
Plantation Agriculture as a Driver of Deforestation and Degradation of Central African Coastal Estuarine Forest Landscape of South-Western Cameroon

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Abstract

Plantation agriculture has a long history of establishment in Cameroon and is increasing at an unprecedented rate with detrimental impacts on coastal estuarine forest landscape. Remote sensing data from Landsat imageries and geographic information system (GIS) techniques were used to analyse changes in the areal extent of plantations within the coastal Atlantic estuarine forest complex area of Cameroon between the periods 1986, 2000 and 2011 to ascertain the extent of deforestation due to plantation agriculture. Given the base year of 1986 (67,792 ha of plantation), the results showed a 67 and 47 % decrease in the dense coastal estuarine forest coverage in 2000 (14,032 ha) and 2011 (24,564 ha), respectively, in the area and an increase in the area occupied by plantations (51,295 ha in 2000 and 68,340 ha in 2011) giving an annual loss of 3.4 % estuarine forest complex and an increase in plantation area of 0.03 % from the periods 1986 to 2011. There is need for better plantation management practices and policies to curb further loss in estuarine forest cover with consequent implications on the Wouri estuary.

Keywords

Plantation agriculture • Coastal estuarine forests • Impact • Deforestation • Degradation • Forest conversion

Introduction

The tropical rainforest including coastal estuarine forests constitutes the most valuable ecosystem of the planet containing 50–90 % of animal and vegetal species on earth (CIDA 2001). They represent over 57 % of global forest cover and are home to over 500 million people (CIDA 2001). Central and West Africa's 200 million ha of tropical

rainforest are the second largest remaining humid tropical forest in the world after the Amazon basin (FAO 1995). They are also known not only for their rich biodiversity but also for the essential ecosystem services such as nutrient and water cycling as well as climate moderation necessary for the proper functioning of the biosphere and the welfare and well-being of humans (Daily 1997; Millenium Ecosystem Assessment 2005; DeFries et al. 2004). Whenever the forest is opened up for agricultural purposes including plantations, the subsisting natural equilibrium in the forest ecosystem is disrupted and the services rendered impaired. Plantation agriculture in particular is established by clearing large areas of natural plant cover for the cultivation of a crop such as oil palm (*Elaeis guineensis* Jacq.), rubber (*Hevea brasiliensis*), cocoa (*Theobroma cacao*), coffee (*Coffea* sp.) and other perennial crops. There are many perspectives of what

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plantation agriculture is, but it is most frequently referred to as a large scale, usually foreign-owned and specialised high-input/high-output farming system that is export oriented (Courtenay 1980). The plantations owned both on large-scale investors and by smallholders are key sources of income for many farmers and countries in the tropics.

Several studies carried out have shown that deforestation due to agricultural activities often leads to severe transformations and degradation of the coastal aquatic ecosystems, especially through water quality changes. Metals tend to be assimilated in sediment with organic matter, Fe/Mn oxides, sulphides and clay thus forming several reactive components which are harmful to the environment (Wang and Chen 2000; Praveena et al. 2010). Hence, sediment is always regarded as the potential reservoir for metals and plays an important role in adsorption of dissolved heavy metals (Wang and Chen 2000; Praveena et al. 2010). Under different physical and chemical conditions, metals in sediment may leach out into the water column as free ions. In turn, contaminated sediments also act as sources of heavy metals when released into the river water. Metals concentration in river water can be regarded as a good indicator of the river contamination. Metal ions can be either an essential nutrient or toxic to living organisms (Salomons and Förstner 1984). When the metals concentration exceeds standard permissible limits, it would have toxic effects on living organisms and cause negative impact on lower life forms. When these metals enter into the food chain through phytoplankton and are biomagnified in aquatic organisms, they would pose potential risk to human health (Alkarkhi et al. 2009).

