International Journal of Agriculture, Environment and Bioresearch

Vol. 09, No. 04; 2024

ISSN: 2456-8643

ECOSYSTEM SERVICES AND LAND USE CHANGES IN RIO DEL REY WETLAND BETWEEN 1990 AND 2020

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https://doi.org/10.35410/IJAEB.2024.5911

ABSTRACT
The Rio Del Rey (RDR) wetland is one of the richest Ramsar sites in west and Central Africa with numerous ecosystem services supporting numerous livelihood activities. The unprecedented rate of exploitation brings about changes in land use/land cover (LULC) with devastating impacts on the ecosystem services on which livelihoods depend. This study sets out to identify the ecosystem services on which livelihood depend in the area and also examine the land use/land cover dynamics. Both primary and secondary data were employed in order to attain the objectives. Primary data were obtained from the field and included livelihood activities which were collected with the use of questionnaires and a camera. A Global Positioning System handset was also used to collect Ground Control Points (GCPs) for LULC change analysis. Secondary data were gotten through the review of literature from libraries and internet. Satellite images for 1990, 2002, 2010 and 2020 were downloaded from the Global Land Cover Facility to produce the land use maps and statistics generated from the maps were used for further land use change analysis. GIS techniques were used in the analysis of satellite imageries. Findings revealed the availability of numerous provisioning goods and supporting services which support livelihood activities. It also revealed five land use/land cover categories in the study area and great transformation in LULC within the period under investigation.

Keywords: Land use/Land cover changes, Rio Del Rey Wetland, Mangrove Ecosystem services, GIS and remote sensing.

1. INTRODUCTION
Mangrove ecosystems are well known the world over for their unique occurrence along the narrow interface between the oceans and the continental landmasses, particularly in the tropical and sub-tropical zones (UNEP 2007, Feller et. al., 2010, Nguyen et. al., 2021). The plants of these ecosystems are well adapted to the saline and muddy nature of their environment and provide an array of ecosystem goods and services which support thousands of human lives through livelihood activities (Quijas Sandra & Balvanera Patricia, 2013). However, natural and anthropogenic factors have been identified as drivers of change in many mangrove ecosystems around the world (Matlhodi et al., 2019). Historically, these changes were associated with variation in the biophysical environment, whereas recent changes are mainly linked to anthropogenic factors (Verburg et al., 2004).
These changes in land use categories over recent years have repercussions on the survival of the mangrove ecosystem and the services they provide at local, regional and global scale. In areas around the world where the level of industrialization is low, the ever increasing population has always dependent on land resources (soil, forest, water, minerals and rocks) for their sustenance

and where these resources are poorly managed, they become vulnerable or susceptible to changes with negative effects in most situations. In Indonesia, for example, investors viewed coastal forest as a common access good and aquaculture as a means to increase their returns. However, after converting mangrove forest into shrimp ponds, farmers found out that the returns from extensive and semi-extensive shrimp culture dropped after a few years (Bosma et al., 2014). This is an indication that over time the transformation of mangrove forest into shrimp ponds had negative impact on the environment and hence livelihoods.

Natural and anthropogenic activities in most parts of the earth surface have brought about a series of land use categories. These land use categories have not been stagnant but remain in a dynamic state over the centuries. Worldwide rates of mangrove forest loss to other land use categories have been high and are accelerating. Approximately 20–35% of mangrove area has been cleared since 1980 largely to accommodate coastal development and aquaculture (Atkinson et al., 2016). According to the FAO, Africa has lost about 500,000 hectares of mangroves over the last 25 years (FAO, 2007). Specifically, in West Africa, mangrove forest areas have diminished from 20,500 km^2 in 1980 to their current 15,800 km^2 while in Central Africa they have been reduced from 6,500 km^2 in 1980 to 4,300 km^2 at present.

Remote Sensing (RS) and Geographic Information System (GIS) are indispensible contemporary technologies with a long and widely accepted history for monitoring land use changes especially in areas with difficult accessibility. Satellite imageries acquired over different time period enable researchers to analyze spatial and temporal interactions between humans and natural phenomena in order to ensure informed decision making within stakeholders and government agencies.

In the Rio Del Rey wetland, there exist over numerous villages with a population of over 87,795 persons who depend on natural resources of the estuary. Human activities have equally given rise to different land use categories such as settlement, farmland, military bases, and degraded mangrove amongst others which have been in a state of flux for decades due to natural and anthropogenic factors. An analysis of these changes in land uses can enables planners and policy makers to have adequate knowledge on the pattern (trend) of change over time, the magnitude and causes. This can enable them take action towards sustainability of the wetland resources such as the mangrove forest. This paper therefore identifies ecosystem services on which livelihoods depend in RDR wetland and the spatio-temporal changes in land use/land cover between 1990 and 2020.

2 MATERIALS AND METHODS

2.1 Study Area

The Rio Del Rey is an estuary of a drainage basin in West Africa whose coastal border falls along the Gulf of Guinea. It is found in the Ndian division of the South West Region of Cameroon between latitude 4° and 5° north of the Equator and longitude 8°20′and 9°10′East of the Greenwich meridian. It covers a total surface area of 165,000ha and lies in the eastern area of the Niger River system. It is situated in the highest biodiversity hotspot in this part of Africa in the shadow of Mount Cameroon and downstream from the Korup, Takamanda and Cross River Forests. Rio Del Rey is bordered by Niger Delta Basin of Nigeria to the west and northwest, and by Rio Muni Basin of Equatorial Guinea to the south. To the north, by the Rumpi Hills of Cameroon and to the east by the Cameroon volcanic line that separates Rio Del Rey basin from the Douala/Kribi Campo Basin. This estuary has been described as an estuary in which "the two rivers Ndian and Massake flow out". The estuary was designated as a Ramsar site number 1908 in 2010(see figure 1).

The climate is of the equatorial type strongly influenced by the proximity of Mount Cameroon (4 095 m), the highest peak in West and Central Africa. The average annual rainfall ranges from 3,500mm to 10,000mm with the number of rainy days up to 250 (Din, 2001) occurring mainly during the rainy season which is very long, that is, from March to November. From the month of December to February there is a short dry season during which intense sunshine prevail. The mean annual temperature ranges from 25.5 °C to 33°C (Din, 2001). The month with the highest temperature is February recording temperatures above 30^0c in places such as Kombo Abedimo, Bamusso and Kombo Itindi while July is the coldest with an average temperature of below 22^0 C at night. This climatic conditions support evergreen forest vegetation which is dominated by the equatorial rain forest and mangrove swamp in contact with the ocean. The mangrove forest is subjugated by the family of Rhizophoraceae which is broken up by a great network of water ways or creeks (Ajonina, 2011, Ndema, 2016). These forests support an abundant biodiversity in the area which is exploited by local dwellers for their survival.

The population of Rio Del Rey was estimated at 87,795 inhabitants in the 2005 population census conducted in Cameroon. In which the population of male stood at 46960 slightly above that of females which stood at 40835. Just like in any other geographical region, these people are not evenly distributed within the six subdivisions in the study area. Ekondo Titi has the highest proportion followed by Bamusso while Kombo-Abedimo harbour the least proportion.

Figure 1: Location of Study Area
(Source: Adapted from MINEPDED-RCM, 2017)

2.2 Method

2.2.1 Data Collection, Processing and Analysis

First, field observation techniques such as the use of questionnaires and picture taking were used to identify the mangrove ecosystem services and livelihood activities. Also, Google Earth was used to locate the study area where the Global Positioning System (GPS) coordinates of its limits were obtained. These were matched up with GPS points taken at the field to be sure of the study area. These coordinates were later used to download raster and elevation data for the area as well as satellite images from the Global Land Cover Facility website. Landsat ETM image files of 1990, 2002, 2010 and 2020 were downloaded and the various bands for each year were modulated and corrected to reveal mangrove forest, water-bodies, settlement and other geographic features using ENVI 4.3. The visible features of interest were digitized and their shape files exported to ArcGIS 10.2 where they were assembled together with the raster and elevation data at WGS84 to produce the maps for each year as JEPG files revealing the location and trends in the areal coverage of mangrove forest, water bodies and other features in the RDR wetland. The polygons representing the various parameters (mangrove forest, water bodies and settlements amongst others) were measured using ArcGIS 10.2 and computed using Microsoft Word Excel 2013 to measure their dynamism over time.

