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Using Remote Sensing and GIS to Evaluate Mangrove Forest Dynamics in Douala-Edea Reserve, Cameroon

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Abstract

Spatial characteristics were useful in understanding impacts of human activities on environmental conditions concerning landuse and landcover. Mangroves are in danger from natural and anthropogenic stressors. This study assesses changes in mangrove forests within Douala-Edea Reserve, looking at the extent of mangrove forests, relative to anthropological impacts on mangrove forests cover changes from 1973 to 2015, using Landsat data. A supervised classification technique was applied to Landsat images (ETM^+ 2001, 2007, 2015, TM 1989 and MSS 1973, 1975). Image classification of eight bands of six Landsat images was done, using the maximum likelihood classification method aided by ground truth data. The collected points were from trips within 2014 and 2015, used for accuracy assessment and final maps production. The results showed mangrove forest has changed dramatically. Between 1975 -2007, mangroves increased by 80 km² (25.15%), settlements increased by 16.71 km^2. Between 1973 -1989 the mangrove/swamp decreased by 168.58km² (56.47%), settlement increased by 24.87km². During the last 14 years (2001-2015), the mangrove/swamp decreased by 149.54 km² (58.38%), settlement decreased by 47.21km² (96.06%). Conclusively, the Douala-Edea reserve significantly changed in mangrove forest cover, and concerted actions are required to reserve the changes. Future mapping and fieldwork could provide information relating to mangrove resource use and better conservation options. The findings provide information to decision-makers on mangrove loss to secure the future of mangroves and ecosystem services in the reserve.

1. Introduction

Mangrove deforestation and depletion are a worldwide issue, despite the managerial efforts of the governing bodies over the past two or three decades. Mangrove forests provide several provisioning services such as food, timber, fuel-wood, etc., which provide economic benefits and security to local coastal communities [1]. Mangrove forests are threatened directly or indirectly exposing the ecosystem to severe environmental threats leading to loss of habitats and biodiversity as a whole. Remote sensing technology has been applied in various ways to characterize mangrove ecosystems. Some of the documented applications include mapping the areal extent, detecting individual species, and providing estimates of structure and parameters such as leaf area, canopy height, and biomass [2]. Generally, all the remote sensing applications in mangrove ecosystems can be categorized into three broad areas, identified as resource inventory; change detection; and selection and inventory of aquaculture sites [3]. The remotely sensed data and the techniques that have been used for characterizing mangrove ecosystems have evolved, moving from a traditional remote sensing approach to a more advanced one. The traditional approach includes the use of aerial photography (AP) and some high-resolution systems [4, 5] which are still very useful today, involving the use of high resolution (multi-spectral) satellite imagery like Landsat and ETM+. Aerial photography is very effective over small areas than satellite remote sensing since it provides fine-grain imagery and it's essential for the accurate assessment of classification procedures performed on other lower-resolution data.

The most common technique associated with aerial photography has been visual interpretation. Cameroon's mangrove area was estimated at 103,817 ha [6] corresponding to the second largest in surface area cover, according to the statistical illustrations presented in the Atlas of the Mangroves of Cameroon, constituting a highly coveted area, due to its location near large cities such as Douala and Tiko where population growth is leading to the occupation of the peripheral space generally occupied by mangroves [7]. The main motivation for the characterization of this mangrove ecosystem was to monitor and evaluate its cover change to better manage and conserve it. The study used the supervised classification and the NDVI in its analysis [8]. Land use and land cover (LULC) is an important components in understanding the interaction of human activities with the environment. The land cover changes due to human land-use activities are regarded as the main reason for global environmental change, so the study on them become the forefront and hot spots of research to scholars [9, 10]. The analysis of the temporal and spatial process of Landuse change and familiarity of the key drive factor in this process along with its role help to in-depth understand the driving mechanism which causes a land-use change in mangroves forests, and in addition, they are the valuable scientific basis of the regional management, decisions and sustainable use of land. Accordingly, [11] humans have altered the natural environment, Landuse and Landcover are dynamic and are an important factor for the comprehension of the interaction and relationship of anthropogenic activities with the environment. Increasing population growth with unsustainable resource use is a major factor responsible for a change in the study area's landscape pattern [12]. The information generated on landscape change and configuration help to analyze global ecological and environmental change.

