellite images. More specifically, we seek to identify the activities carried out by the local populations and determine agents and drivers of land use and land cover change of the Mbalmayo forest reserve.

2. Material and Methods

2.1. Study Site

The Mbalmayo Forest Reserve is situated in the chief town of the Nyong and So'o Division, in the Center region of Cameroon. It lies between 3˚31' North and 11˚30' East at an altitude of 335 m and covers 650 km^2. The area is under equatorial climate with rainfall range between 1600 - 1700 mm and temperatures 19 - 28˚C (Foahom, 1983). The reserve is part of the bioclimatic zone of dense humid evergreen to weakly deciduous forests (Morellet, 1952). The Mbalmayo city's economy depends on agriculture follow by brewing and wood industries (Peltier

& Njoukam, 2006). Some research and academic institutions frequently carried their activities in the reserve. The actual study was conducted in IRAD compartment covering 1000 ha. It borders the Forestry National School in the north and the Ebogo touristic forest at West. It is limited to the West and North by the Nyong River, in the South by So'o River, and at East by a village track and the Mbalmayo municipality forest. The entire reserve is extended to the municipalities of Mbalmayo and Menguemé (**Figure 1**).

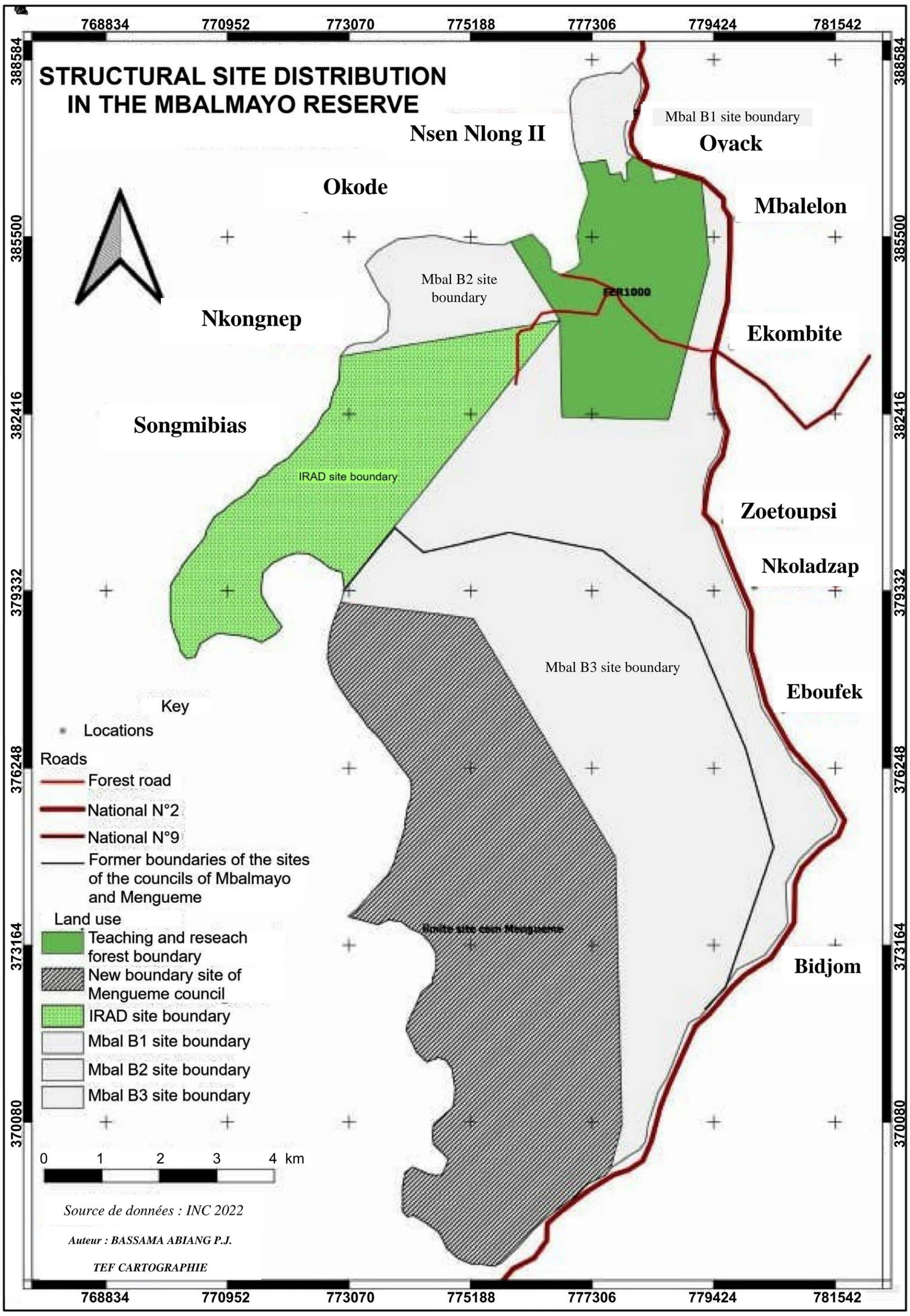

Figure 1. Localisation of the Mbalmayo forest reserve. Source: MINFOF 2020.

The agricultural practices are subsistence agriculture and shifting slash-and-burn agriculture practices. The old fallow system is the most common cropping system where crops are a mixed and dominated by groundnuts (*Arachis hypogea*), cassava (*Manihot esculenta*), and maize (*Zea mays*) cultivated mostly twice a year. The first farms being set up in March-April with corn and peanuts. They are harvested in June-July. Cassava associated with it stays for another 6 to 12 months. This farm thus represents a granary which is placed under the responsibility of the woman although the man holds the responsibility of clearing. The second type of farm is that of off-season and is cultivated by approximately 70% of the households. In this zone, arable land is relatively scarce: around 30% of households practice the old fallow system. Secondary forests continue to be exploited by those who lack old fallow land. Fifty two percent of households cultivate the flooded valleys for off-season crops. The average number of fields in this category is significantly high (Zapfack, 2005).

2.2. Ethnobotanical Studies