Moreover, deforestation and degradation following plantation establishment are also important factors of climate change contributing up to 30 % of greenhouse gases especially carbon dioxide (CO₂) that is known to cause global warming with consequent implications on the rise in sea level (Mitchell et al. 2007) especially as forests are carbon dioxide 'sinks' informing many of the current international efforts at mitigating climate change with current initiatives such as reducing emissions from deforestation and degradation (REDD+). The UN- REDD+ works to benefit the climate by preserving the tropical forest ecosystems to enhance the continuous delivery of environmental goods and services to ameliorate climate change impacts. Therefore, effective management of coastal agroforests as well as plantations will enhance the prospect of deriving environmental benefits of forests from them. This study aims at analysing changes in the areal extent of plantations within the coastal Atlantic estuarine forest complex area of Cameroon between the periods 1986, 2000 and 2011 to ascertain the extent of deforestation due to plantation agriculture as a basis of searching for ways to enhancing sustainability of the plantation ecosystem.

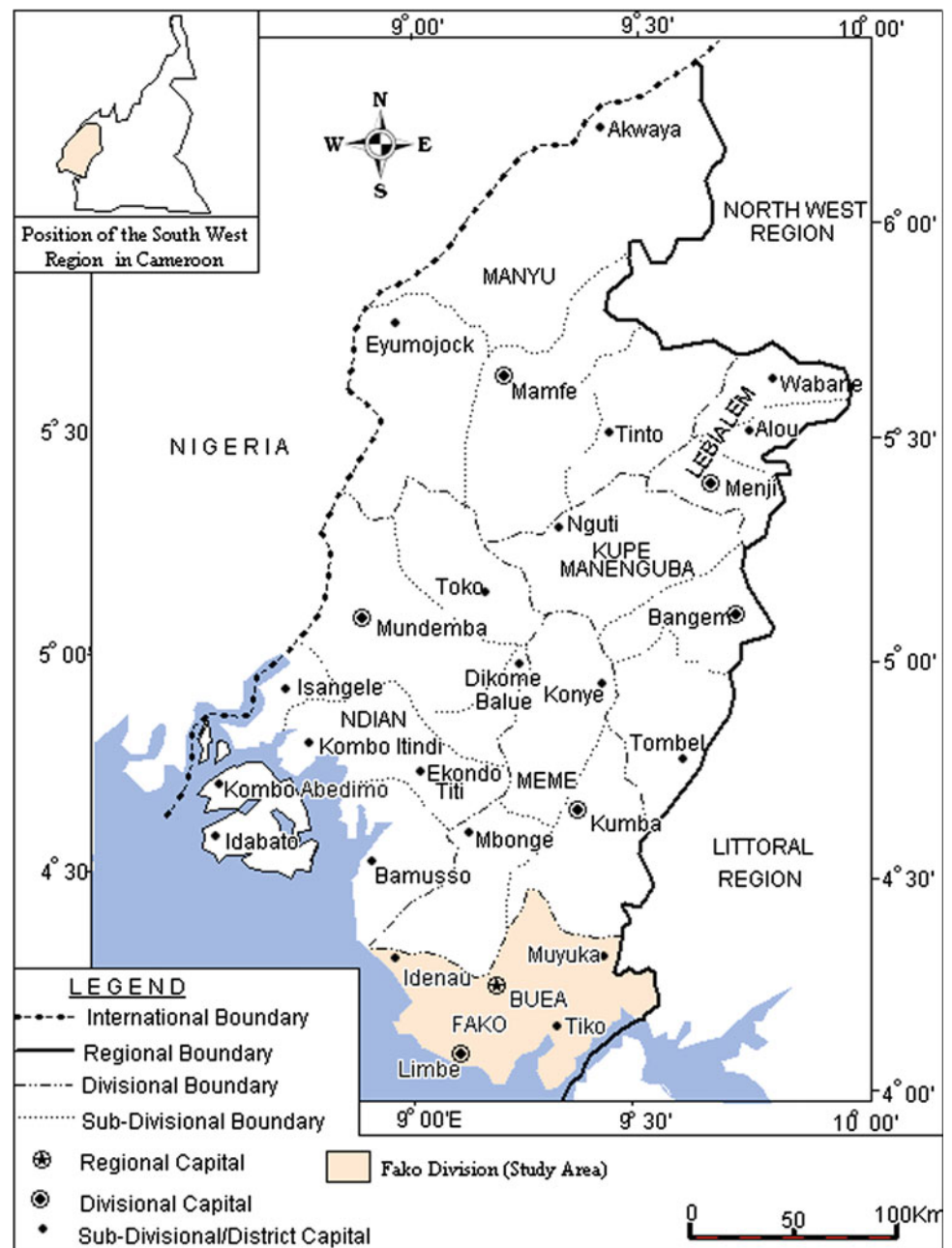
Methods

Site Description

The south-west region of Cameroon is located approximately between latitude 4° and 6° and longitude 8° and 9°45' east of the equator, covering an area of approximately 24,571 km². It is bordered to the north by the Federal Republic of Nigeria, to the east by the north-west region, to the west by the Atlantic Ocean and to the south by the Littoral Region (See map, Fig. 1). The area is characterised by a humid equatorial climatic type with high rainfall. Due to the orientation of the slopes of Mount Cameroon, it receives the monsoon winds at right angle. As a result of this, the moisture transported by the monsoon from the ocean is deposited in the form of heavy rainfall. The Limbe area has an annual rainfall average of 4,050 mm (Neba 1987). Rainfall reaches a peak of about 7,000 mm in July and August. Debuncha that is the wettest place in West and Central Africa has an annual rainfall of 10,000 mm which is the highest in the region. The relative humidity of the area is strongly influenced by its maritime location and is at 75–80 %. The maximum annual temperature of the area is 25 °C, while the minimum is 24.7 °C suggesting a relatively high constant temperature with a low range. Neba (1987) puts the annual temperature at 24 °C. The vegetation of the area is characterised by the equatorial rainforest type. It forms the discontinuity of the