Knowledge of the nature of LULC change and its configuration across spatial and temporal scales is consequently indispensable for sustainable environmental management and development [13]. Remote sensing technology is principally appropriate for mapping environmental phenomena such as land use and land cover as field-based mapping is practically difficult, remote sensing observations provide continuous monitoring across varied spatial and temporal scales [14]. Application of remotely sensed data made it possible to study the change in land cover in less time, at a low cost, and with better accuracy in association with Geographical Information System (GIS), providing a suitable platform for data analysis, update, and retrieval [15]. Emphasizes are laid on the need to measure landscape dynamics quantitatively [16], by incorporating landscape patterns and change from satellite image analysis. National spatial databases enable the monitoring of temporal dynamics of LULC due to its primary importance in accounting for natural resource planning [10]. Similar research studies have been done in the neighboring mangrove zones [17, 6], and covered canopy dynamics [17] for those within it focused on assessing parameters like litter fall, structural characteristics, water and soil properties and considerably varying areas depending on the site [18]. The study determined the extent and distribution of mangrove forests in the Douala-Edea reserve and identified the rates and causes of change using multi-temporal satellite data and field observations. In the context of mangrove dynamics, as spatial changes in vegetation patterns over time, our analysis sought to answer the following research questions: how much mangrove forest remains and what is the rate and causes of change.

2. Methodology

2.1 Study Site Location

The Douala-Edea Wildlife Reserve (DEWR), is located in the southwestern part of Cameroon, in the littoral region, between Wouri and Senegal Maritime Administrative Division of the Kribi-Douala basin of the Atlantic Ocean. It lies between latitude 3° 14' and 3°, 53' North and longitude 9° 30' and 10° 05' East. The DEWR is covering an area of 160,000 ha; it stretches about 100 km along the Cameroon coastline [19]. The DEWR (Figure 1) was established in 1932. It was designated a wildlife park for scientific purposes in 1971, and by 1974 the reserve had a conservator and guard post. The local communities in and around the reserve are highly dependent on the mangroves for both subsistence and commercial uses [20, 21]. Therefore, mangroves are under severe pressure from anthropogenic activities and natural disasters.

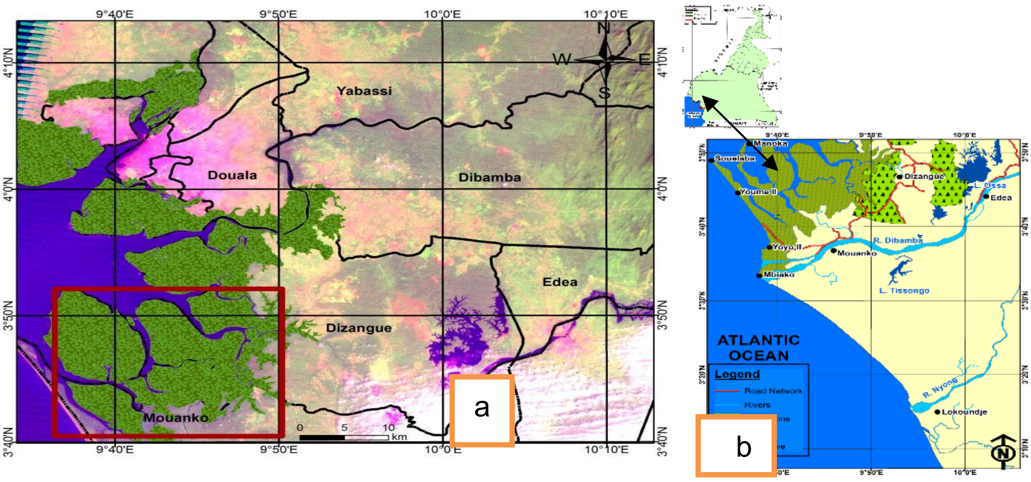


Figure 1: Location of the mangroves of the Douala –Edea Reserve Cameroon and study site in the red enclosure. (*Source*: Field survey, 2015). **b)** Study area map with representative areas of mangroves in the Douala Edea Wildlife Reserve on the Cameroon map detailed to show the communities with mangroves.

The Salinity in Douala mangroves is zero during the rainy season [22]. While along the estuary, during the long rainy season, the salinity of the mangrove area is always less than 10‰. During the dry season, measurements show that it varies between 4 and 20‰ [23], less than 30 km away from the ocean. The mangrove forest consists mainly of the *Rhizophora racemosa* (red mangrove), *Rhizophora mangle,* and *Rhizophora harrisonii*; and isolated particles of *Avicennia sp* or *Laguncularia racemosa* (white mangrove) in association with Nypa palm (*Nypa fruticans*). Rhizophora makes up more than 90% of Douala-Edea mangroves, with *Rhizophora racemosa* (red mangrove) being exceptionally big, especially at the Sanaga and Wouri estuaries, where over 100cm in diameter and 50m in height have been recorded, with tree stocking rates of 911 stems/ha, $88.6m^2$/ha and $1315m^3$/ha (for trees of 5cm and above in diameter) [19].

2.2 Data acquisition and classification

This study made use of satellite images obtained from the United States Geological Survey (USGS) and the Global Land Cover Facility (*www.Glcf.umiacs. und.edu*) websites. These images were processed using the remote sensing software ENVI 4.4 (2004) and maps were produced using the ArcGIS 9.3 (1999) software. The primary data used is optical multispectral satellite images that were acquired and processed. Satellite data was acquired from the Landsat sensor (MSS, ETM+, and TM) only.