2.2.2 Land Use/Land Cover Change Detection

Change detection was performed through the overlay method based on generated vector themes of different years. 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 attribute tables of the output themes were summarized in definition tables and results were exported in MS-Excel Package to compile areas of change for each information category. Change detection analysis entails finding the type, amount and location of land use/land cover changes that are taking place (Yeh et al., 1996)

2.2.3 Assessment of the Rate of Land Use/Land Cover Change

The estimation for the rate of change for the different covers were computed based on the following formulae (Kashaigili, 2006):

$$\% \, Cover \; change = \frac{Area_{iyearx} - Area_{Iyearx+1}}{\sum_{i=1}^{n} Area_{iyearx}} \, x \, 100 \qquad (1)$$

$$Annual \; rate \; of \; change \; = \frac{Area_{iyearx} - Area_{iyearx+1}}{t_{years}} \qquad (2)$$

$$\% \, Annual \; rate \; of \; change = \frac{Area_{iyearx} - Area_{iyearx+1}}{Area_{iyearx} \; x \; t_{years}} \, x100 \qquad (3)$$

Where: $Area_{iyearx}$= area of cover i at the first date,

$Area_{iyearx+1}$= area of cover i at the second date,

$\sum_{i=\;1}^{n} Area_{iyearx}$ = total cover area at the first date and

t_{years} = period in years between the first and second scene acquisition data

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3. RESULTS

3.1 Mangrove Ecosystem services dependent livelihood activities

There are many livelihood activities in RDR wetlad which depend on the wetland ecosystem services as shown on figure 2. These livelihood activities can be categorized into two that is those that rely on the provisioning services and those that rely on the supporting services.

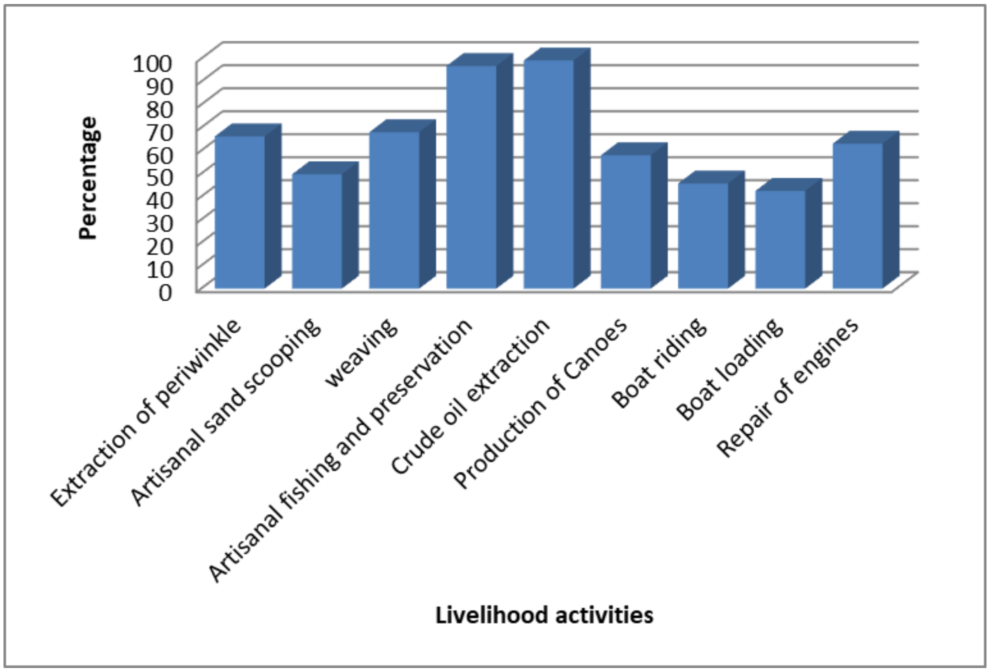

Figure 2: Show livelihood activities identified in RDR

3.1.1 Provisioning Services and Livelihood Activities

❖ **Extraction of Periwinkles (*Tympanotonus fuscatus*)**

Periwinkles as commonly called in the study area are edible mollusks which normally live in the sea but during high tides, water carried some into creeks where they are abandoned on the sandy beaches or within the mangroves. Based on community knowledge, different types of periwinkle exist in the area identified by the differences in the shapes of their shells and the facts that they have different taste in the mouth. The males have jointed legs while the females don't have legs at all. This indicates the need for a proper nomenclature of the species in the area.

The collection and selling of periwinkles is an important activity within the study area. The collection method is usually selective hand picking to avoid the inedible male species and the activity is dominated by females and children. Once periwinkles have been collected and accumulated for about three days, it is transported in bags to the Oron and Ikang markets in Nigeria where it is sold. 66.25% of respondents attest to the fact that they are regularly involved in the collection and sale of periwinkles from the RDR. The shells of this mollusk are used in the area as a building material. During construction, the periwinkle shells are used as a replacement for gravel given that rocks are very scarce in the basin.

❖ **Artisanal Sand Scooping as a Livelihood Activity**

Sand is another ecosystem good present within RDRW which is extracted and used for the construction of modern infrastructures. Sand scooping from the sandy rivers and beaches is an

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important livelihood activity in the study area involving mostly male youths. They simply scoop the sand and dump in heaps onshore pending purchase and transportation to building sites. This activity boomed during the implementation of the Bakassi special package during which numerous building projects were being carried out in the area. 49.7% of respondents agreed to the fact that sand is one of the commodities traded within their localities (see plate 1).

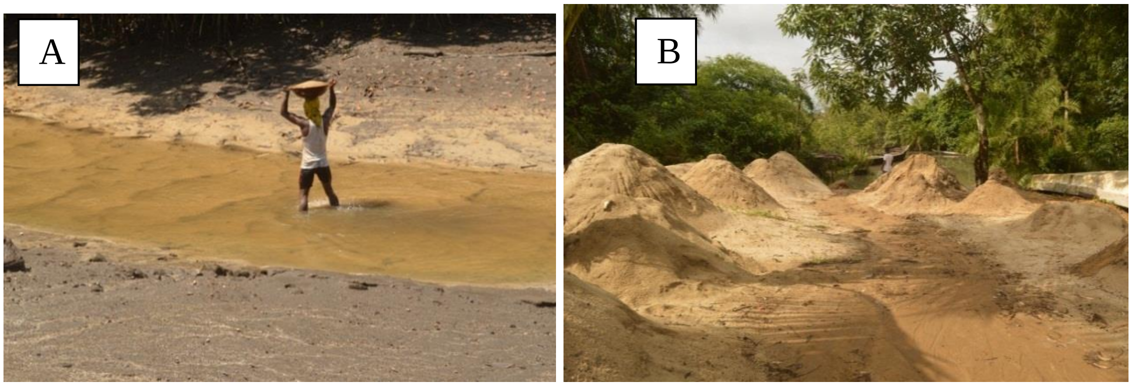

Plate 1: Artisanal sand mining in Isangele, A) a youth scooping sand with a container at Oron while B) heaps of sand deposited by different youths at the sand market Isangele (Source: Field Work, 2020).

- **Weaving of Baskets, Mats and Construction of Huts as a Livelihood**

Another vital livelihood activity within the area is weaving of baskets, plating of mats and the construction of huts using Nypa palm front. Nypa palm (*Nypa fruticans*) is an invasive species which was transported from Nigeria to the study area by ocean current. Its structure is very similar to the Raphia Palm well described by Knecht & Argenti (1999) except for the fact that it is tolerant to salty water. The compound pinnate leaf (frond) and the rhachis or the main stems are very useful for the building of huts, weaving of baskets and mat making within the study area (plate 2). The production of mats and weaving of baskets are livelihood activities which mostly involve women living in large fishing camps. Women involved in the activity reported that in a day, a woman can produce up to 12 mats which are sold at the cost of 300frs CFA each or two baskets at the cost of 1000frs each. While the baskets are commonly used to carry fish from boat to huts, the mats are used for roofing of huts and to cover the sides (plate 3). Though just 20% of respondents agreed to be involved in this activity, most persons in the area have made use of their products.

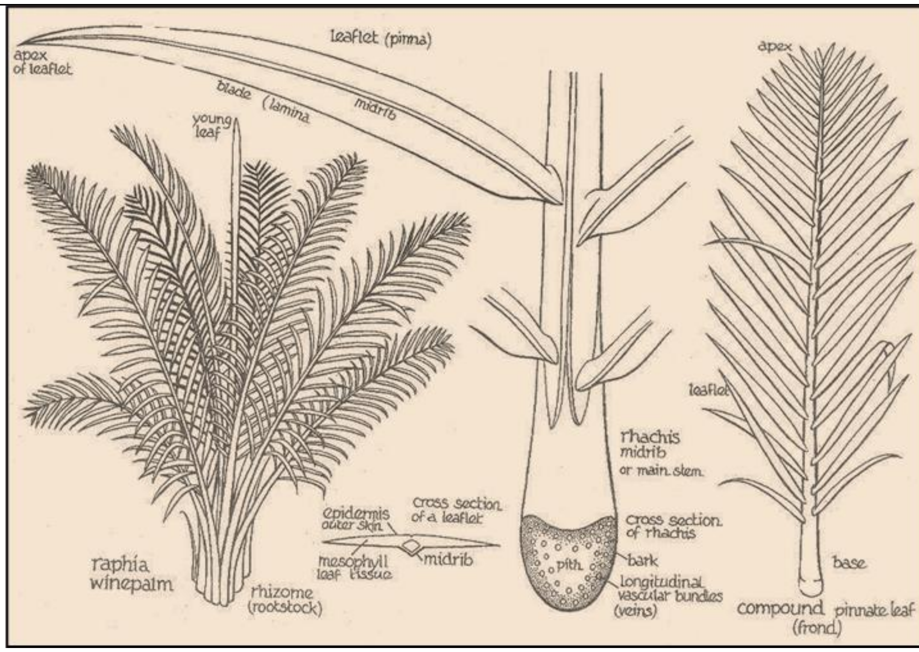

Plate 2: Parts of Nypa palms (Source: adapted from Knecht & Argenti, 1999)

Plate 3: Partial view of huts constructed with mats at Tinkoro fishing camp
(Source: fieldwork, 2022)

❖ **Artisanal Fishing and Fish Preservation as Livelihood Activities**

The abundance of fishery resources in RDR estuary has attracted many fishermen who practice artisanal fishing at varied scale as a major livelihood activity. These fishermen use different techniques to catch fish such as drum-fishing, fish-trapping, casting of nets, fish poisoning, dynamite fishing amongst others.