swampy vegetation which is dominant along the Cameroon coastline (Neba 1987). The luxuriant evergreen forest is comprised of a variety of tree species such as *Lophira alata*, *Sacoglottis gabonensis* and *Erythrophleum ivorensis*. The largest National Park—Korup National Park—with many rare and endangered species and the Limbe Botanic garden among others are found in this region. As a result of man's intervention, the climax vegetation has been cut down for human activities such as agriculture, communication, transportation and urbanisation. The secondary vegetation is now widespread with the luxuriant vegetation occupying peripheral positions mostly at high altitudes (Neba 1987). One conspicuous feature of human intervention is the domination of the vegetation by Cameroon Development Cooperation (CDC) plantations at the foot of Mount Cameroon (Fig. 2).

Mount Cameroon (4,100 m), the highest physical feature in West Africa and an active volcanic mountain which lastly erupted in May 2000, is found in this region (Neba 1987). The area is well drained and is an important watershed as most of the streams take their sources from Mount Cameroon and flow across the west slopes cutting V-shaped and U-shaped valleys before draining into the sea. The Wouri estuary lies to the east of Mount Cameroon and empties into the Bight of Biafra (Fig. 3). It is fed by the Mungo, Wouri

Fig. 1 Map of the south-west region showing the study area



and Dibamba rivers. To the west of the estuary are the slopes of Mount Cameroon covered with banana plantations.

Agriculture is the mainstay of the Cameroon economy. Pesticides are not regulated and also contribute to pollution. Pesticides that have long been banned elsewhere are still in use. The growing population is increasing production of export crops such as coffee, cocoa, bananas and palm oil, using imported pesticides and fertilizers. Typically fertilizers contain urea, ammonia and phosphorus. Pesticides applied are mostly DDT and other derivatives of organohalogenes (Sama 1996).

Overview of Plantation Agriculture in Cameroon

Plantation agriculture managed by the CDC is an important economic activity in south-western Cameroon, employing over 15,856 workers and contributing significantly to the national economy. The 2002 statistics of the Consultative Group for International Agricultural Research (CGIAR) estimates that agriculture accounts for 43 % of the GDP of the area. Rubber and banana have been grown in the forest zone of south-western Cameroon for close to a century (CDC Reports). Plantation agriculture began in the south-western region of Cameroon in 1885, when the two leading German