The ethnobotanical study was carried out following a series of surveys using a pre-established questionnaire containing questions on: the respondent, the use of plants (particularly on non-timber forest products and wood), the parts used, the access to resources, the local perceptions of forest degradation. Surveys mainly involved household heads and 42 people aged 27 to 65 were inter-viewed, including 16 women and 26 men. Only people carrying out activities in the reserve were surveyed. These surveys were carried out in the IRAD concession of the Mbalmayo reserve forest in order to assess the perception of population on the state of reserve. The method used was semi-structured interview. Questions were prepared ahead of time and this allows us to be prepared during the interview and allow informants the freedom to express their views in their own terms.

2.3. Data Collection and Analysis

In order to develop land use/land cover maps over the past decades, we have used Landsat 5TM, Landsat 7ETM+ and Landsat 8OLI satellite images taken in 1990, 2005 and 2020 respectively. These images are GLCF GeoCover (Global Landcover Facility) data, produced under contract with NASA (National Aeronautics and Space Administration). They contain location information provided by the NGA (National Geospatial Agency) and USGS (US Geological Survey) and are freely downloadable from the website www.landcover.org. GeoCover data has the advantage of being orthorectified: the geometric deformations of the image have been corrected in order to obtain a correct planimetric image that can be easily integrated into a geographic information system (GIS). In order to reduce cloud cover, images from the dry season period were selected. These different images were processed using ENVI 5.3 software to extract desired information. They are provided in the standard Geotiff format, with a UTM (Universal Transverse Mercator) projection based on the WGS 84 Datum. The processing of satellite images was carried out in two stages (**Figure 2**): pre-processing and supervised classification (Bamba et al., 2010; Barima et al., 2010). All processing was performed using ERDAS Imagine 14.0 software (Leica Geosystems GIS & Mapping, LLC, 2003).

The classification stage consisted in defining the nomenclature of different land cover (Dense forest, fields, light forest ,grassy savannah, buildings etc.) based on the LCCS model (Land Cover Classification System) of FAO (Di Gregorio & Jansen, 2005), later on, followed the colored composition of bands; (2-4-1) for the scene of 1990, (5-4-3) for the scene of 2005, and (6-5-3) for the scene of 2020 using the Envi 5.3 software. Afterwards, the sampling plots were materialized on a homogenous zone in order to develop an algorithm based on the recognition of the reflection of spatial entities, after which followed the supervised classification of images.