For the fish to reach the final consumers, it necessitates preservative activities in abet to enable the fish remain in a consumable state. Two preservative methods are used which include fish smoking and fish icing. Fish smoking is a major livelihood activity which is widespread in the study area and majority of those involved are women. While fish icing is another method of fish preservation which is simply the adding of ice in the container in which the fish is found so that the temperate of the fish is reduced. This prevent the process of decay from starting in the fish and this activity is limited to areas which are very closed to major cities where the fishermen can easily return to the main town with fresh fish which is sold to the public. These towns include Idenua, Limbe towns and Ekondo Titi. The ice comes from factories such as SITRABCAM in blocks which are loaded in a boat and taken into the sea where it is used by fishermen to preserve fish. When it comes to this 96.8% of respondents agreed to be involved in one way or the other making fishing and fish preservation to be amongst the most important livelihood activities in the area.

Plate 4: Smoked fish landing at the Idenua port from Bamusso
(Source: field work 2022)

Plate 5: Bags load of ice block at Idenua port waiting for transportation into the fishing zone (Source: fieldwork, 2022)

❖ **Oil Exploration**

RDR is blessed with crude oil resources and many oil companies have been involved in oil exploration and exploitation within the area since 1972 when oil was first discovered. An inventory in the east of the area alone identifies 12 concessions, 43 oil fields, 44 prospects and 112 oil wells (Fozao et al, 2017). In addition to the existing oil wells within the RDR basin, three more blocks were advertised by the National Hydrocarbons Corporation (SNH) in 2019 for interested international companies to submit mining proposals. Out of the nine blocks advertised two onshore blocks and one offshore block are found in the RDR, that is, Ndian River block (2530km^2), Bakassi block (736.9km^2) and Bolongo block (390km^2) respectively (SNH, 2019). Oil exploitation is a major income generating activity in the country and the companies involved in the process employ many workers to carry out this activity. During the survey, 99.2% of respondent acknowledged the exploitation of crude oil in the study area.

3.1.2 Supporting Service and Livelihood Activities

❖ **Transport Service Delivered and related Livelihood Activities within the RDR**

Transportation is an indispensible aspect of development necessary for movement of people, information and goods from one place to another. The different means of transportation available for RDR since pre-colonial era has been limited to road and water. However, the lone earth road linking the area to Mundemba and to the rest of the country has remained blocked since 2016 with the onset of the Anglophone crisis. The only means of transportation now available is through navigable waters and the dense network of creeks and rivers provide navigable waters to the plethora fishing camps within the area. Livelihood activities within the area related to transportation are as follows;

- **Production of Transport Canoes as a Livelihood Activity**

An essential livelihood activity which is linked to fishing and transportation in the area is the production of dugout canoes which begin with the extraction of logs of various sizes and length from the nearby equatorial forest. The logs are then curved into semi-circular structures using axes and controlled fire (plate 6). The production of these canoes is a widespread activity in the different subdivisions that make up the study area. It takes three weeks to two months for a dugout canoe to be produced depending on its size and the number of labourers used. The price ranges from 150.000frs CFA for small canoes to 400.000frs CFA for very large sizes. The canoes might be modified with the use of plank and nails to increase size and space for an engine to be installed. When this is done the price may go up to two million francs CFA and above.

Plate 6: The production process of dugout canoe at Bateka in Isangele,
(Source: Field Work, 2022)

- **Boat Riding as a Livelihood Activity**

The movement of people to and fro the different communities within the RDR can only be achieved by means of water transport. This has given rise to a number of commercial speed boats and boat riders within the area. An average commercial boat can carry up to 15 passengers with light luggage and navigate across the water to its destination. This activity thrives in areas where population meets the threshold like in Isangele, Bamusso, Idabato and Idenau Subdivisions. The Idenau- Ikang rout is the main corridor between Nigeria and Cameroon in South.

The movement of these boats from Isangele to Idenau port and back is mostly on Tuesdays and Saturdays while between Isangele and Ikang is on Tuesdays and Fridays (Table 1). These arrangements are due to the fact that the demand for this service is low while between Ikang and Isangele the service follows the markets days. The boat riders in the area have organized themselves into unions for the sake of maintaining peace and order when it comes to which boat should load. 45.7% of respondents acknowledged this activity within their communities.

Table 1: Trip Frequencies within the Study Area

Area	Frequency in a week	Days
Isanguele and Idenau	Twice	Tuesdays and Saturday
Idabato and Idenau	twice	Wednesday and Saturday
Idenau and Bamusso	daily	Monday to Sunday
Idenau and Ikang	daily	Monday to Sunday
Isanguele and Ikang	twice	Tuesday and Friday
Ekondo Titi and Ikang	Twice	Tuesday and Friday
Ekondo Titi and Idenau	daily	Monday to Sunday

(Source: Field Work, 2022)

- **Boat Loading as a Livelihood Activity**

Given that there are no modern port facilities within study area, the unloading of heavy luggage from boats onshore and loading is done manually by youths. In areas where such cargo boats are frequently received, unloading has become a livelihood activity for the youths and this has been identified at Isangele, Idenau and Ikang beaches. In Isangele and Idenau beaches those carrying out this activity have also oganised themselves into unions and when a boat is to be loaded or unloaded, it is the leaders of the union who decide on the amount to be paid and the group of persons to do the job. At the end, it is the responsibilities of the leaders of the union to collect the agreed amount and distribute to those who did the job. This activity is very important at Isangele where lots of building materials such as cement, iron rods and zinc frequently received at the port. At the Idenau and Ikang ports, this livelihood activity is even more important because of the high volume of trade between Cameroon and Nigeria.

- **Repair of Boat Engine as a Livelihood Activity**

The presence of many engine boats within the area used either for transportation or for fishing has led to the repair of boat engines becoming an important activity especially at Idabato, Idenau and Ikang. This activity however, is still very reticent at the Idenau and Idabato ports with just a few persons involved while at the Ikang beach the activity is booming.

3.2 Land Use/Land Cover Categories in Rio Del Rey Wetland

In Rio Del Rey wetland, five major land use categories were identified which include: intact mangrove, degraded mangrove/Nypa palms, settlement, water bodies and farmland. These major land use categories were found to occupy varying proportions of the wetland in the different study periods which have been changing at varying levels over the study period.

3.2.1 Land use/land cover for 1990

During the 1990 study period, various categories of land use/land cover were identified in RDR wetland with varying proportion which are presented on Map 3.1. and the statistical data generated are presented on table 3.1

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Table 3.1 Land Use/Land Cover Data for 1990

Land cover	1990	% cover 1990
Agricultural Land	2322.483	1.76
Clouds	2788.204	2.11
Degraded mangrove / Nypa Palms	33771.53	25.60
Intact Mangroves	87299.27	66.17
Settlements/Bare soils	151.9054	0.12
Water bodies	5592.7	4.24
Total	**131926.1**	**100**

Source: Generated from the land use/land cover map of 1990

Map 3.1: Land use/land cover map for RDR Wetland 1990

Amongst these land use categories, intact mangrove forest occupied the highest surface area, that is 87299.27ha (66%) closely followed by degraded mangrove 33771.53ha (25%) and water bodies 5592.7 (4%). Settlement/baresoils were still at the instigation stage occuping less than 1% of the surface area while farmland or agricultural land was almost insignificant with a surface area coverage of just 2%. Figure 3.1 displays the different proportion of the surface area occupied by different land use categories in 1990. Although cloud cover appears like one of the land use/land covers categories in the figure, it is just a weather condition which is temporary.