Fig. 2 A three-dimensional image of the area showing the location of plantations

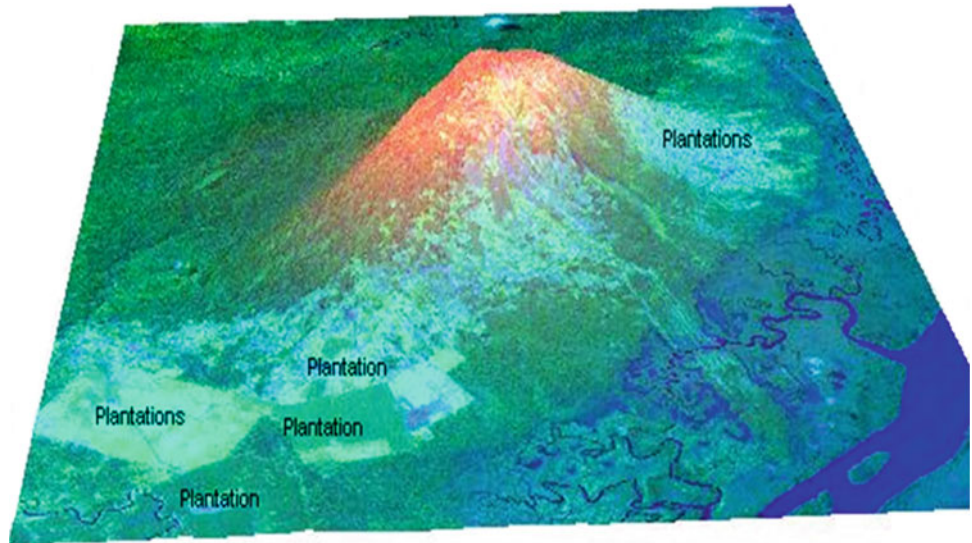
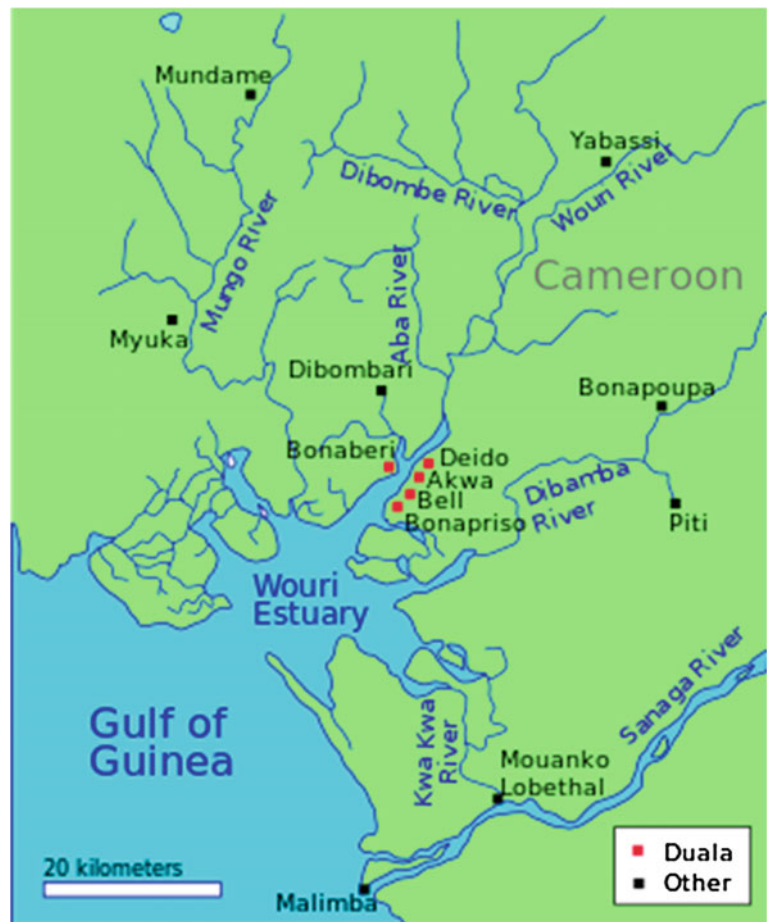