All the optical multispectral images used were obtained from the Landsat sensor and were acquired already geo-referenced (WGS 1984 projection and datum: UTM Zone 32 N). Due to the high reflectance in band 7 and the high reflectance of vegetation in bands 4 and 3, these bands were used to generate false-colour composites in the classification process and for the NDVI analyses. They were used in combination with band 2 (Landsat MSS: 342, Landsat TM, and ETM+: 742). In this study, a total of 6 Landsat images were used: MSS 1973 which was acquired on the first of February, 1973; MSS 1975 obtained on the sixth of June, 1975; TM 1989 acquired on the fourth of February, 1989; ETM+ 2001 which was obtained on the twenty-sixth of April, 2001, EMT+ 2007 image obtained on the 5th of January, 2007 and EMT+ 2015 which was obtained on the first of January, 2015. Image selection was based on the availability of images within the geographic coordinates defined, reduced cloud cover, the time interval of at least 8 years, and spatial resolution.

Vegetation types identified from the 1973-2015 images were counterchecked by carrying out fieldwork for primary and secondary data in the study area to update data interpreted from the image. A GPS was used to record ground coordinates for different vegetation types on the map to increase the accuracy of reference points. A GPS-guided field investigation was conducted in April and July 2015. The fieldwork supported the interpretation of TM and ETM+ images and delineation of the general land cover types and mangrove/marsh areas. The field observations provided independent reference data for the accuracy assessment. The obtained coordinates were later used to validate the observed Landuse and vegetation cover types on the satellite images before classifying the land use and vegetation cover changes over time [24].

Training sites were identified after prior field knowledge and the Normalized Differential Vegetation Index (NDVI) tool used for quality supervised classification as it provides 27 vegetation indices needed to detect the presence and relative abundance of pigments, water, and carbon as expressed in the solar-reflected optical spectrum (400 nm to 2500 nm) (Figure 2). NDVI calculation was defined by the following equation [25]:

$$\mathrm{NDVI} = \frac{4-3}{4+3} \qquad \text{-------------------------- Eq. (A.1)}$$

Where: 3 and 4 referred to bands 3 and 4 of the satellite images used. The value of the NDVI index ranges from -1 to 1 and the common range for green vegetation was 0.2 to 0.8.

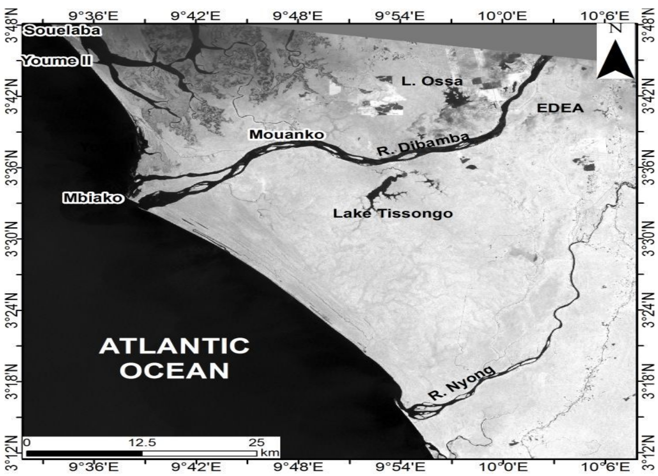


Figure 2: NDVI classified 2001 image. The lighter the color (grey to white) the more the vegetation, while negative values represented by very dark bands imply no vegetation (which could either be bare soil, settlement, water, marsh, cloud, etc.).

From the NDVI classification and field assessment, 6 training sites (Landcover classes) were defined and classified as: mangrove/swamp or marsh, settlement, plantations/agricultural land, forest, cloud cover, and water bodies (Table 1).

Table 1: Training sites classification and description

Training sites / Landcover classes	**Description**
Mangrove/swamp or marsh	Characterized by mostly trees with deep roots (mangrove) surrounded by a mixture of water and soil (marsh or swamp)
Settlement	This constitutes built-up areas (roads, houses) and bare soil
Plantations /agricultural land	Large and/or small hectares of land cultivated by corporations for the economic purpose (plantations) or by individuals for subsistence agriculture (agricultural land)
Water bodies	Ocean, springs, streams, lakes, and rivers
Cloud	Areas covered by the cloud made it impossible to define them. The presence of clouds is a common occurrence in images taken in the tropics and it is impossible to remove them during the classification process.
Forest	Area covered by vegetation not being mangroves