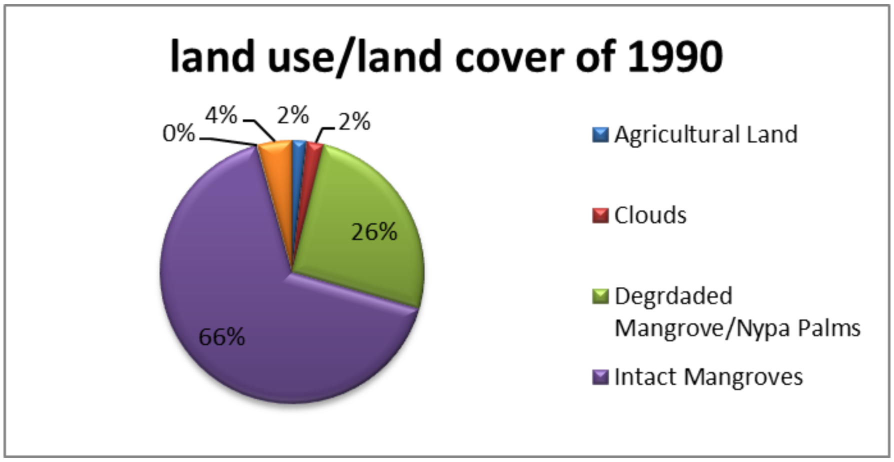

Figure 3.1: Proportion of land occupied by different land use categories in 1990 (Source: Generated from land use map of 1990)

The different LULC categories for 1990 were equally presented following the Subdivisions in the study area on table 3.2 and figure 3.2. The analysis shows that agricultural LULC occurred mostly within Ekondo Titi(58%) and Isangele(39%) with over 97% of the land use while only 3% is shared between Kombo Itindi, Kombo Abedimo and Idabato while Bamusso showed no agricultural land at all. Intact mangrove and Degraded mangrove LULC categories occurred within all the Subdivision bust a greater proportion of Intact mangrove occurred in Kombo Itindi, Isangele and Ekondo Titi while Degraded mangrove occurred more in Bamusso, Ekondo Titi and Kombo Itindi than in the other subdivision. Settlement/Bare soil LULC category occurred mostly at Isangele, Ekondo Titi and in Bamusso (figure 3.2).

Table 3.2: LULC Categories for 1990 Spread within the Subdivisions

1990	Bamusso	Kombo Itindi	Kombo Abedimo	Isangele	Ekondo Titi	Idabato
Agricultural land	0	31.195	5.656	457.46	786.571	3.85
Clouds	1312.3	0	220.16	1.62	0	1246.238
Degraded Mangrove/NP	8331.04	6526.031	5189.089	3383.97	9623.934	1404.705
Intact Mangroves	15764.78	38813.51	24835.96	44234.74	33333.73	15727.55
Settlements/Bare soils	13.83	0	2.16	73.65	62.263	0
Water bodies	791.624	1812.897	1210.53	1645.61	410.951	957.76

Source: Generated from the land use map of 1990

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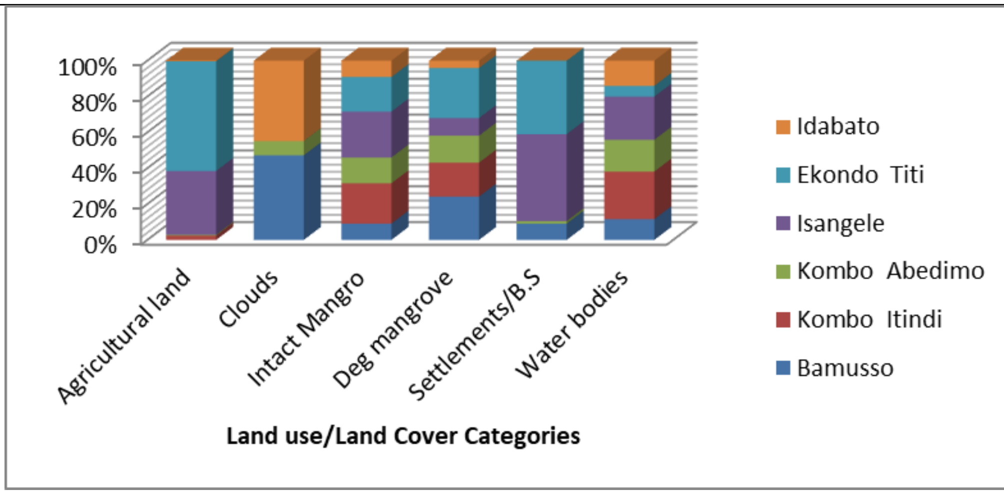

Figure 3.2: LULC categories for 1990 spread across Subdivisions in RDRW

3.2.2 Land use/land cover for 2002

The land use/land cover for the study period 2002 for RDRW is presented on Map 3.2 and the statistical data derivered from the LULC maps are presented on table 3.3. The Statistical data clearly portrays Intact mangroves as the largest LULC category with a surface area of 90387.89ha which is 68.5% of the whole Ramsar site followed by Degraded mangrove forest/Nypa palms with a surface area of 18649.43ha (14.14%) while agricultural land occupied the third position with 12447.14ha (9.43%).

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Map 3.2: Land use/land cover map for RDR Wetland 2002

Table 3.3: Land Use/Land Cover Data for 2002

Land cover	2002	% cover 2002
Agricultural Land	12447.14	9.43
Clouds	337.6736	0.26
Degraded mangrove / Nypa Palms	18649.43	14.14
Intact Mangroves	90387.89	68.51
Settlements/Bare soils	1321.033	1.00
Water bodies	8783.775	6.66
Total	**131926.9**	**100**

Source: Generated from land use map of 2002

When the LULC data for RDRW for 2002 (table 3.3) is spread across the different subdivisions, a great variation in the proportion of the land occupied by the different LULC categories is revealed. The data on table 3.4 and figure 3.3 revealed that agricultural land category now occurs in all subdivisions of the area but Ekondo Titi, Bamusso and Isangele have the higher proportion while Kombo Itindi, Kombo Abedimo and Idabato have very small proportion of the LULC category. Similarly, Degraded mangrove/Nypa palm and Intact Mangrove LULC categories occurs in all six subdivisions. However, a greater proportion of the degraded Mangrove/Nypa palm category occurs in Isangele and Kombo Itindi and a greater proportion of the Intact Mangrove occurs in Kombo Itindi, Kombo Abedimo, Bamusso and Isangele. Again, Settlement/Bare soil LULC category appears in all six subdivisions but by proportion Isangele comes first followed by Bamusso and Ekondo Titi while Idabato, Kombo Itindi and Kombo Abedimohave very small proportions.

Table 3.4: LULC Categories for 2002 Spread within the Subdivisions

2002	Bamusso	Kombo Itindi	Kombo Abedimo	Isangele	Ekondo Titi	Idabato
Agricultural land	3079.527	690.65	21.04	1454.62	6933.19	9.56
Clouds	116.8776	60.68	5.73	7.937	20.51	113.52
Degraded Mangrove/N. Palm	1292.76	6048.35	2051.84	6156.65	1114.815	2330.57
Intact Mangroves	22340.28	30409.32	25522.16	20095.97	10853.67	8574.78
Settlements/Bare soils	448.9391	21.26	12.46	544.295	227.44	58.63
Water bodies	1804.26	2981.697	2052.62	2906.45	1474.923	1663.07

Source: Generated from the land use map of 2002

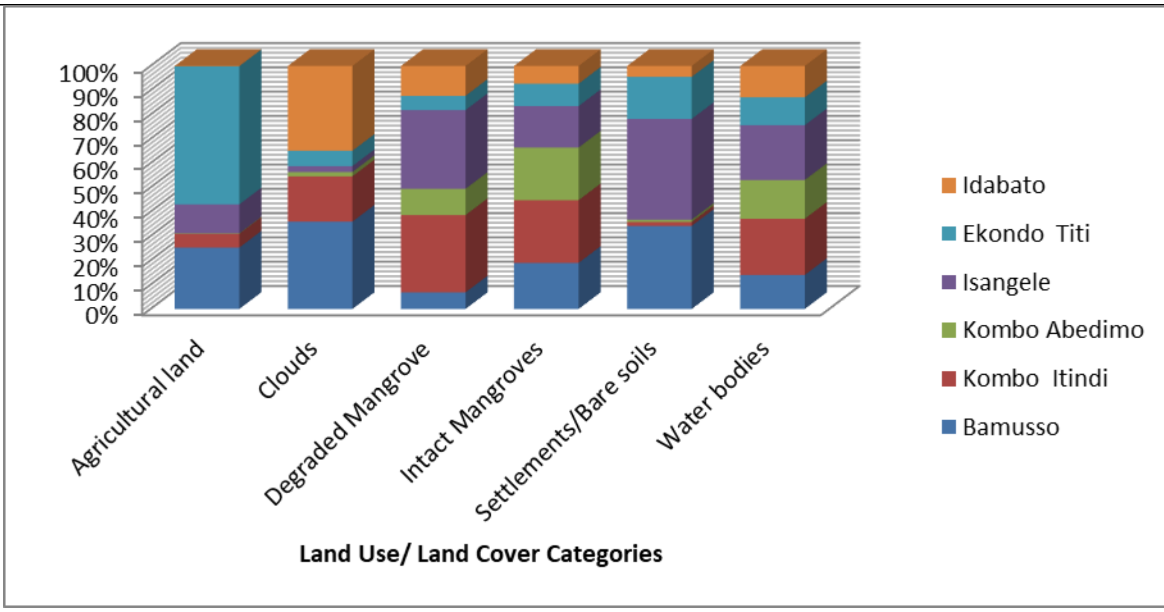

Figure 3.3: LULC categories for 2002 spread across Subdivisions in RDRW

3.2.3 Land use/land cover categories for 2010

The land use/land cover for the study period 2010 for RDRW is presented on the map 3.3 and the statistical data derivered from the land use/land cover maps are presented on table 3.5. The data represnted on the table clearly reveals Intact mangroves as the largest land use/land cover category with a surface area of 81025.6ha which is 61.4% of the whole Ramsar site followed by Degraded mangrove forest/nypa palms with a surface area of 22266.94ha (16.88%) while agricultural land occupied the third position with 14161.25ha (10.73%).