Fig. 3 Map showing the Wouri estuary and the rivers



firms in German Cameroon, Woerman and Jantzen und Thormalen, founded two plantation companies (Courtenay 1980). The massive expropriation by these two firms altered

the sociology and history of the various Bakweri clans. German companies exploited the traditional land ownership of the native people to their advantage. The vast level land

was used for plantation agriculture and the people were forcefully displaced from their homes and herded off onto strange and unfriendly patches of land around the plantations. In a nutshell, the Germans alienated about 400 square miles of the most fertile land around the Mount Cameroon alone and stripped the people of over 200,000 acres of their most fertile lands. The size of the plantations kept on growing under British supervision following the defeat of the Germans after the First World War (Cameroon Development Corporation Report 1970). The spread of plantations slowed during the depression years between 1920 and 1940. However, following the return of peace and favourable conditions for international trade and investments after the end of World War II in 1945, the plantation system started expanding once again. In January 1947, CDC was created to take over and manage the plantations. The expansion continued through the following two decades. It accelerated during the immediate post-Independence era, about 1960–1965, which saw direct involvement of the national governments of the newly independent states in the establishment and running of plantations. Thereafter, the expansion slackened, mainly because of a decline in external investments following the growing political instability and state control of the national economies and the attendant erosion of foreign investors' confidence in them (Halfani and Barker 1984). Since about 1975, the plantation system has witnessed rejuvenation as a strategy for stimulating agricultural production. In the south-western region of Cameroon, the area under plantations increased from about 20,000 in 1960 to over 73,788 ha in 2006 (CDC Report 2006).

Data Collection

Relevant data for the study were collected from both primary and secondary sources. Primary data set was collected from the field with the use of the global positioning system (GPS). Secondary data included data collection from documented sources especially plantation records of the Cameroon Development Corporation on plantation ages, areal extent, cultural practices, yields, economics, among others. Information on the flora and fauna was obtained from organisations involved in conservation such as the Mount Cameroon Project, The German Technical Cooperation (GTZ), Delegations of Forestry and Wildlife in the area.

Landsat satellite imageries for the year 1986, 2000 and 2011 were also obtained from the global land cover facility (GLCF) website. Other sources include journals, internet and books. Due to the fact that Mount Cameroon is most of the time clouded, the factors that governed the choice of the satellite imageries were the quality of the imageries available and time interval.

Data Analysis

GIS and remote sensing were used to determine land cover change following the establishment of plantations in the area between 1986 and 2011. The activities that were carried out include satellite image processing and classification for land cover change detection. Changes in the areal extent of the plantations were analysed using Landsat imageries of the site for 1986, 2000 and 2011 to be able to monitor the extent of deforestation for plantation agriculture that has taken place in the area. The landsat imageries were georeferenced to the coordinate system of the study area (WGS84, projection: UTM zone 32). Erdas Imagine 9.2 software was used in processing and analysing the imageries. Visual interpretation of satellite imageries was enhanced through the use of linear stretching. Clouds and clouds shadows present on images used for the study were reduced through masking techniques in Erdas Imagine Software.