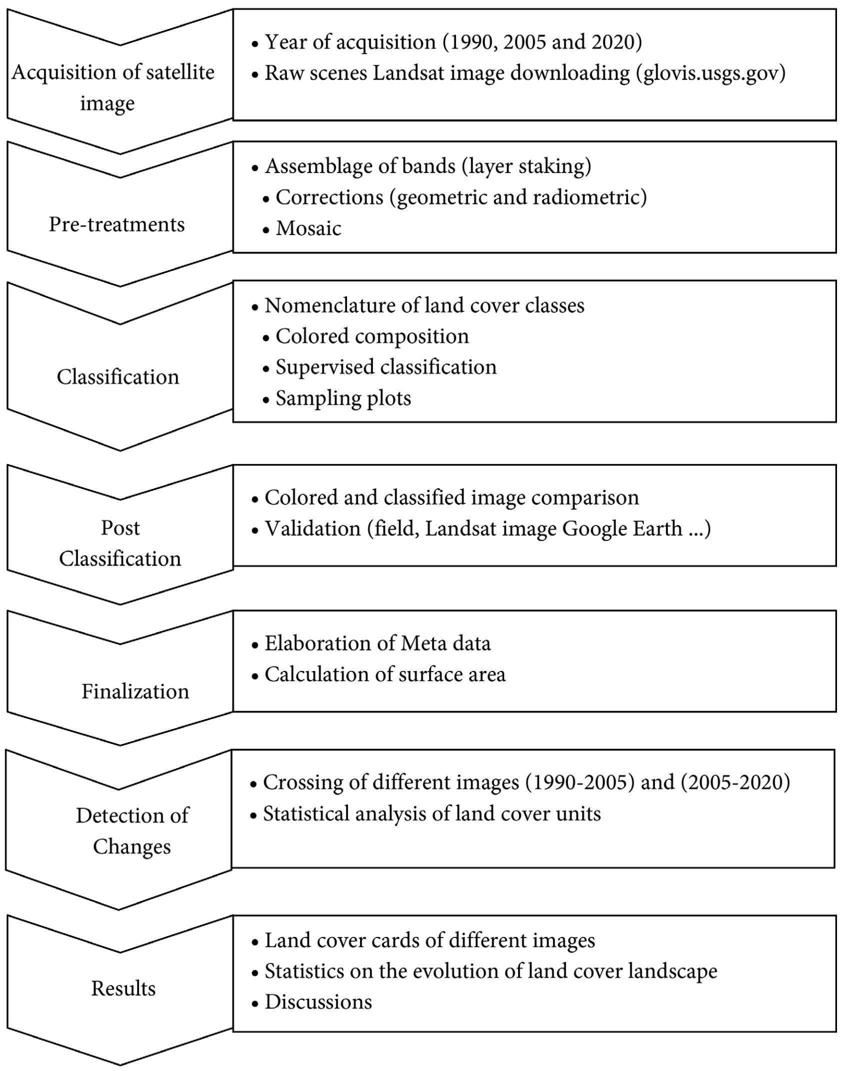

Figure 2. Flowchart showing the different stages of processing satellite images to obtain land cover maps.

In Post classification, change detection method was used to compare independently produced classified images. This was achieved via an extraction of statistics for time series analysis and trends of change of the different identified land uses and land cover classes. Finally, vectors derived from digital processing in ENVI were imported into Arc Map 10.2 software for the extraction of the layers to be used, digitization, generation of databases, and production of maps. **Figure 2** shows the different phases of image processing.

3. Results

3.1. Economic Activities and the Drivers of Deforestation According to Population

The respondents were mainly people carrying out activities within the reserve. 42 people aged 27 to 65 were interviewed, including 16 women and 26 men. The data from the surveys of the 47 farmers met in the forest constituted several elements among which we can cite the method of tree management and the needs of the local population (firewood, service wood, NTFPs).

Wood is an important resource for all respondents in this locality. For 34% of respondents, wood is intended for several uses, in particular energy wood (firewood, charcoal) and lumber (**Figure 3**). Generally, this collection is done in their fields. The preference of the tree to be exploited depends on its uses, and its presence in the fields determines the type of crop. The uses cited for ligneous plants are among other things, food, medicinal (by using the leaves, roots, bark) and traditional. Main use of NTFPs in the reserve.