In this study, change detection was performed through the overlay method based on generated vector themes of different years. Change detection was done between supervised classified images of 1973-1989 (16 years difference), 1975-2007 (32 years difference), and 2001-2015 (14 years difference) using the first year as a common baseline data year for the periods. The overlay was performed by intersecting feature themes so that the boundaries and attributes of themes were combined to form the derivative output theme. The estimation for the rate of change [26], for the different covers, was computed based on the following formulae:

$$\%\ Cover\ change = \frac{Area_{iyearx} - Area_{iyearx+1}}{\sum_{i=1}^{n} Area_{yearx}} X\ 100 \qquad \textbf{Eqn. 1}$$

$$Annual\ rate\ of\ change = \frac{Area_{\ iyearx} - Area_{iyearx+1}}{t_{\ years}} \qquad \textbf{Eqn. 2}$$

$$\%\ \text{Annual rate of change} = \frac{\text{Area}_{\text{iyearx}} - \text{Area}_{\text{iyearx+1}}}{\text{Area}_{\text{iyearx}} \text{ x t}_{\text{ years}}} \text{X100} \qquad \textbf{Eqn. 3}$$

Where: $Area_{\ i\text{-}year\ x}$= area of cover i at the first date, $Area_{\ i\text{-}year\ x+1}$= area of cover i at the second date, $\sum_{i=1}^{n} \text{Area iyearx}$ = total cover area at the first date, and *t years* = period in years between the first and second scene acquisition data.

The flow chart below (Figure 3) summarizes the procedure applied in this study to carry out change detection of the identified classes over the years.

3. Results and Discussion

3.1 Land cover and land use classification

Accuracy assessment [27], was done based on the classified classes used during the study on the maps acquired from the USGS and Global Landcover facility sites. Classification accuracy was necessary to establish the performance of derived thematic map with ground truth or other reference data set. Information was evaluated using producer's and user's accuracy. Six classes were selected for the study after the pre and post-classifications which included: I) mangrove/ swamp/marsh ii) Forest s iii) plantation/ agriculture, IV) settlement v) water bodies and VI) cloud cover. The study was elaborated with a focus on the mangrove/ swamp/marsh area to assess the changes over the years.

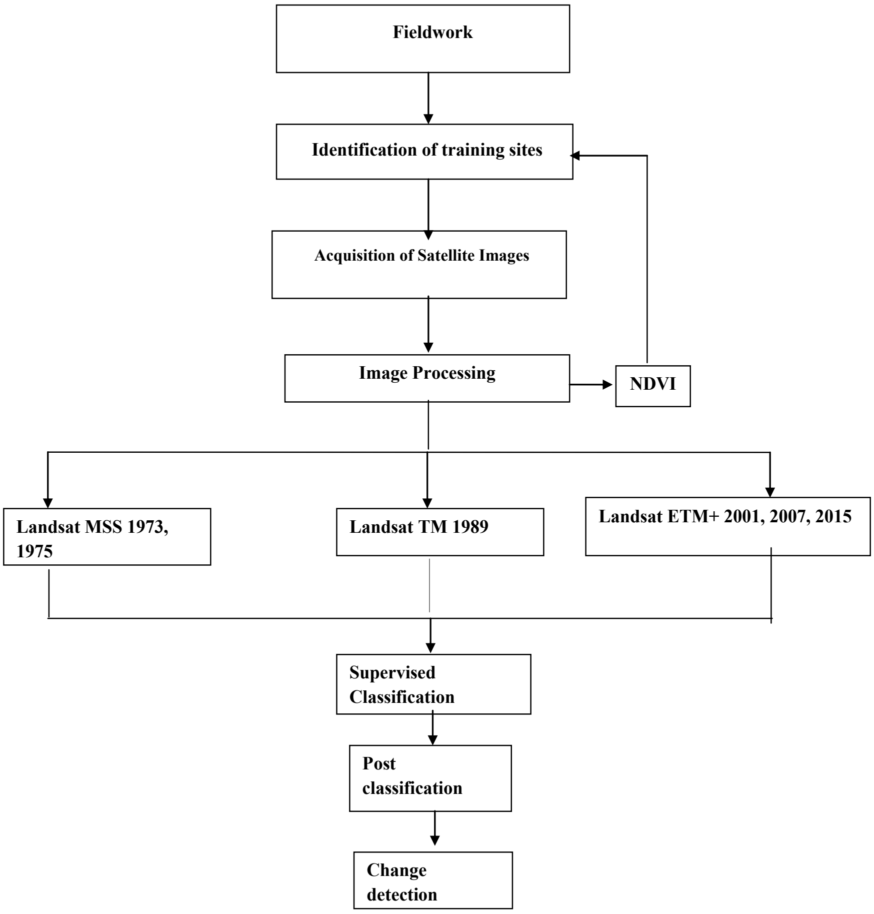


Figure 3: Scientific approach used in this study. The determination key was used to interpret Landsat images for 1973, 1975. By comparing all vegetation maps (1989, 2001, 2007, 2015), a view of the dynamics of the forest was obtained and together with local observations enabled us to gain insight into the hypotheses accounting for the observed dynamics.