Table 3.5: Land Use/Land Cover Data for 2010

Land cover	2010	% cover 2010
Agricultural Land	14161.25	10.73
Clouds	1470.552	1.11
Degraded mangrove / Nypa Palms	22266.94	16.88
Intact Mangroves	81025.6	61.42
Settlements/Bare soils	3609.509	2.74
Water bodies	9392.126	7.12
Total	131926	100

Source: Generated from land use map of 2010

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Map 3.3: Land use/land cover map for RDR Wetland 2010

The LULC data for the different categories spread across the Subdivisions in the RDRW for the period 2010 shows great variation just like for the previous years but some patterns from the previous years are maintained. Agricultural land category for example maintains Ekondo Titi and Bamusso as the subdivisions have the largest proportions of agricultural land. In the same manner Intact Mangrove and Degraded mangrove/Nypa Palm maintain the same pattern as in the previous years thought with very insignificant changes in the proportions. Settlement/Bare soil has portrayed a changing pattern within the previous study periods. In 1990 the largest proportion of this LULC category occurred in Isangele followed by Ekondo Titi but in 2002 it occurred in Isangele and Bamusso. In 2010, Kombo Abedimo takes the lead with the largest proportion of Settlement/Bare soil category, followed by Isangele.

Table 3.6: LULC Categories for 2010 Spread within the Subdivisions

2010	Bamusso	Kombo Itindi	Kombo Abedimo	Isangele	Ekondo Titi	Idabato
Agricultural land	3848.116	774.597	170.46	1691.68	7990.07	51.43
Clouds	5.01	4.85	1178.595	49.685	0.062	231.93
Degraded Mangrove/NP	1873.47	7564.71	5016.68	6407.06	1206.06	2533.55
Intact Mangroves	21383.49	28596.68	17122.58	22316.41	9695.07	7112.34
Settlements/Bare soils	286.46	347.8569	1633.353	685.19	145.28	501.73
Water bodies	1768.97	3145.53	2046.344	2240.1	737.35	1632.64

Source: Generated from the land use map of 2010

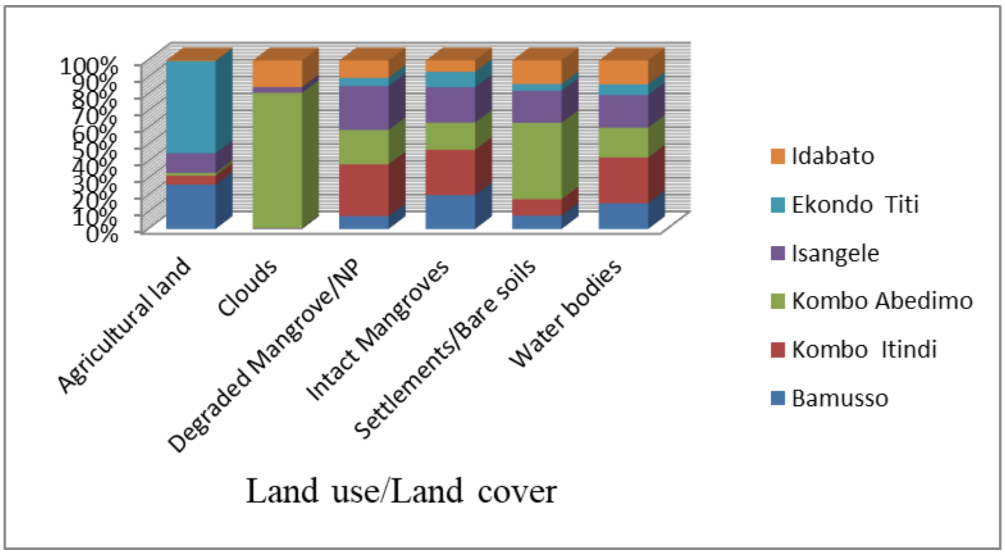
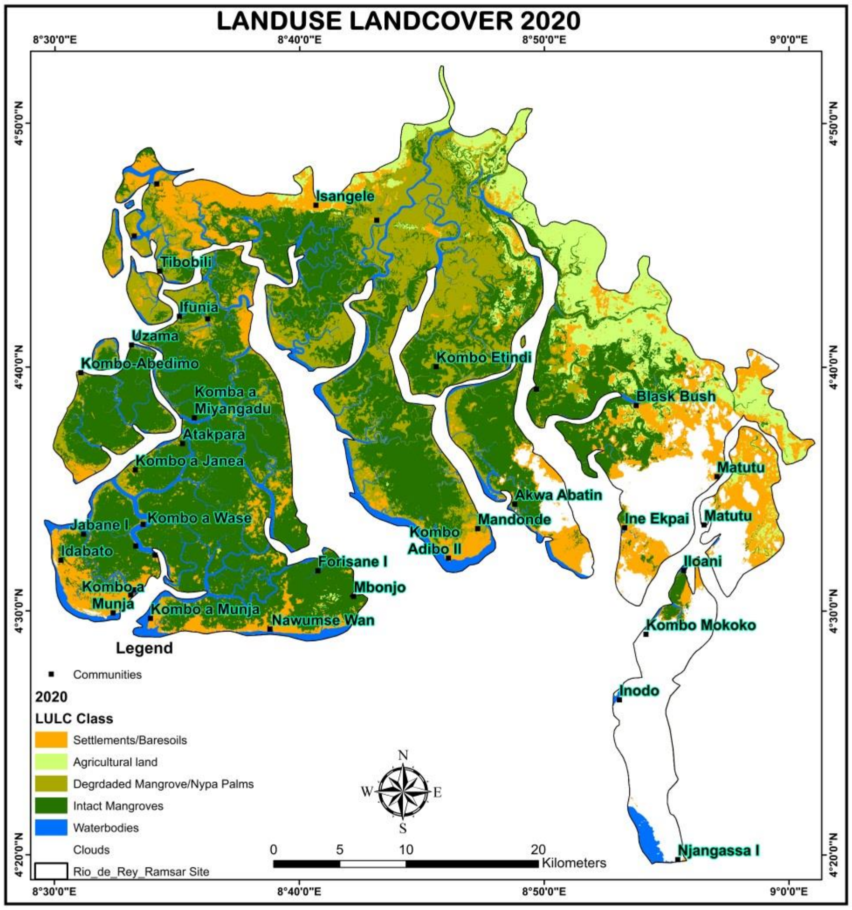


Figure 3.4: LULC categories for 2010 spread across Subdivisions in RDRW

3.2.4 Land use/land cover categories for 2020

The land use/land cover for the study period 2020 for RDRW is presented on map 3.4 and the statistical data derivered from the land use/land cover maps are presented on table 3.7. The data represnted also reveals Intact mangroves as the largest land use/land cover category with a surface area of 54265.29ha which is 41.13% of the whole Ramsar site followed by Degraded mangrove/Nypa Palms 23800.6ha (18.04) while Settlements /Bare soils with a surface area of 18167.99ha (13.77). In this study period cloud cover which is not a permenant land use/land cover but a weather condition which makes it difficult for the actual land cover/land use on the surface of the earth to be visible was quite significant covering an area of up to 15403.63ha (11.68%).