The survey revealed the need for NTFPs for the Mbalmayo reserve forest populations. Indeed, all respondents agreed that they use non-timber forest products from the forest, mainly for medication (37%), wood (34%) and food (24%).

The vegetation of the Mbalmayo reserve forest appears to be progressively degraded. Indeed, 90% of the respondents answered in the affirmative to the question of whether the vegetation is degraded, against 10% who did not observe degradation. Unsustainable exploitation of timber and non-timber forest products, presence of several farms inside the reserve, the cultivation techniques uses (slash and burn agriculture) constitute some drivers of degradation highlighted. All respondents use fire to clear the land because, according to them, it reduces the ardour of work. They set fire in the dry season and it is during this period that most of the woodcutting is done. However, about 66% of farmers use firebreaks to limit damage when fire passes.

3.2. Land Use/Land Cover Dynamics of Mbalmayo Forest Reserve from 1990-2020

From the hybrid image classifications of Landsat scenes of 1990, 2005 and 2020, seven main land cover classes were identified namely; mature secondary forest, young secondary forest, savanna, fallows and crops, built, bare soil and water surface (**Figure 4**).

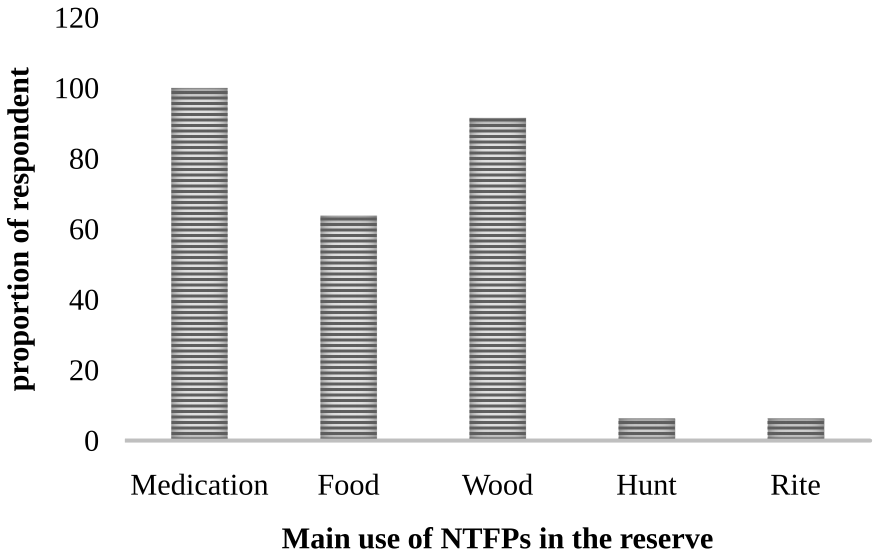

Figure 3. Main use of NTFPs in the Mbalmayo forest reserve.

