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Ethnographic Dependence of Local Communities on Ecosystem Resources and Drivers of Change in the Eastern Rio Del Rey Mangroves, Cameroon

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Abstract

Mangrove ecosystems support coastal livelihoods but are subject to changing land use and community practices. This study examines 1) ethnographic dependence of local communities on mangrove ecosystem resources and 2) land use/land cover changes (LULCC) from 1995 to 2025 in the Ekondo-Titi segment of the Rio Del Rey estuary. Using a mixed-method approach, a total of 200 questionnaires were distributed in four sample communities of Matutu 1, Black Bush and Ekondo-Titi Beach, focus group discussions in Ekondo-Titi Beach, Matutu 1, and Matutu 2, alongside supervised land-cover classification of remotely sensed imagery for 1995, 2010, and 2025. The results revealed a high community reliance on mangrove resources with all communities relying heavily on provisioning ecosystem services. Majority of the respondents had little or no traditional knowledge on mangrove use. For LULCC from 1995 to 2025, cropland and settlement/bare soil increased by 3641.3 ha (10.8% increase) and 3371.0 ha (10.0% increase) respectively, while dense mangrove forest decreased from 11425.1 ha in 1995 to 7165.3 ha in 2025, giving a negative percentage change (−12.7%). These results suggest an urgent need for sustainable management strategies to balance ecological preservation with community livelihoods.

Keywords

Ekondo-Titi Mangrove Stretch, Ethnographic Dependence, Ecosystem Resources, Land Use/Land Cover Changes (LULCC)

1. Introduction

Mangroves are coastal forests (mangal) that are found or associated with salt or brackish water, estuaries, along river banks and lagoons in the tropical and subtropical regions (Enoh et al., 2024). Mangroves dominate majority of the world's tropical and subtropical coastline, forming 15 million hectares of forests worldwide, which provide habitats for rich biodiversity, ranging from bacteria, fungi and algae through to invertebrates, birds and mammals (Manju et al., 2012). They are the world's most productive ecosystems having a high primary production, high rates of recycling and provide a high supply of nutrient source that supports many complex food chains (Feka & Manzano, 2008; Forkam et al., 2020). African mangrove forests cover over 3.2 million ha and are grouped into three major coastal segments namely, Western Atlantic, Central Atlantic and Eastern Indian Ocean, representing 49%, 37% and 14% of mangroves found along the coasts of Africa (Ajonina et al., 2013). Within the various regions in Africa, mangroves are very diverse, with significantly different species structure and composition (FAO, 2007). FAO (2007) reported that as of 2005, about 70% of all African mangroves were found in just five countries, including Nigeria (32%), Mozambique (12%), Madagascar (9%), Guinea (9%) and Cameroon (8%), while the remaining 30% are found in other countries, such as Gambia, Guinea-Bissau, Kenya, Senegal and Ghana.

Cameroon is among the rare countries in the world harbouring the tropically and sub-tropically restricted salt water tolerant inter-tidal forest communities called mangroves (Atlas des Mangroves du Cameroun, 2018). The mangrove forest ecosystem in Cameroon covers 200,000 ha, representing 30% of the total coastal area, and these forests are the most important in Central Africa and the 6th most important in Africa (Ajonina, 2008; Fongnzossie, 2022). Mangroves in Cameroon have a great structural peculiarity, being the most gigantic in Africa, reaching over 100 cm in diameter and 60 m in height, especially around the Wouri estuary (Atlas des Mangroves du Cameroun, 2018). These forests offer a range of important ecosystem services, such as Regulatory services ranging from coastal zone stabilization, carbon sequestration, micro and global climate amelioration; Supporting services ranging from food chain support to acting as nursery grounds and habitats for many marine and other aquatic fauna; Provisioning services sustaining the livelihoods of 30% of the country's population living in these coastal areas, supplying a wide range of Provisioning services especially timber and non-timber products including fisheries products; and as well as Cultural services being havens for spiritual activities of most festivals with huge ecotourism and environmental educational potentials (Nyangoko et al., 2022).

Ethnographic dependence is the extent to which local communities rely on mangroves ecosystem resources for livelihood, subsistence, income, cultural practices, and perceived ecosystem services. The coastal communities of Rio Del Rey and local communities along the Ekondo-Titi mangrove stretch in particular have historically depended on mangrove resources for their livelihoods, including fishing, fuel wood collection, and traditional medicine (Feka & Manzano, 2008). However, like many mangrove ecosystems globally, those in the Ekondo-Titi area face increasing threats from both anthropogenic and natural factors (Duke et al., 2007). Climate change, overexploitation, and pollution are among the key drivers of change affecting these vital ecosystems (Alongi, 2015).