ISSN: 2456-8643



Map 3.4: Land use/land cover map for RDR Wetland 2020

Table 3.7: Land Use/Land Cover Data for 2020

Land cover	**2020**	**% Cover 2020**
Agricultural Land	11439.89	8.67
Clouds	15403.63	11.68
Degraded mangrove/Nypa Palms	23800.6	18.04
Intact Mangroves	54265.29	41.13
Settlements/Bare soils	18167.99	13.77
Water bodies	8849.058	6.71
Total	**131926.5**	**100**

Source: Generated from land use map of 2020

Table 3.8: LULC Categories for 2020 Spread within the Subdivisions

2020	Bamusso	Kombo Itindi	Kombo Abedimo	Isangele	Ekondo Titi	Idabato
Agricultural land	1057.5	774.6	170.46	1691.68	7990.07	51.43
Clouds	13804.08	4.85	1178.59	49.69	0.062	231.93
Degraded Mangrove /Nypa Palms	151.98	7564.71	5016.68	6407.06	1206.06	2533.55
Intact Mangroves	2760.81	28596.68	17122.58	22316.41	9695.07	7112.33
Settlements/Bare soils	6244.36	347.86	1633.35	685.194	145.28	501.73
Water bodies	155.12	3145.53	2046.34	2240.096	737.35	1632.64

Source: Generated from the land use map of 2020

LULC data for the different categories spread across the Subdivisions in the RDRW for the period 2020 continue to show great variation (table 3.8 and figure 3.5). However, the patterns portray continue to change with time. Agricultural land category, the largest proportion occurred in Ekondo Titi followed by Isangele instead of Bamusso as it was in 2010. For degraded Mangrove/Nypa palm category, Bamusso completely loss its own proportion to other land uses. Bamusso also loses almost all its own proportion of Intact mangrove. This pattern probably is not what exists because the data shows that much of Bamusso was covered by cloud during the 2020 study period

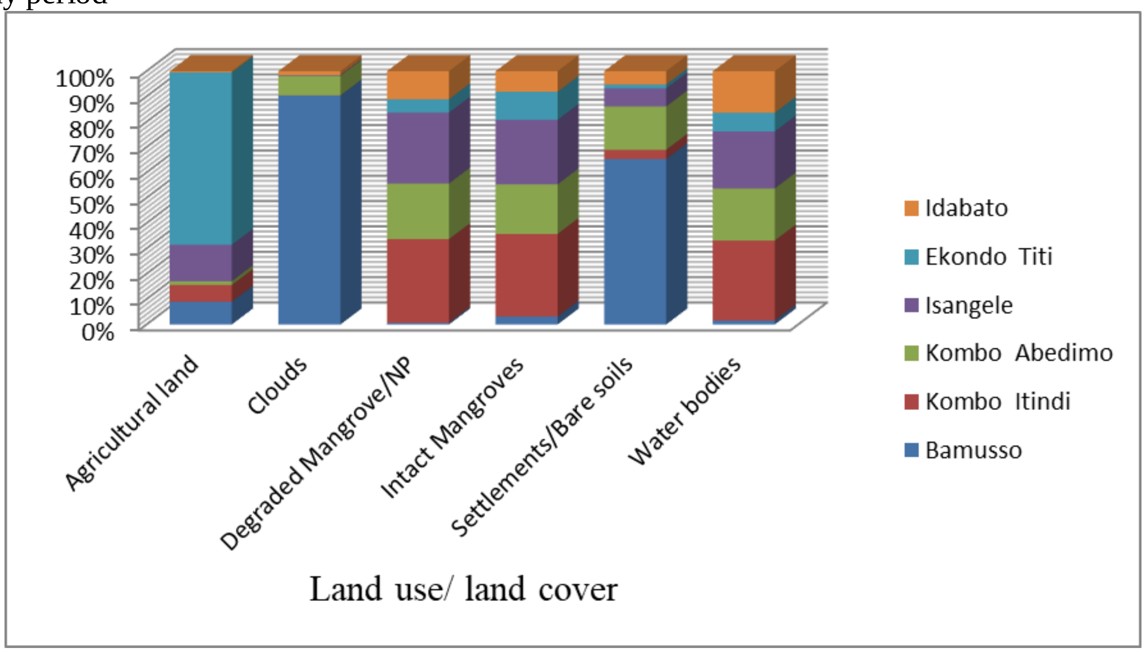


Figure 3.5: LULC categories for 2020 spread across Subdivisions in RDRW

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3.3 Spatio-Temporal Changes in Land Use/Land Cover for RDRW

The land use/land cover analysis for the study period show enomous variation in the land use/land cover categories over the years. Table 3.9 present the land use/land cover for the different study periods.

Table 3.9: Areal Coverage for the Different Land Use Categories

Land use/Land cover categories	**1990**	**2002**	**2010**	**2020**
Agricultural Land	2322.483	12447.14	14161.25	11439.89
Clouds	2788.204	337.6736	1470.552	15403.63
Degraded mangrove / Nypa Palms	33771.53	18649.43	22266.94	23800.6
Intact Mangroves	87299.27	90387.89	81025.6	54265.29
Settlements/ Bare soils	151.9054	1321.033	3609.509	18167.99
Water bodies	5592.7	8783.775	9392.126	8849.058
Total	**131926.1**	**131926.9**	**131926**	**131926.5**

Source: Generated from land use map of 1990, 2002, 2010 and 2020

3.3.1 Land Use/land Cover Dynamics between 1990 and 2002

During the 1990-2002 change period, all land use/land cover categories experienced changes. Agricultural land, settlement/Bare soil, Intact mangrove and water bodies experience an increasing trend. Among these land uses, agricultural land experienced the greatest increase in its surface area from 2322.483ha in 1990 to 12447.14ha in 2002, an increase of 10124.66ha (7.67% change) which depicks an annual change rate of 843.72ha (0.64%). Agricultural land category was closely followed by water bodies category with an increase in surface area of 3191.08ha (2.42%) while the category with the least increase in its surface area is settlement/bare soil category with an increase of only 1169.13ha (0.89%).

On the other hand, only two land use/land cover categories experience decrease in the their surface area during the 1990-2002 change period. These are the degraded mangrove/Nypa Palms and cloud cover and amongst them, degraded mangrove forest/Nypa palms decreases from 33771.53ha to 18649.43ha, a decrease of 15122.1ha (11.5%) see table 3.10.

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Table 3.10: Land Use/land Cover Dynamics between 1990 and 2002

	1990		2002		Land use/land cover dynamics between 1990 -2002			
Land use/land cover category	**Area(ha)**	**% cover**	**Area(ha)**	**% cover**	**Area**	**%**	**Annual change rate**	**%**
Agricultural Land	2322.483	1.76	12447.14	9.43	10124.66	7.67	843.72	0.64
Clouds	2788.204	2.11	337.6736	0.26	-2450.53	-1.86	-204.21	-0.16
Degraded mangrove / Nypa Palms	33771.53	25.60	18649.43	14.14	-15122.1	-11.5	-1260.2	-0.96
Intact Mangroves	87299.27	66.17	90387.89	68.51	3088.61	2.34	257.4	0.2
Settlements/Bare soils	151.9054	0.12	1321.033	1.00	1169.13	0.89	97.43	0.07
Water bodies	5592.7	4.24	8783.775	6.66	3191.08	2.42	265.92	0.2
Total	**131926.1**	**100**	**131926.9**	**100**	**0.84**	**0.00**	**0.00**	**0.00**

Source: Computed from land use map of 1990 and 2002

3.3.2 Land Use/land Cover Dynamics between 2002 and 2010

During the 2002-2010 change period, all land use/land cover categories also experience changes. All land use/land cover categories show an increasing trend except for intact mangrove forest category which show a decrease in its surface area from 90387.89ha in 2002 to 81025.6ha in 2010 a decrease of 9362.28ha (7.10%). Among those that experience an increase trend, degraded mangrove forest/nypa palms category experience the most staging increase by gaining 3617.51ha from other land use/land cover categories (table 3.11).

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Table 3.11: Land Use/land Cover Dynamics between 2002 and 2010

Land use/land cover category	2002		2010		Land use/land cover dynamics between 2002-2010			
	Area(ha)	% cover	Area(ha)	% cover	Area	%	Annual change rate	%
Agricultural Land	12447.14	9.43	14161.25	10.73	1714.10	1.30	214.26	0.16
Clouds	337.6736	0.26	1470.552	1.11	1132.88	0.86	141.6	0.11
Degraded mangrove / Nypa Palms	18649.43	14.14	22266.94	16.88	3617.51	2.74	452.19	0.34
Intact Mangroves	90387.89	68.51	81025.6	61.42	-9362.28	-7.10	-1170.3	-0.89
Settlements/Bare soils	1321.033	1.00	3609.509	2.74	2288.48	1.73	286	0.21
Water bodies	8783.775	6.66	9392.126	7.12	608.35	0.46	76.o4	0.06
Total	**131926.9**	**100**	**131926**	**100**	**-0.9621**	**0.00**	**0.00**	**0.00**

Source: Computed from land use map of 2002 and 2010

3.3.3 Land Use/land Cover Dynamics between 2010 and 2020

In the same vain, during the 2010-2020 change period, all land use/land cover categories experience changes (table 3.12). However, intact mangrove forest alongside water bodiescategories and agricultural land categories experienced decrease in their area coverage while degraded mangrove/nypa palms, cloud cover and settlement/bare soil categories experienced an increase in their surface area. In this change period, the highest surface area change was experienced by intact mangrove forest which decreased from 81025.6ha in 2010 to 54265.29ha in 2020 a decrease of 26760.3ha (20.28%). This was followed by settlement/bare soil land use/land cover category which experienced a tremendous increased from 3609.509ha in 2010 to 18167.99ha in 2020, an increase of 14558.48ha (11.04%)