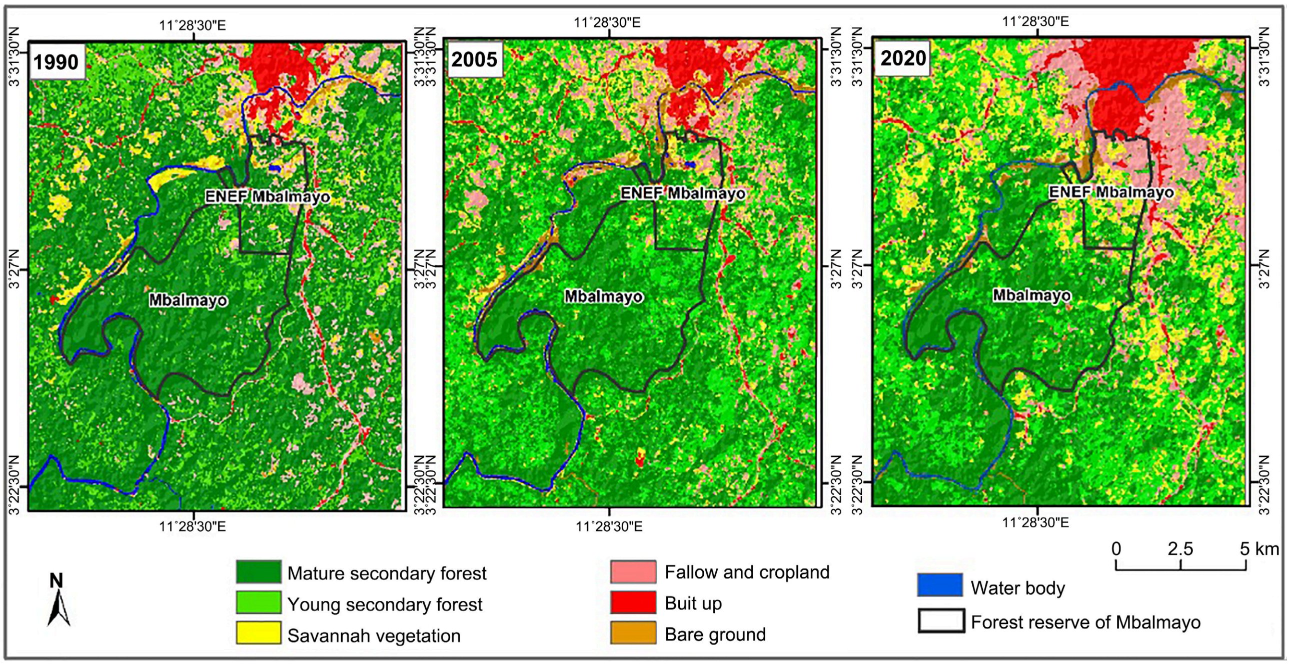

Figure 4. Land use/land cover types between 1990 and 2020.

- Secondary forest: Forest that has been logged and has recovered naturally or artificially, divided into mature secondary forest and young secondary forest.
- Savanna vegetation: It is an assembly of grass and herbs. This cover is at the boundaries of sparse vegetation representing formally sparsely dense surfaces that have lost their tree covering.
- Fallows and crops: Agricultural land with crops (cereal, vegetable, and fruits) and old and young fallows.
- Built area: Areas occupied by settlements (cities, villages, roads, and other building).

- Bare soil: There are partly boulders of stones and rocks and sections of the soil with insignificant vegetation cover or no vegetation cover at all. They constitute sections of lands obtained from savanna cover as a result of scorch heat action or drought conditions and fires.
- Water surface: Rivers, ponds, and reservoirs.

The analysis of the evolution of land use/land cover in the Mbalmayo forest reserve and its surroundings between 1990 and 2005 is summarized in Table 1 and Figure 4. It appears from this table that between 1990 and 2020, the proportions of dense vegetation decreased and that of savanna, built, bare soil and sparse vegetation increased. Over the last 30 years, the forest reserve of Mbalmayo and its surroundings have undergone notable land use and land cover (Figure 4). The comparison with the help of Table 1 of the land use/land cover show that changes were more significant between the years 1990-2005 compared to the years 2005-2020, with a marked decrease in the area of dense forests. The mature secondary forest lost over the past 30 years 6993 ha (26.92%) of its surface, which corresponds to an average rate of deforestation of 233.1 ha/year.

Land use and land cover changes are also observed in young secondary forests, savannas, buildings and bare soils which increase their area from 1990 to 2005. We went from 3781 ha in 1990 to 7166 ha in 2005 for young secondary forest, 1073 ha in 1990 to 2297 ha in 2005 for savannas, 856 ha in 1990 to 1002 ha in 2005 for buildings and 300 ha in 1990 to 572 ha in 2005 for bare soils. Indeed, the different types of land use are likely to be transformed into crop fields, which leads to changes in forest cover.

In 1990, forest reserve of Mbalmayo consists mainly of mature (65%) and young (14%) secondary forest, followed by savannas (4%), fallows and crops (9%). The Mbalmayo reserve and its surroundings had a total area of 25,803 ha. This area is divided into secondary forest occupying an area of 20,775 ha (80.51% of the total area), savannas occupying an area of 1073 ha (4.16% of the total area), fallows and crops with an area of 2397 ha (9.29%), buildings which represent an

Table 1. Change in land use/land cover from 1990 to 2020 in Mbalmayo forest reserve.