The overall total accuracy of the 2007 image was lower than that of the other images. This was attributed to cloud covers that characterized the image in the eastern part (Figure 4). Also, the Landsat ETM+ sensor from where it was derived had developed some technical problems over the years which may have affected the accuracy of the classification. The period from 1989 to 2015 as indicated in the images, shows a high intrusion of settlement which is today being controlled by the government due to over-exploitation within the creek zones. In this study, producer's accuracy (PA) refers to the original image used, while the user's accuracy (UA) is the classification of images just carried out to realize study objectives. Using the maximum likelihood classification method with a threshold of 0.4, the producer's and the user's accuracies for the 1973 imagery for mangrove/swamp/marsh were 97.24% and 69.32% respectively (Table 2).

Table 2: Accuracy assessment for the supervised classified Landsat sensor images

Land cover classes	**Maximum likelihood classification (threshold: 0.4)**							
	1973		**1989**		**1975**		**2007**	
	Prod. Acc. (%)	**User Acc. (%)**	**Prod. Acc. (%)**	**User Acc. (%)**	**Prod. Acc. (%)**	**User Acc. (%)**	**Prod. Acc. (%)**	**User Acc. (%)**
Mangrove/ swamp/ marsh	97.24	69.33	94.49	98.03	98.82	85.90	98.04	87.80
Settlement	-	-	53.91	5.82	-	-	78.33	60.26
Plantation/ agricultural land	94.85	16.00	74.43	98.56	93.16	100.00	76.57	93.66
Forest	91.87	99.83	98.81	97.97	85.63	98.93	95.76	85.33
Water bodies	99.70	100.00	99.61	100.00	99.78	100.00	87.86	100.00
Cloud cover	99.52	89.31	98.02	71.05	95.75	96.06	96.04	94.50
Overall Accuracy	96.64		98.80		98.31		90.08	
Kappa Coefficient	0.94		0.92		0.96		0.88	

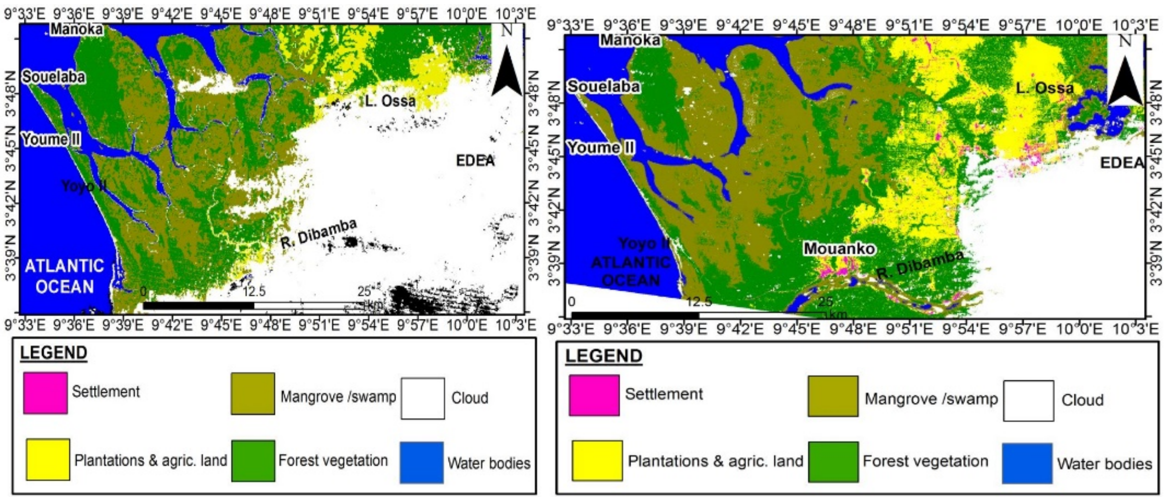
From the post-classification matrix, the overall accuracies for the different images are given thus: 96.64% (kappa coefficient = 0.94) in 1973, 98.31% (kappa coefficient = 0.96) in 1975, 98.80% (kappa coefficient = 0.92) in 1989, 96.43 (Kappa coefficient = 0.84) in 2001, 90. 08% (kappa coefficient = 0.88) in 2007, and 91.66 (kappa coefficient = 0.89) in 2015. Despite the overall classification accuracies, the individual class accuracies for mangrove/ swamp/marsh and the other class cover types were appreciably different.

Overall mangrove/swamp/marsh classification accuracy in 1989 was 98.80% (Kappa coefficient = 0.92), with user and producer accuracies of 98.03% and 94.49%, respectively. For the 1975 imagery, the mangrove/swamp/ marsh had a UA of 85.90%, and PA of 98.82%. The producer's and user's accuracy for the mangrove/swamp/marsh for the 2001 image was 99.12% and 89.48% respectively. While for the 2007 imagery, it was 87.80% and 98.04% for the UA and the PA respectively. A PA of 100.00% and a UA of 86.56% were obtained for the 2015 image (Table 3).