Table 3.12: Land Use/land Cover Dynamics between 2010 and 2020

Land use/land cover category	2010		2020		Land use/land cover dynamics between 2010-2010			
	Area(ha)	% cover	Area(ha)	% cover	Area	%	Annual change rate	%
Agricultural Land	14161.25	10.73	11439.89	8.67	-2721.35	-2.06	-272.1	0.2

Clouds	1470.552	1.11	15403.63	11.68	13933.08	10.56	1393.3	1.05
Degraded mangrove / Nypa Palms	22266.94	16.88	23800.6	18.04	1533.663	1.16	153.37	0.1
Intact Mangroves	81025.6	61.42	54265.29	41.13	-26760.3	-20.28	-2676.0	-2.3
Settlements/Bare soils	3609.509	2.74	18167.99	13.77	14558.48	11.04	1455.8	1.1
Water bodies	9392.126	7.12	8849.058	6.71	-543.068	-0.41	-54.3	-0.04
Total	**131926**	**100**	**131926.5**	**100**	**0.488423**	**0.00**	**0.00**	**0.00**

Source: Computed from land use map of 2010 and 2020

3.3.4 Land Use/land Cover Dynamics between 1990 and 2020

The land use/land cover analysis for the study period show enomous variation in the land use/land cover categories over the years as shown on figure 3.6. Some land use categories changed into others, reducing their spatial extent and increasing others while some show a more complex situation. Generally, dense mangrove forest showed a decreasing trend over the periods under investigation (1990-2020). The intact or dense mangrove forest cotegory showed the most staging decrease where the surface area covered by intact mangrove forest decrease by 33034ha in its surface area over the period as presented on table 3.13. Also, degraded mangrove/nypa palm decreases by 9970.93ha over the period under investigation.

Conversely, agricultural laud and Settlements/Bare soils categories depicted an increasing trend throughout the study period (1990 to 2020). Settlements/Bare soils categories increase tremendously by 18016.08ha (13.66%) while agricultural land increases from 2322.483ha in 1990 to 11439.89ha in 2020, an increase of 9117.4ha (6.91%) see table 3.13.

Table 3.13: Land Use/land Cover Dynamics between 1990 and 2020

Land cover	**1990**	**2020**	**Area Δ in 3 decades**	**% Δ in 3 decades**
Agricultural Land	2322.483	11439.89	9117.409	6.91
Clouds	2788.204	15403.63	12615.43	9.56
Degraded mangrove / Nypa Palms	33771.53	23800.6	-9970.93	-7.56
Intact Mangroves	87299.27	54265.29	-33034	-25.04
Settlements/Bare soils	151.9054	18167.99	18016.08	13.66
Water bodies	5592.7	8849.058	3256.358	2.47
Total	**131926.1**	**131926.5**	**0.369035**	**0.00**

Source: Computed from land use map of 1990 and 2020

The comparative status of LULC by categories over the study period is quite visible on figure 3.6 and depicts an increasing trend for agriculture, settlements/bare soil and degraded mangrove. Agricultural land use land cover category had a sharp increase between the 1990-2002 change period which is equally reflected by a sharp decrease in the degraded mangrove land use category for the same period. This implies that during the period agricultural LULC took up some degraded LULC category. Intact mangrove LULC category shows a decreasing trend over the study period and a very sharp decrease during the 2010-2020 change period which probably is caused by cloud cover. The extensive cloud cover in 2020 makes it difficult for what is on the surface of the earth to be seen hence the sharp decrease in intact mangrove LULC category. The water bodies LULC category remain almost unchanged over the period except for the slight increase which occurred during the 1990-2002 change period.

The comparative status of LULC categories is augmented by the change detection map for the study area (map 3.5) which shows areas which have not change over the study period, the areas which have change, the direction of change and the magnitude of change that has taken place within the study area and over the study interval.

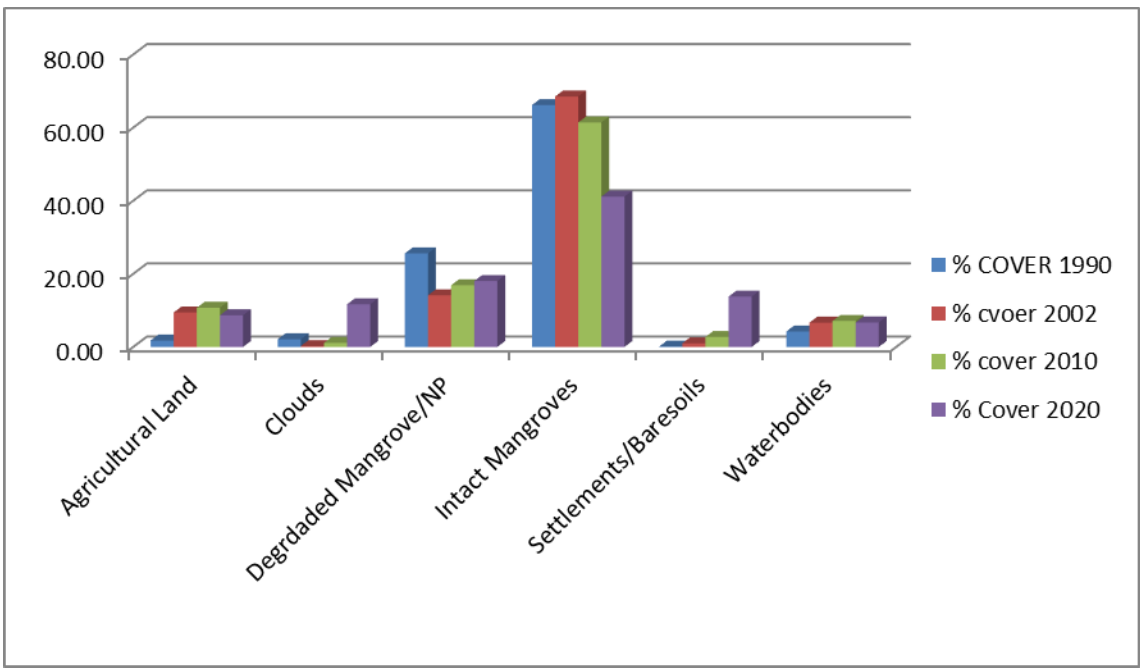
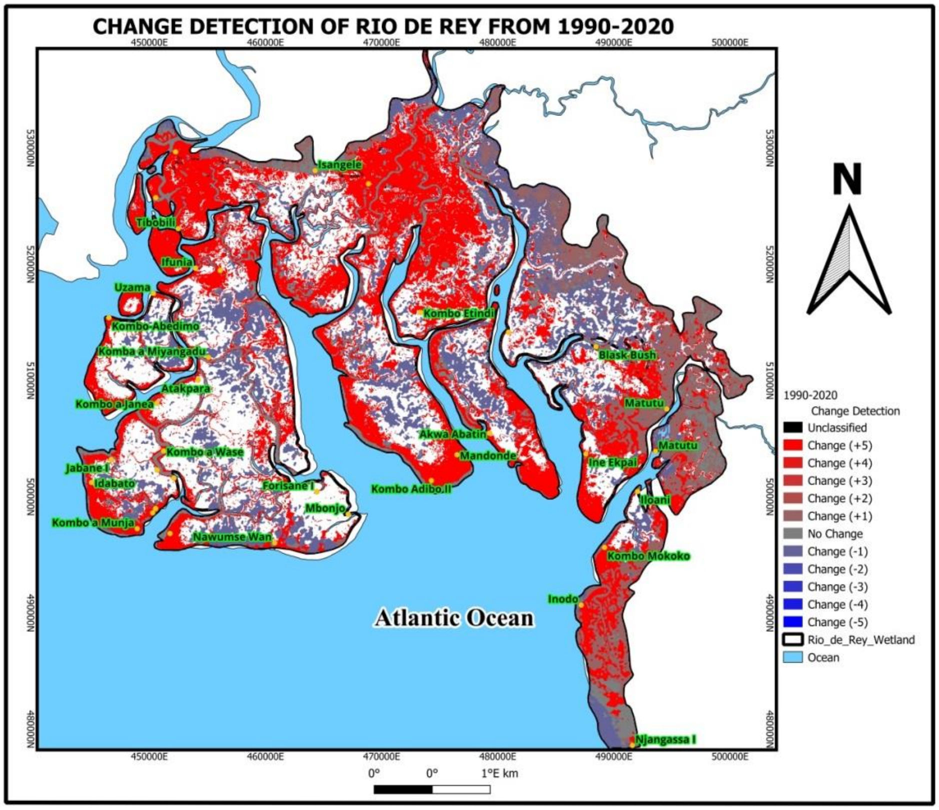


Figure 3.6: Comparative status of land use/land cover during 1990, 2002, 2010 and 2020