Land cover/Land use	1990		2005		2020	
	Area (ha)	%	Area (ha)	%	Area (ha)	%
Mature secondary forest	16,994	65.86	12,232	41.71	10,001	38.94
Young secondary forest	3781	14.65	7166	27.95	6859	26.70
Savanna vegetation	1073	4.16	2296	8.95	3506	13.65
Fallows and crops	2397	9.29	2036	7.94	2897	11.28
Built	856	3.32	1002	3.91	1521	5.92
Bare soil	300	1.16	572	2.23	473	1.84
Water surface	402	1.56	337	1.31	427	1.66
Total	25,803	100.00	25,803	100.00	25,803	100.00

area of 856 ha (3.32%), bare soil and water surface with respectively 300 ha and 400 ha (1.16% and 1.56% of the total area)

It can be seen that the reserve and its surroundings have undergone a change in 2005 compared to that of 1990. The dense forest has experienced a loss of area, which leads to an increase in the area of other types of land use. Despite the fact that secondary forest has experienced a reduction in size due to the establishment of plantations, it has always remained dominant. The area of mature secondary forest (16,994 ha; 65.86%) in 1990 decreased to 12,232 ha (47.71%) in 2005. This loss of area of mature forest (4762 ha) goes with an increase in the areas of young secondary forests from 3781 ha (14.65%) in 1990 to 7166 ha (27.95%) in 2005; savannas of 1224 ha, 1073 ha (4.16%) in 1990 to 2297 ha (8.96%) in 2005; buildings of 146 ha, 856 ha (3.32%) in 1990 to 1002 ha (3.91%) in 2005; bare soils of 272 ha, 300 ha (1.16%) in 1990 to 572 (2.23%) in 2005. The area of fallows land and crops decreased from 361 ha, 2397 ha (9.29%) in 1990 to 2036 ha (7.94%) in 2005 (**Table 1**).

In 2020, we also observe changes in the Mbalmayo reserve and its surroundings compared to 2005. Indeed, we see that the area of secondary forest has suffered a loss of 2231 ha, we have gone from 12232 ha (41.71%) in 2005 to 10,001 ha (38.94%) in 2020. This decrease in the area of mature secondary forests goes hand in hand with the increase in certain types of land use, in particular savannas which increased from 2297 ha (8.96%) in 2005 to 3506 ha (13.65%), an increase in its surface area of 1208 ha, fallows and crops increased by 861 ha on the area (2036 ha in 2005 compared to 2098 ha in 2020), buildings increased from 1002 ha (3.91%) in 2005 to 1521 ha (5.92%) in 2020, an increase of 519 ha. With regard to young secondary forests and bare soils, there is rather a decrease in area; we pass respectively from 7166 ha (27.95%) in 2005 to 6859 ha (26.70%) in 2020 and 572 ha (2.23%) in 2005 to 473 ha (1.84%) in 2020.

Changes in the state of the forest cover from 1990 to 2020 is summarized in **Table 2**.

Table 2. Summary of changes of land cover and land use from 1990 to 2020.

Land cover/Land use	Annual change from 1990 to 2020 (%)		
	1990-2005	2005-2020	1990-2020
Mature secondary forest	−18.16	−8.77	−26.92
Young secondary forest	13.29	−1.24	12.05
Savanna vegetation	4.80	4.69	9.49
Fallows and crops	−1.35	3.34	1.99
Built	0.59	2.01	2.60
Bare soil	1.07	−0.39	0.68
Water surface	−0.24	0.35	0.11

Negative value signify a lost while positive values signify gains in percentages.

The mature secondary forest has experienced a significant change in the period from 1990 to 2005 (−18.16%) compared to the period from 2005 to 2020 (−8.77%). The savannah vegetation experienced a slight change in its area from 2005 to 2020 (4.69%) compared to the period 1990-2005 (4.80%). With regard to fallows and crops, there are changes in its area, at a rate of −1.35% for the period 1990-2005 against 3.34% for the period 2005-2020. For buildings, the changes in the period 2005-2020 are greater (2.01%) than the period 1990-2005 (0.69%).

4. Discussion

The increased presence of standing burned trees, burned stumps and residues of illegal sawing testifies on the one hand to the neglect of ligneous trees in favour of food crops and on the other hand to the absence of forest control in the Mbalmayo forest reserve. Thus, after cultivation season, the search for fertile plots forces farmers to move, dragging old plots in a fallow state, which accelerates degradation. Agriculture therefore appears to be the main cause of degradation of the Mbalmayo forest reserve. Recent studies show that even classified forests are facing many anthropogenic pressures that lead to their degradation and deforestation (Zekeng et al., 2019; Djiongo et al., 2020; Fokeng et al., 2020; Temgoua et al., 2021). Similar drivers are found in other parts of Cameroon by Momo et al., (2018) in the Koupa-Matapit gallery forest and Temgoua et al., (2018) in the Ajei community forest. Agriculture has been identified as the main activity in the locality. The local populations therefore create agricultural plantations within the reserve in order to be able to extend their cultivable land consequently have a higher income when selling products coming from these plantations.