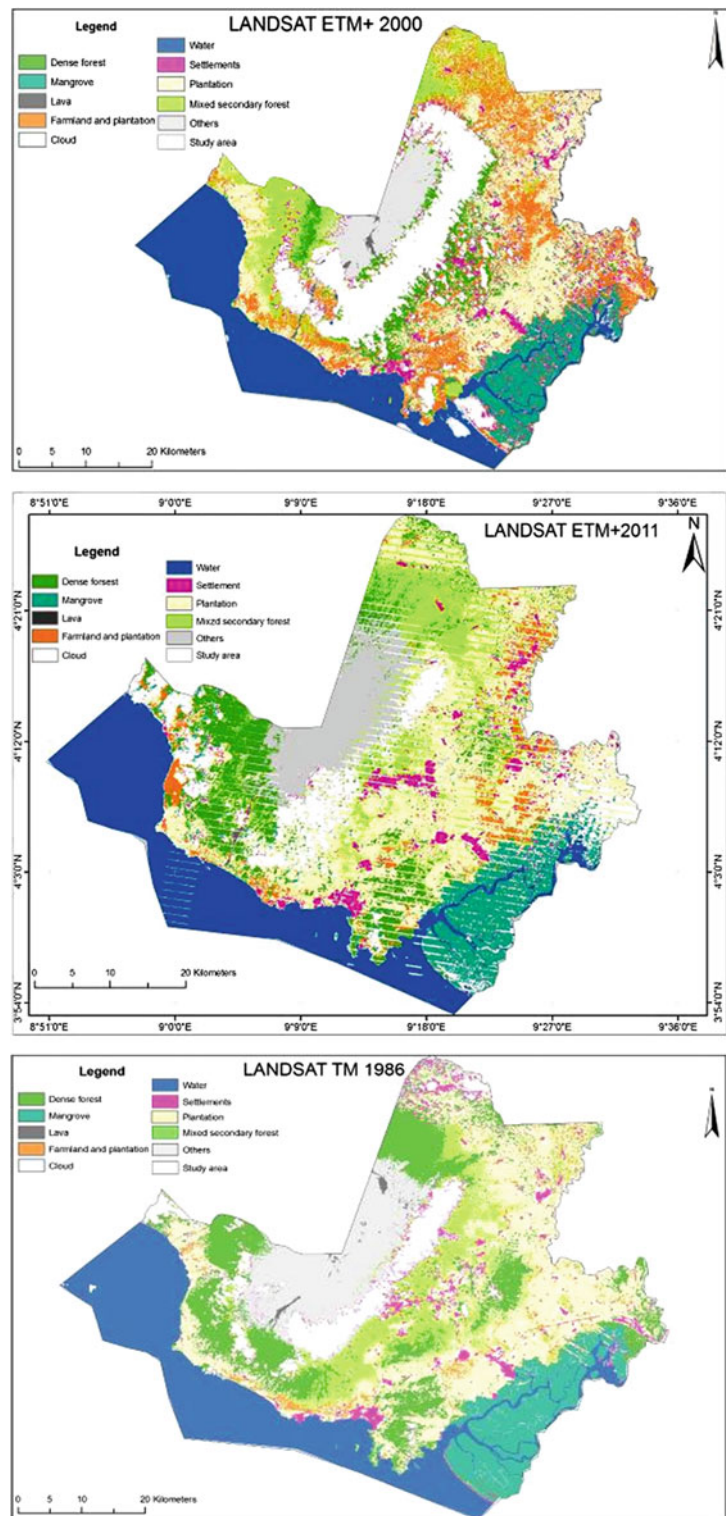
Two main steps were followed in land cover mapping. First, unsupervised image classification was carried out prior to field visits, in order to determine strata for ground truthing. Supervised classification based on maximum likelihood classifier algorithm was then used in the classification of the 1986, 2000 and 2011 images. This was based on 130 training sets or ground control points collected. Expert knowledge was used in selecting the 130 points on spot at good distances away. The sample points collected were used to validate classification results.

Some 25 % of the collected ground control points were used to train the data and the remaining 75 % were used for the analysis. The image classification accuracy was assessed by calculating the Kappa coefficient. The Kappa statistics is an estimate of the measure of overall agreement between image data and the reference (ground truth) data. Its coefficient falls typically on a scale of 0 and 1. It is often multiplied by 100 to give a percentage measure of classification accuracy. Kappa values are classified into 3 groupings: a value greater than 0.80 (80 %) represents strong agreement, a value between 0.4 and 0.8 (40–80 %) represents moderate agreement and a value below 0.4 (40 %) represents poor agreement (Congalton 1996). Post-classification method (Lu et al. 2004) of change detection was used in analysing the result from the land cover maps.

Results and Discussion

Figures 3, 4 and 5 show the land cover change between 1986 and 2011. They indicate that the secondary forest, farmlands and the plantations have considerable overlap in their spectral reflectance. It was however, difficult to separate the dense forest and the plantations based on their

Fig. 4 Land cover changes from 1986 to 2011 around the Mount Cameroun estuarine forest complex



spectral characteristics. The difficulty is probably related to the similarity in the ground cover of both land cover classes. The similarity in the crown cover offers a similar reflectance surface for both land cover types, leading to an overlap in their spectral characteristics. However, textural differences in the land cover classes associated with the regular spacing

of trees in the plantations and the fact that plantations are laid out in consecutive regular blocks made easy the demarcation between the plantation and the forest. Hence, the regular spatial arrangement of trees in the plantations possibly contributes to the textural differences between plantations and the forest. The secondary forest and the