Map 3.5: Change Detection map between 1990 and 2020

Table 3.14: LULC transformation matrix in percentages between 1990 and 2020

Percentage	**Intact Mangrove**	**Degrade Mangrove/ Nypa Palms**	Settle- ment	**Agricultural land**	**Water bodies**	**Clouds**	**Class Total**
Intact Mangrove	**42.715**	59.736	28.23	18.923	0.144	30.304	100
Degraded Mangrove /Nypa Palms	39.886	**14.569**	9.591	1.797	0.258	6.944	100
Settlement	2.146	1.306	**10.01**	1.36	0.069	6.772	100
Agricultural Land	1.803	11.87	20.217	**62.313**	97.486	1.5	100
Water bodies	6.488	0.613	5.843	0.093	**1.816**	34.719	100

Clouds	6.961	11.907	26.109	15.514	0.227	**19.76**	100
Class Total	100	100	100	100	100	100	0
Class Changes	57.285	85.431	89.99	37.687	98.184	80.24	0
Image Difference	-7.324	-33.005	74.334	4117.749	-95.933	1421.26	0

Source:

3.4 Change Detection Matrix between Initial and Final States

Change detection matrix between the initial (1990) and final (2020) was calculated using ENVI 5.1 software. Table 3.14 shows the shifts of land cover classes over a 30 year period. From 100% of Intact mangrove in 1990, 42.715% is retained while 39.886% was transformed to Degraded mangrove/Nypa Palm category, 2.146% to settlement, 1.8% to agricultural land, 6.488% to water bodies and 6.961% to Cloud categories during the period. For degraded mangrove/Nypa palm LULC category, 59.736% out of 100% in 1990 is transformed to Intact mangrove while 1.3% to settlement, 11.87% to agricultural land, 11.9% to cloud, o.6% to water bodies categories and 14.569% is maintained as Degraded mangrove/Nypa palm. The transformation matrix table is also presented in m^2 and number of Pixels in appendix IV and V respectively).

3.5 Net Changes for the different Study Periods

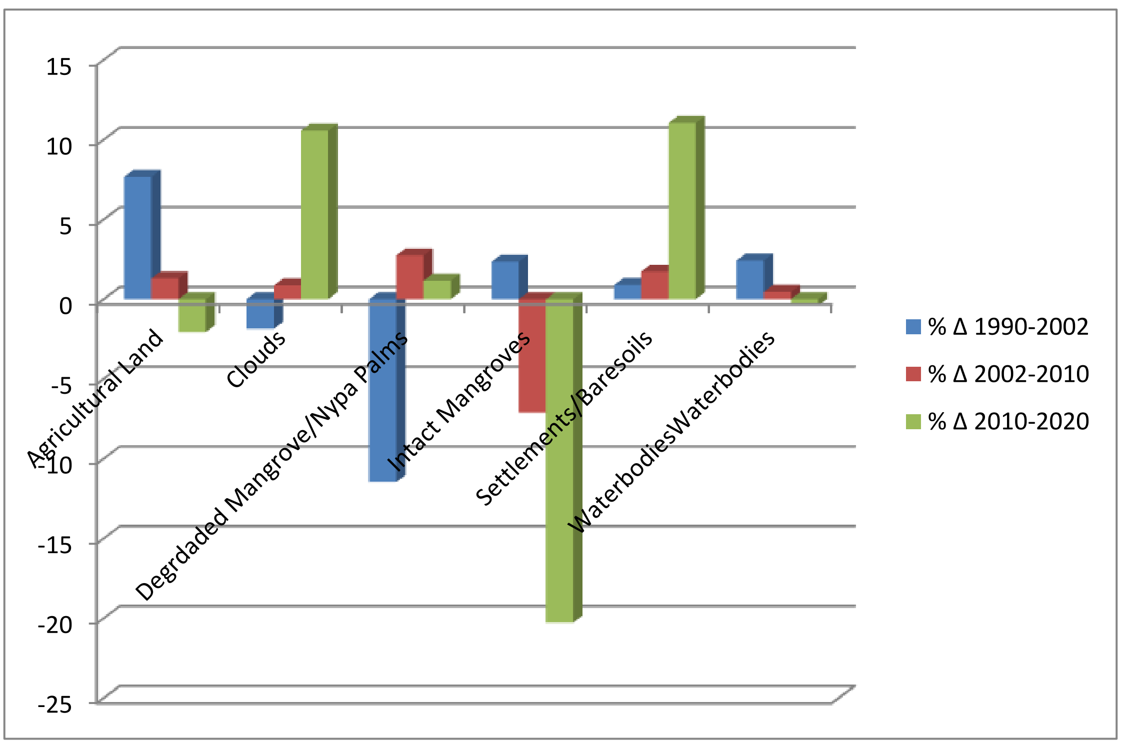


Figure 3.7: Net Changes for the different Study Periods

Source:

4. DISCUSSIONS

To analyze the spatio-temporal changes in land use within the Rio Del Rey Wetland between 1990 and 2020, land use categories were earmarked based on their distinguishing feature using GIS technology and ground trothing. The analysis of the areal coverage of these land use categories over the study period revealed a devastating decrease of Intact mangrove forest from 87299.27ha in 1990 to 54265.29ha in 2020, a decrease of about -33034ha corresponding to about 25.04% of the mangrove forest stand of 1990 and a decrease of 0.83% per annum. This finding is in line with the finding of Longonje & Lysinge (2018) and WRI, 2003a.The situation of decrease in Intact mangrove at Bamusso during the 2010-2020 study period result from the heavy cloud cover in the aerial photo and not a real situation on ground.

The most devastating decrease in the areal coverage of Intact mangrove occurred during the 2010-2020 change period where the Intact mangrove reduces from 81025.6ha in 2010 to 54265.29ha in 2020 a decrease of about 20.28%. The most dramatic changes the areal coverage of Intact mangrove occurred during the 1990-2002 change period at Isngele and Ekondo Titi. At Ekondo Titi, the Intact mangrove reduces from 33333.7ha to 10853.7ha, a decrease of 67.4% while at Isangele, it decreases from 44234.7ha to 20096ha a decrease of 54.6%. 1990-2002 corresponds to the arm conflict period over the Bakassi peninsular between Nigeria and Cameroon which happens to be part of the RDRW. During conflict, there is little or no control over the behavour of the people and resource exploitation.

Degraded mangrove/Nypa Palm LULC category on its path has shown great variation over the study period and within the different studied subdivisions. Generally, the surface area covered by degraded mangrove/NP LULC category was at maximum during the 1990 study period and dropped dramatically during the 2002 study period before increasing steadily for the rest of the study period. Looking at the different subdivisions, the greatest decrease in this category occurred in Ekondo Titi where the surface area covered by degraded mangrove/NP dropped from 9623.93ha in 1990 to 1114.82ha in 2002 followed by Bamusso subdivisions where it also dropped from 8331.04ha to 1292.76ha in the same period. The dropped in the areal coverage of degraded mangrove/NP were probably taken up by agricultural LULC category which shows a corresponding increase in it areal coverage during the same period and within the same Subdivisions.

These land use changes have great effects on ecosystem services and the livelihood activities they support. The effect include decrease in fish catch both in quantity and fish species due to the destruction or continuous removal of the intact mangrove which is a habitat and a breeding ground for most of the fish species. The destruction of the intact mangrove forest and decrease in fish catch has a corresponding devastating effect on livelihood activities related to fishing such as fish smoking, production of new fishing boats and the repair of engines meant for fishing boats. Land use changes have equally resulted in the increase of transport boats and boat riders in the area especially between Ikang and Idenua where assortments of goods are traded. This is because livelihood activities related to fishing are no longer lucrative as before.

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5. CONCLUSIONS

After several visits and interaction with communities in the study area, the research appreciates the fact that all six sub-divisions under study are endowed with profuse wetland resources. Numerous ES emanate from the natural resource base on which the livelihoods of thousands of communities dwellers depend for survival. Among the livelihood activities supported by this wetland, Artisanal fishing/fish preservation, crude oil extraction and extraction of periwinkle were the most popular ES to respondents.

Despite all the ES enjoyed by the communities in the area, analysis of satellite images reviewed ongoing transformation where the Intact mangrove forest is experiencing decreasing trend over the study period with the most dramatic decrease occurring at Isangele followed by Ekondo Titi during the 1990-2002 change period.

This land use transformation in RDR wetland was found to be more severe during the 1990-2002 period which corresponded with the Cameroon–Nigeria armed conflict era than during the post conflict era (2002-2020) indicating high rate of extraction in a time of lawlessness and chaos.

6. RECOMMENDATIONS

The government of Cameroon and its international partners has acknowledged the overwhelming resource endowment of the RDR wetland by naming it a Ramsar site since 2010; however, there is need to come up with a management plan and a unit. Though efforts toward the development of a management plan have been made through the GEF project entitled, “PINESMAP-BPCE – Participatory Integrated Ecosystem Management Action Plan for Bakassi Post Conflict Ecosystem”, concrete actions towards implementation are still far fetch. Further delay towards more concrete actions will only exacerbate the current situation.

To the inhabitants of the area both Cameroonians and Nigerians, it is important to strictly adhere to the rules of the traditional and other local institutions to continuously benefit from the resource base of the area. Contrarily actions may propel degradation with devastating action at both local and regional levels.

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