The 47 people surveyed and carrying out activities in the forest reserve are all farmers, who through their activities such as conversion into agricultural land of both large and medium plantations as well as smallholders and harvesting firewood have a negative impact on woody formations and species richness. This can be illustrated by the practice of fallow after a growing season; the farmer can decide for the following season to leave a field fallow and thereby convert other forest formations into agricultural land. Since the agricultural revolution, the world has lost much of the vegetation cover (Goudie, 1996). According to this author, nearly 16% of the forest is transformed into arable land. These transformations lead to the disappearance of certain habitats in certain parts of the terrestrial globe. Zapfack (2005) noted that agricultural land use causes land cover changes. The disappearance of certain natural habitats is frequent in the dense humid forest zone of southern Cameroon. In the Yaounde region and even in many others localities in the South, the original forests have disappeared, probably with plant and animal species. The state of degradation of the forest here results in excessive cutting and slash-and-burn agriculture. In Asia for example, Sakthivel et al. (2010) highlighted illegal lumbering, forest fires and shifting cultivation as leading causes to land use and land cover change in the tropical deciduous forest in Kalrayan hills in India. These findings do clearly reveal that agricultural expansion generally affects land cover conditions and status and is at the center of most forest lost registered in the world. The uses made of ligneous resources have been replaced, these are food, wood energy, traditional medicine and traditional rites. The respondents also noted that the rarity or even the disappearance of certain species that are highly valued in the pharmacopoeia, such as *Baillonella toxisperma*, *Mammea africana*, and many others. Dan et al. (2012), in their study of the swamp forest of Lokoli in Benin pointed out that the almost daily human presence within the forest, the research and harvesting of NTFPs and other wood products are at the origin of the loss or the disappearance of species.

Analysis of Landsat 5TM, Landsat 7ETM+ and Landsat 8OLI satellite images taken in 1990, 2005 and 2020 respectively has made the assessment of the evolution of forest cover in the Mbalmayo forest reserve and its surroundings over the past three decades possible. Land use leads to a change in vegetation cover. Vegetation is experiencing an essentially regressive evolution. This regression is much more important in dense forest vegetation. Since the agricultural revolution, the world has lost much of the vegetation cover (Goudie, 1996). According to this author, nearly 16% of forests have been transformed into cultivable land. Changes in forest cover over a period of 8 - 10 years and at a precise scale using images presented at different time periods remain the most appropriate tool to detect changes in vegetation cover (Mahmoud et al., 2010). The results obtained show that the forest reserve of Mbalmayo lost from 1990 to 2020 an area of 6993 ha (26.92%) of its forest cover, corresponding to an average deforestation rate of 0.89% or 233.1 ha/year. Temgoua et al., (2021) at the end of their work within the Melap reserve forest also obtained results showing an ongoing deforestation process. This trend of decreasing forest cover in favour of other land use types was observed by many authors in other protected areas in Cameroon. Some of these authors are Wafo et al. (2005) in Laf-Madjam forest reserve; Fokeng & Meli (2015) in Santchou wildlife reserve; Djiongo et al. (2020) in Bouba Ndjidda national park and Fokeng et al. (2020) in Metchie-Ngoum forest reserve. However this deforestation rate is higher than that found by Rogers (2011) who obtained a deforestation rate of 0.05% in Central Africa, and lower than those of Momo et al. (2012) who obtained a deforestation rate of 50.9% in the forest mountains of Kilum-Ijim, a value which follows the trend reported globally indicating that 50% of tropical forests have been severely degraded or converted for agriculture (Wright, 2005; FAO, 2007; Stork et al., 2009). This trend is similar to those observed by many authors in Cameroon and in Africa (Momo et al., 2012; Fokeng & Meli, 2015; Momo et al., 2018; Temgoua et al., 2018) and in other African countries (Avakoudjo et al., 2014; Benoudjita & Djinet, 2017; Zakari et al., 2018).