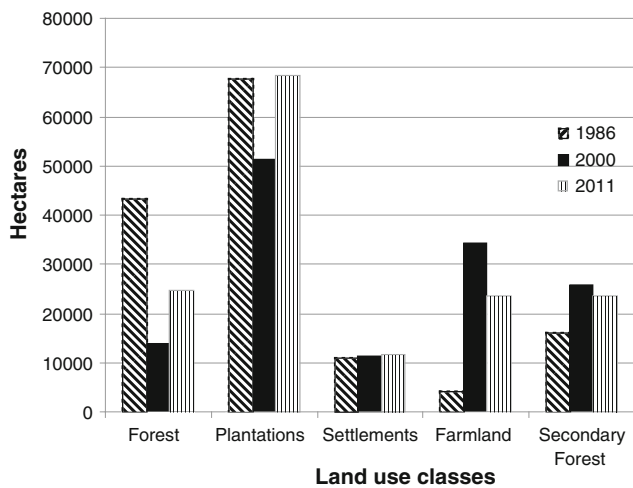


Fig. 5 Land cover change between 1986 and 2011

farmlands were also separated based on the textural differences observed. The Mount Cameroon area is permanently clouded throughout the year. Though the clouds somehow acted as a natural impediment to classification, it was still possible for various classes to be identified. Nine land cover classes were discriminated based on the spectral, textural and structural characteristics observed on the satellite images. These include the following: water, settlements, lava, and the dense forest, plantations, mixed secondary forest, mangrove, farmlands and the clouds. Clouds and clouds shadows present on images were reduced through masking techniques. Figures 3, 4 and 5 show the land cover map of the study area in 1986, 2000 and 2011, respectively.

Accuracy Assessment

The Kappa statistics gave an overall accuracy of 88 %. This value falls within the range described by Congalton (1996) as a strong agreement. These high-accuracy results demonstrate that the combined use of spectral and textural characteristics increased the number of classes in the final classification and also with a good accuracy (Table 1).

Land Cover Change Detection Qualification and Quantification

Land cover change analysis over the period 1986 to 2011 in the area revealed four important land cover changes as can be seen in Fig. 5. The results revealed that the dense forest coverage was lower in 2000 than in 2011. The total surface areas occupied by the dense forest were 43,280.9, 14,032 and 24,564 ha, respectively, for the year 1986, 2000 and 2011. The results revealed a decrease in the dense forest coverage in 2000 and 2011. There were a 67 and 47 % reduction in forest area in the year 2000 and 2011, respectively. More than half of the forest area existing in

1986 was gone in the year 2000 pointing out clearly the impact of deforestation due to plantation agriculture in the area.

The results show that settlements had a steady increase throughout the study period (11,022, 11,312 and 13,512 ha for the year 1986, 2000 and 2011, respectively). The area classified as farmlands increased between 1986 and 2000 and decreased in 2011 (4,149, 34,453 and 23,515 ha). The plantations increased in 2011 and decreased in the year 2000 (Table 2). The year 2000 witnessed a 24 % (16,497 ha) reduction in the area occupied by plantations compared with 1986. The year 2011 witnessed a 33 % (17,045 ha) increase in the surface area occupied by plantations. The decrease observed in the year 2000 was because of CDC policy to surrender land to various communities.

There have been conflicts between CDC and the various Bakweri clans whose lands were taken by the colonial masters for plantation agriculture. In the early 90s, the matter was taken to court by the various Bakweri chiefs. The court ordered CDC to release part of the land to the natives. As from the year 1998, the corporation started allocating land to over 55 village communities, schools, municipal councils, churches, companies and non-governmental organisations (CDC Report 1999). This was in conformity with the procedure for the surrender of CDC land thereby accounting for the decreased observed in the year 2000.

Land Cover Dynamics

The results of land cover change in the area between 1986 and 2011 revealed some important changes which were consistent over the years. From these results, it is observed that the rate of conversion of dense forest to plantations, secondary forest and other land uses dropped from 2,089 ha a year between 1986 and 2008 to 957 ha a year between 2008 and 2011. The reason for this drop can be attributed to an increase in awareness on the dangers of deforestation demonstrated by some conservation NGOs in the area. Plantations expanded during the two periods with the rate of expansion in the second period increasing to almost a third the rate in the first period from 1,178 ha per year to 1,549 ha per year. The difference in the land cover change rates between the two periods is due to some plantation management policies. The CDC policy of expansion may account for this increase.