Generally, mangrove ecosystems play pivotal roles in coastal economies (Ahmad & Glaser, 2016), contributing to an annual estimate of US$ 2000-9000 per ha (Alongi, 2014). Mangrove forests thus, influence both local and national economies, in addition to livelihoods (Uddin et al., 2013). Mangroves are heavily used traditionally and commercially worldwide by local communities as a source of fuel wood and charcoal for cooking and heating, wood for construction of houses, huts, fences, bridges as well as timber for furniture and many other products (Alongi, 2002; Forkam et al., 2020).

It has been observed that the presence of mangrove ecosystems on coast lines saves lives and property during natural hazards such as cyclones, storm surges and erosion (Enoh et al., 2024). These ecosystems are also well known for their economic importance. They are breeding, feeding and nursery grounds for many estuarine and marine organisms like fishes. Hence, these areas are used for captive and culture fisheries. According to Nyam et al. (2014), the crabs form the most abundant and important crustaceans and consequently, play significant roles in mangrove ecosystems. The most prominent are indisputably the fiddler crabs (*Uca* spp.), which create burrows at all levels of the shore (Hogarth, 2015). Other fauna includes reptiles such as crocodiles, alligators, lizards, snakes and turtles, as well as amphibians including ground frog, tree frogs and toads. The Sunderbans of Bangladesh for instance, harbours about 35 reptile species such as saltwater crocodiles (*Crocodylus porosus*), rock pythons (*Python molorus*) and monitor lizards (*Varanus* sp.) (Kathiresan & Bingham, 2001). Mangrove ecosystems have rich fish biodiversity of importance which comprise fish with commercial value which serve as important links in food web, while others live there temporarily and spend greater part of their life stages elsewhere (Kathiresan & Bingham, 2001). The ecosystem has a very large unexplored potential for natural products useful for medicinal purposes and also for salt production, apiculture, fuel and fodder (Vovides et al., 2011), and the Ekondo-Titi mangroves in the eastern part of the Rio Del Rey estuary are recognized as important reproduction areas and hiding environment for both migratory and resident birds (Fongnzossie, 2022). Of the 28,946 water birds of 59 species found in the Cameroon coastal wetlands, 23,353 birds, 80% is found in Rio del Rey, making it the richest site (Ajonina, 2008).

Despite the unique ecological functions performed by mangroves, over the years, mangrove wood has been over exploited for fish smoking, fuel wood, coal production and building materials for local and national use (Simon & Raffaelli, 2012). Mangrove and associated coastal areas have been lost annually at about 1% in Cameroon but this varies greatly within the regions with Douala-Bonaberi area in Douala being the highest at 6.2% per year (Atlas des Mangroves du Cameroun, 2018), with the driving factors being coastal population growth, urbanization, fish processing, sand extraction and uncoordinated policies and government economic coastal development programs including accentuated pollution from extractive and processing industries. According to Enoh et al. (2024), the constant use of mangroves by local communities for economic purposes poses a significant threat to mangrove sustainability. Thus, leading to environmental degradation, destroying breeding grounds for fish and other aquatic organisms, shelter for organisms, birds seeking food and shelter from predators (Polidoro et al., 2010; Enoh et al., 2024). In the context of the study area, local communities rely heavily on mangrove resources as their source of livelihood. Unfortunately, information regarding the magnitude of community dependence on these resources and specific drivers of change on mangrove ecosystem is lacking. In this regard therefore, this study aimed at providing a comprehensive assessment of the ethnographic dependence of local communities on ecosystem resources in the eastern part of Rio Del Rey estuary and identify specific drivers of change in the mangrove ecosystem.