Table 3: Accuracy assessment for the supervised classified Landsat sensor images

Land cover classes	**Maximum likelihood classification (threshold: 0.4)**			
	2001		**2015**	
	PA (%)	**UA (%)**	**PA (%)**	**UA (%)**
Mangrove / swamp/ marsh	99.12	89.48	100.00	86.56
Settlement	77.22	6.46	72.13	25.73
Plantation/ agricultural land	64.78	66.93	86.63	90.15
Forest	98.17	98.85	83.99	92.90
Water bodies	89.60	99.92	99.94	100.00
Cloud cover	95.88	88.61	98.95	99.71
Overall Accuracy	96.43		91.66	
Kappa Coefficient	0.84		0.89	

The mangroves/swamp/marshes were identified by their almost darkish (different from the other vegetation spectral) tone and similar to other studies describing its irregular shape from the satellite image [28]. It is inferred from the Landuse map that the study area is prominent in settlement cover and the human intrusion is more due to the quest for survival through plantation/agricultural activity. The swamp/marsh nature of the mangroves area is due to the presence of the many water bodies within and around it. Studies found similar situations with the presence of water bodies making the soil saline and adaptive to support the mangrove vegetation growing poleward [29]. The mangrove vegetation is a multi-use ecosystem that acts as a bio-shield to many coastal communities from natural calamities such as coastal erosion, cyclone, and storm surges and provides a nursery ground for fish prawns and crabs. Mangrove/swamp/marshes represented on the image (Figure 4) by olive green colour, smooth texture, and irregular shape, located in the intertidal area and associated with quiet depositional areas.



a) 1975 classified image

b) 2007 classified image

Figure 4: images for 1975 and 2007 showing maximum likelihood classification

These species act as a barrier for the coast, which protects the coast from cyclones and tsunamis and also serves as a nursery ground for fishes, crabs, and shrimps. Plantations and agricultural land are represented by bright yellow, coarse to smooth texture with a defined boundary. But the period from 1989 to 2015 as indicated on the images used, shows a high intrusion of settlement which is today being controlled by the government due to over-exploitation within the creek zones.

Based on a supervised maximum likelihood classification on images which was implemented on 1973, 1975, 1989, 2001, 2007, and 2015 images acquired, the final classification products provide an overview of the major land use/cover features in the study area and how surface area variations occurred over time (1973- 2015).

3.2 Land Cover classification

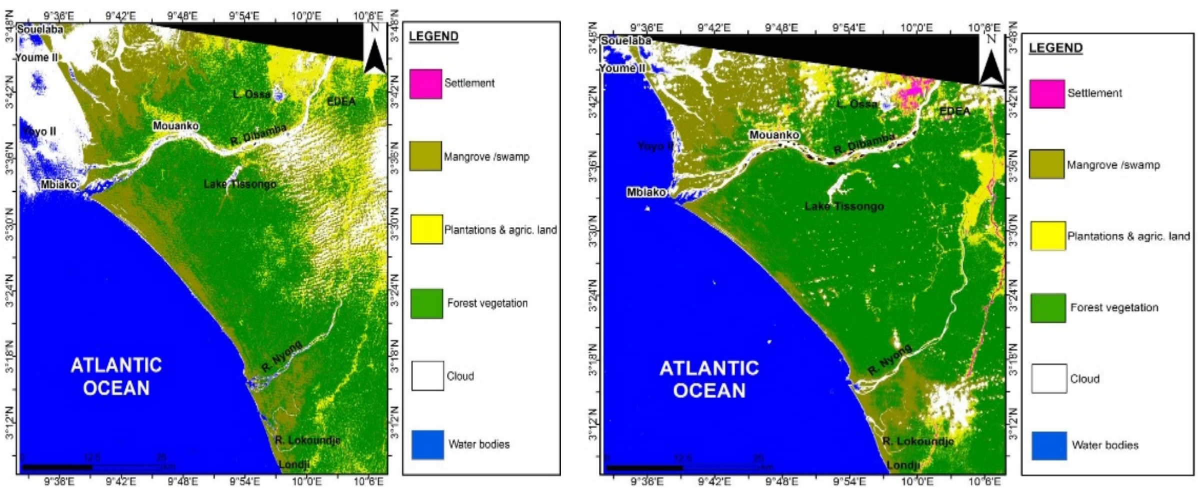
3.2.1 Land Cover classification between 1975 and 2007 (32 years)

The total surface areas covered by the classes in 1975 and 2007 images were 1780.62 km² and 1757.41 km² respectively with a difference of 23.21 km². The total surface area occupied by the mangrove/swamp/marsh in 1975 was given as 325.45 km² while it was 405.78 km² (difference of 25.15%) in 2007 indicating it's an increase in the land surface by 80.33 km². This difference of the mangroves area comparatively from the 1975 and 2007 images characterized by an increase of 25% was firstly attributed to the coarseness (57 m) of the 1975 image which made it difficult to completely identify all the mangrove areas and the large cloud cover that characterize this image (Figure 4). Another factor was the increasing awareness of mangrove importance over the years since the population presently occupying the area for settlement was not significant back then in 1975. Again, the increase in the managerial decision for sustainable management of Cameroon's mangrove ecosystem [30] could have led to the increase in surface area.