The observed decrease in forest cover and increase in plantation coverage in the area is a pointer to the fact that plantation encroachment is one of the causes of deforestation in south-western Cameroon. The increase in the surface area occupied by plantations is due to its positive economic impact in the country as a whole which is linked to the high

Table 1 Accuracy assessment classification

Class name	Reference totals	Classified totals	Number correct	Producers accuracy (%)	Conditional kappa for each category (K [^])
Unclassified	1	1	1	–	0.8407
Forest	6	7	6	100.00	0.7852
Mixed secondary	4	5	4	100.00	1.000
Water	4	4	4	100.00	0.6588
Others	0	0	0	–	1.000
Farm and plantation	7	4	4	57.14	1.000
Plantation	6	5	5	83.33	1.000
Lava	2	2	2	100.00	1.000
Settlements	13	11	11	84.62	1.000
Cloud	2	2	2	100.00	1.000
Mangrove	3	4	3	100.00	0.7364
Totals	58	58	52		
Overall classification accuracy		= 89.66 %			
Overall kappa statistics		= 0.8834			

Table 2 Surface area occupied by various land uses in the study area

Landuse (ha)	1986	2000	2011
Dense forest	43,280.9	14,032	24,564
Mixed secondary forest	16,253	25,916	23,515
Plantation	67,792	51,295	68,340
Farmland and plantation	4,149	34,453	23,515
Mangrove	21,557	16,286	17,855
Settlements	11,022	11,312	13,512
Lava	835	667	278
Cloud	20,608	40,270	23,238

demand of banana and other plantation produces in the Western world. This has caused many national and international companies to be increasingly involved in this activity. Also, various assistance schemes such as the supply of free seedlings and financial assistance to individuals and community-based organizations such as the common initiative groups through the South West Development Authority (SOWEDA) have made the process of starting a plantation fairly easy.

The role of plantation agriculture in modifying the natural forest cover has been documented by other researchers. Hartemink et al. (2008) attributed the high rate of forest conversion to intensive agricultural plantations in the tropical regions as largely due to the increasing population in the region. Serneels (2001) discovered that changes in the land cover of the Kenyan Embu Highlands were due to the

introduction of commercial plantations in the area which resulted to a decrease in the natural vegetation cover.

The struggle to satisfy the basic human livelihood demands is generally accepted as the main trigger behind forest conversion in tropical areas (CIDA 2001). The rate of current deforestation is alarming and remains a critical issue regarding its implication for the global carbon cycle and biodiversity. The annual deforestation rate in the area due to plantation agriculture is 1.3 % which is greater than the FAO (1995) annual deforestation rate of 0.6 % in Cameroon.

Several studies carried out around the world also revealed the negative impacts of plantation agriculture on biodiversity loss. Koh and Wilcove (2008) looking at the impact of oil palm agriculture on tropical biodiversity in Malaysia and Indonesia acknowledged that oil palm plantations in Malaysia and Indonesia have replaced forests and,

to a lesser extent, pre-existing cropland. More importantly, their study revealed that the conversion of primary forests and logged forests to oil palm plantations decreases the species richness of forest birds by 77 and 73 %, respectively. A similar analysis conducted for Indonesia between 1990 and 2005 revealed that oil palm-cultivated area in Indonesia increased by 3,017,000 ha (FAO 2007). The effect of deforestation on estuaries is much more rapid in the tropics than in temperate zones because of intense rainfall. Deforestation has been shown to increase soil erosion and sediment loads in rivers typically by a factor of 10 (Wolanski and Spagnol 2000).

Conclusion

Estuaries form a transition zone between river environments and maritime environments and are subject to both marine influences, such as tides, waves and the influx of saline water; and riverine influences, such as flows of fresh water and sediment largely influenced by deforestation. The inflows of both sea water and fresh water provide high levels of nutrients in both the water column and sediment, making estuaries among the most productive natural habitats in the world. The sea water entering the estuary is diluted by the fresh water flowing from rivers and streams. The pattern of dilution varies between different estuaries and depends on the volume of fresh water, the tidal range and the extent of evaporation of the water in the estuary.

Plantation agriculture is a major driver of deforestation and biodiversity loss in south-western Cameroon. Based on the changes observed, better management practices can be put in place to ensure the sustainability of resources and the proper functioning of the estuarine ecosystem for the well-being of man and the environment.

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