The Mbalmayo forest reserve is part of the Permanent Forest Domain (DFP) and therefore classified among the forests for integral protection. The changes observed then in the evolution of its forest cover over the last 30 years, especially since there are villages all around, suggest that the populations who are in constant search of land to exercise their subsistence activities, are the main players in the loss of forest cover in the area. Indeed, the Operational Unit for Monitoring Forest Cover (2019) in its report indicates that all the causes of deforestation are due to human activities. Of these, 60% were caused by agriculture (subsistence or industrial) which remains the main cause of forest cover loss nationwide regardless of land use category. As for logging activities, they cause 34.45% of disturbance on the whole forest areas encroached and lost. Temgoua et al. (2018) noticed from field observation that, farmers practicing slash and burn farming techniques, cattle head men are the principal agents causing land use change. They are accompanied by loggers who harvest wood for construction and housing purposes in the forest.

The results also showed a clear progression of young secondary forests during the period 1990-2020. The latter result from the degradation of old forests and can be qualified in this context as secondary post-cropping forests. Post-cultivation secondary forests are mainly home to ruderal and ubiquitous plant communities, very different from those of primary forest (Zapfack et al., 2002) and probably require several centuries before returning to the state of primary forest (Cascante-Marín et al., 2006; Barlow et al., 2007; Álvarez-Yépiza et al., 2008; Kassi & Decocq, 2008), although secondary forests can sometimes be an interesting complement from a species conservation point of view (Castillo-Campos et al., 2008; Dent & Wright 2009). Zapfack et al. (2002) have shown that primary and secondary forests in Cameroon have only 42% similarity in terms of specific composition and do not provide equivalent ecosystem services. The images also show an increase of built-up area. Urbanization and the expansion of infrastructure and population growth could explain this situation. When population pressure is intense enough, people also accentuate off-season crops in swamps in order to supply markets and meet their needs.

The current mature secondary forest cover of the Mbalmayo forest reserve is 10,001 ha, which corresponds to the data obtained after verification in the field. There is a decline in the areas of young secondary forests as well as that of old forests. In fact, we went from an increase in area of 3385 ha (13.3%) in 1990-2005 to a decline of 307 ha (−1.27%). Large areas of forests are therefore disappearing each year under the human action of man, who exerts pressure on forest species, thus leading to their death and probable disappearance. The Operational Unit for Monitoring Forest Cover (UOCSF) in 2019 reports with regard to protected areas such as the National Parks of Bakossi, Douala-Edéa and Tchabal Mbabo and in certain unnamed forest reserves located in the Center and South Regions Cameroon, it has been detected signals of deforestation due to agricultural activities and logging for timber harvesting. Knowing that these massifs are forest titles with a vocation of integral protection, it is necessary to awaken the conscience of the personnel of MINFOF in order to be more vigilant to accentuate the actions of protection of titles of this category.

5. Conclusion

This study aimed to present the changes in forest cover in the Mbalmayo reserve over the past 30 years, based on GIS analysis of satellite images. The methodological approach used for the processing of the satellite images chosen within the framework of this study shows us that observation and measurements in the field constitute an effective means for the characterization of the vegetation cover of the forest reserve of Mbalmayo and its surroundings. Thus, we have identified 7 types of land use, namely old secondary forests, young secondary forests, savannas, fallows and crops, buildings, bare soil and finally water surfaces. From 1990 to 2020, the mature secondary forest cover is in a trend of progressive deforestation. There is an area loss of 6993 ha (26.92%) of its surface, corresponding to an average deforestation rate of 0.89% (233.1 ha/year). This is explained by the fact that there is a human activity in the forest, by the cuts made by the populations in their growing need to extend land for the practice of agriculture and for exploitation lumber. Given that the forest reserves are classified in the Permanent Forest Domain, and therefore intended for integral protection, it therefore becomes urgent to redefine a management plan for the Mbalmayo forest reserve which will define how the forest must be managed to optimize the use of its resources and contribute to their sustainability. It also requires the participation of the local population, for example through the recognition of user rights. It would be important to make floristic inventories to have an idea of the specific richness of the forest reserve in order to delimit the zones to be granted more vigilance to limit the activities of the local populations and also to launch a program of reforestation.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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