The forest area surface changed from 297.37 km² in 1975 to 405.19 km² in 2007 indicating an increase of the surface area with a difference in the area of 107.82 km² (44.55%), Forest vegetation is represented by a green, irregular shape and coarse texture for the 1975 image. It forms an important ecosystem role in preserving the natural treasures of the reserve. The plantation/agricultural land also changed from 80.53 km² in 1975 to 235.29 km² in 2007, with an increased area difference of 154.76 km² (26.62%) in 2007. From the images, it was observed that because the marsh area of the mangrove contains water, some rivers have also been classified as marshes. The cloud cover dominated the 1975 image due to the period, the distance from where it was taken, and the fact that the study area is found in the tropics which favours cloud cover. No classification was present for settlement probably Settlement was not classified for the images taken in the 70s due to the coarse nature of the images (57 m) that made it difficult to easily identify settlement.

3.2.2 Land Cover classification between 1973 and 1989 (16 years)

During this 16year period (1973-1989), there was a substantial decrease by 56.47% (168.58 km²) in mangrove/marsh/swamp area from 735.14 km² to 566.56 km² respectively, a similar decrease recorded in line with other research [31] while the settlement increased from a non-significant level to 24.87 km² (Figure 5). There were also observed significant changes in land-use patterns and forest cover within the Douala-Edea wildlife reserve mangrove area during this period. In 1973 water bodies occupied the largest surface of 1672.86 km². This is closely followed by the forest class covering an area of 1423.2 km² (Figure 5). Similar studies by several authors [21, 32], have shown changes in the mangrove dynamics in Cameroon concerning government laws, with regards to its surface area changes; although this study is one of its kind within the Douala-Edea mangrove forest.



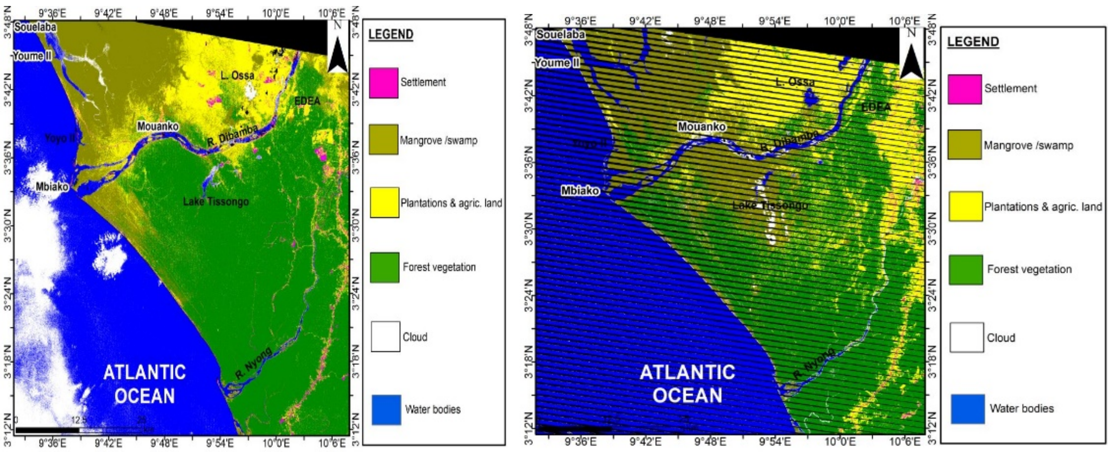
a) 1973 classified image b) 1989 classified image

Figure 5: Images for 1973 and 1989 showing maximum likelihood classification

Mangrove/swamps/marsh (735.14 km²) comes next, then clouds (579.05 km²) and lastly plantations/agricultural land (442.39 km²). Similar to the 1975 image, no class existed for settlement. In 1989, water bodies increased to 1851.83 km² with an area difference of 178.97 km² (1.45%). This increase is related to the presence of limited cloud on the 1989 image that made it possible to classify previously covered water bodies in the 1973 image. Water bodies continued to take the lead in area coverage in 1989. The next large class was forest cover. This class (forest) was characterized by an increase of 271.3 km² (24.71%) from 1423.2 km² in 1973 to 1694.5 km² in 1989 (Figure 5). Plantation/ agricultural land decreased in area by 77.77% (201.24 km²) from 442.39 km² (1973) to 241.15 km² (1989) in area. The smallest class was a settlement that occupied an area of 24.87 km².

3.2.3 Land Cover classification between 2001 and 2015 (14 years)

The results show cloud cover, water bodies, forest, mangrove/swamp and settlement classes for the 14-year interval decreased from 2001 to 2015, the total surface area decreased by 1251.59 km² in terms of coverage from 4892.94km² in 2001 to 3641.35km² in 2015. The total surface area occupied by the mangrove/swamp/marsh in 2001 was 655.45 km² which reduced to 505.91km² in 2015, corresponding to a difference of 58.38 % (149.54 km²) and attributed to over exploitations [33]. In 2001, the forest was the largest class, followed by the water bodies, mangrove/swamp class, cloud cover, agricultural/plantation land, and the least class was settlement (Figure 6). Forest occupied 1726.09 km², 593.85 km² by the cloud cover, 1345.92 km² by the water bodies, 64.81 km² by settlement, 506.82 km² was covered by the plantation/agricultural land, and 655.45 km² by the mangrove/swamp (Figure 6).



a) 2001 classified image b) 2015 classified image

Figure 6: Images for 2001 and 2015 showing maximum likelihood classification

This decrease in surface area on the 2015 image is attributed to the technical error of the Landsat ETM+ sensor which resulted in lines cutting across the image that was defined as unclassified (Figure 6), and also because the mangroves are being used often by the communities, the area is prone to decrease. This difference could also be attributed to some anthropogenic (clearing) aspects disturbing the mangrove growth. The mangrove/swamp (149.54 km²) shows a decrease with 58.38% (505.91 km²); forest (558.67 km²) had a decrease of 42.06% (1167.42 km²); settlement (17.6 km²) corresponded to a 96.06% decrease in 2015; plantation/agricultural land increased by 52.05% (571.81 km²) with a 64.99 km² difference; cloud cover (72.37 km²) decreases by 521.48km² (32.68 %), while water bodies (1306.24 km²) decrease by 39.68 km² in area. Thus, as the mangrove/swamp/marsh class decreased in line with the research results of [34], the encroached water bodies are being reclaimed for settlement land. There existed an increased rate of the plantation/agricultural land based on the fact that these mangroves are either being harvested or areas left loose due to the direct clear-cutting for farming or plantation development within the communities. These findings are in line with similar studies supporting the decline, being used for socio-economic purposes by the communities [23] as processed by the remote sensing classification techniques [35, 36].

3.3 Species utilization and perceptions by the respondent

The people's perception based on the changes obtained from field ground-truthing and satellite images, clearly brought out some common human activities that affected the mangrove area, especially when observed from the land use/cover classifications of the study site [37]. Nevertheless, exploitation of mangroves in the reserve was an activity mainly undertaken by residents. These findings are in line with other research studies [20], which showed mangrove ecosystems are traditionally used for the production of firewood, charcoal, boats production and maintenance, thatching, fish traps, timber, and poles for houses as well as cultural sites. Despite the risk that could be posed by water (e.g., drowning), it is still the main medium for the harvesting and transportation of mangroves and other creek products since there exist a law forbidding the harvesting of mangroves and the species within the creek.

The study reports that mangroves and its other species exploitation is a major source of income to the families due to the valuable products and income they benefit from the creek over years, not until the government now conserves the product but it could never be 100% conserved since the lives of the inhabitants according to the respondents its dependent on the creek. The inhabitants gave varying reasons as to why the mangrove area has varied over the years, change detection studies have been conducted in other areas, similar to this research [38], revealing the factors that have led to a variation in mangrove surface area. To the respondents, based on the fact that all the parts of the species are consumed, it's quite unsustainable because the roots, stems, and even branches are being harvested while the other species' catch sizes are often indiscriminate once they have to catch for home use or commercial purposes. Based on the correspondents, the reports took into consideration some respondents who said the mangrove surface area had been increasing since the government now controls entry and the idea that the mangroves fast replicate and also due to the fear of government law as the reason for the interview, thus any difference in mangrove/swamp class according to such people was based on the natural factors like wild wind and a plant no longer being a water-resistant species.

Conclusion

This study achieved its goal of mangrove forest dynamics within the Douala-Edea reserve using the GIS and Remote Sensing data. The classification results showed confirmation with the field ground-truthing data with overall accuracies from the post-classification matrix for the different images being given thus: 96.64% (kappa coefficient = 0.94) in 1973, 98.31% (kappa coefficient = 0.96) in 1975, 98.80% (kappa coefficient = 0.92) in 1989, 96.43 (Kappa coefficient = 0.84) in 2001, 90. 08% (kappa coefficient = 0.88) in 2007, and 91.66 (kappa coefficient = 0.89) in 2015 at a maximum likelihood thresh hold of 0.4. The largest conversion of mangrove class to other classes was observed from 1973 to 1989 (16 years).

The loss of mangrove from 1973 to 1989 was 22.93%, while between 2001 to 2015 mangrove losses was 22.82%. Also, the overall change of mangroves in the classified years from 1975 to 2007 showed an increase in the surface area by 24.68% (80.32km^2). The ecosystem services of fishing, firewood for fish smoking, wood for constructions, and housing maintenance revealed by the study are all factors attributed to the declining mangrove surface area. The findings provide an updated baseline to inform decision-makers on mangrove loss to secure the future of mangroves and ecosystem services in the reserve.

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