2. Materials and Methods

2.1. Description of Study Area

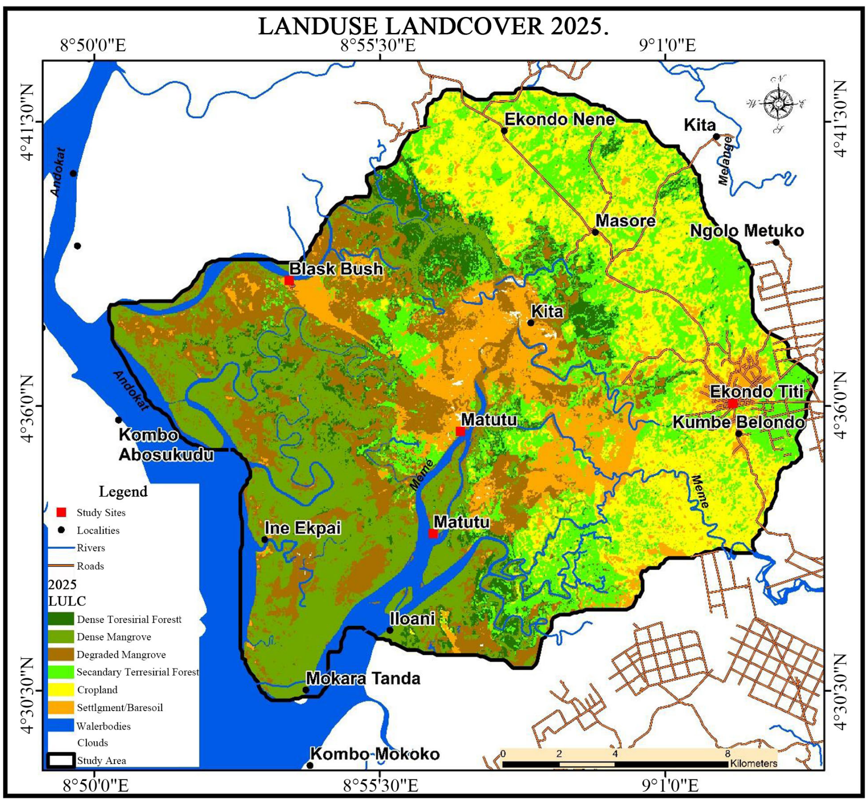


Figure 1. Location of the eastern part of the Rio del Rey mangrove estuary.

The Ekondo-titi mangrove stretch is located some 56 km from Kumba and 120 km from Buea, the regional capital. The subdivision is located between latitudes

4˚30'30''N - 4˚41'40''N and between longitude 8˚50'0''E - 9˚1'0''E (**Figure 1**). The vegetation consists of three main types of ecosystems: mangroves, swamp forests, and Atlantic forests, which form the Korup rainforests. According to current taxonomic knowledge, seven (7) species constitute the floristic composition of the Rio del Rey mangrove ecosystem. These include *Rhizophora racemosa*, *Rhizophora harrisonii*, *Rhizophora mangle* (Rhizophoraceae), *Avicennia germinans* (Avicenniaceae), *Laguncularia racemosa*, *Conocarpus erecrus* (Combretaceae), and the exotic palm *Nypa fructicans* (Arecaceae) (Fongnzossie, 2022). It has an equatorial maritime climate with temperatures ranging between 22˚C and 30˚C, with rainfall ranging from 1800 mm to 4000 mm annually. Maximum rainfall occurs between July and October when the South West Monsoon winds or the Westerlys are strongest and minimum between December and January when the North east trade winds or hamattan are dominant (PNDP, 2013). The area has a total population size 151,772, with their main activities being fishing, agriculture, fish smoking, and trade of wood and non-wood forest products (Fongnzossie, 2022).

2.2. Data Collection

A mixed method approach was employed in this study including field surveys alongside a total of 200 semi-structured questionnaires established randomly in the various sampling communities which consisted of residents and mangrove-resource users in the four communities; Matutu 1 (30), Matutu 2 (50), Black bush (50), and Ekondo-titi beach (70). These respondents were selected from households and resource-user groups as described by (Enoh et al., 2024), with inclusion based on residence in the community, direct or indirect knowledge of mangrove resource use, and willingness to participate. Prior informed consent was obtained verbally. They consisted of both males and females of different age groups, composed of both men, women and children of different ages and occupations. Children below 18 years were included in the survey because some young people in these areas participated in household livelihood activities linked to mangrove resources such as periwinkle gathering. However, informal parental/guardian consent was sought before the survey. The questionnaires received a 100% return rate. Focus group discussions in three communities; Ekondo-titi beach (10 participants), Matutu 1 (10 participants), and Matutu 2 (8 participants), giving a total of 28 participants (**Figure 2**). The groups were selected by the village heads in each of the communities, based on the participants' knowledge of their communities and the groups involved both men and women of different age groups, using the questionnaire. The data acquired through these sources included reliance on mangrove resources, knowledge of traditional mangrove practices, perceived drivers of change, alternative sources of livelihood, resource use, cultural practices, and perceived changes in the mangrove resources. Ethnographic dependence was measured using questionnaire items on types of mangrove resources used, frequency of collection, purpose of use, perceived economic importance, cultural knowledge, ecosystem services derived, observed changes, and perceived drivers of change. Secondary data were collected from published books, articles and journals. These reviewed works aided in acquiring in depth knowledge on mangrove resource uses and drivers of change.

Determination of Land Use Land Cover Changes

Land Use Land Cover Changes (LULCC) data were sourced from Landsat imageries for different years (1995, 2010, 2025). Satellite images from three distinct sensors were utilized: SPOT 3 for the year 1995, Landsat 7 Enhanced Thematic Mapper Plus (ETM+) for 2010, and Landsat 9 Operational Land Imager/Thermal Infrared Sensor (OLI/TIRS) for the year 2025. The selection of these satellite platforms was informed by their spatial and temporal resolutions, radiometric quality, and availability of historical datasets that ensured continuity and comparability of land cover trends over time. The SPOT 3, Landsat 7 ETM+, and Landsat 9 OLI/TIRS were used because they provided the best available historical coverage for the selected years, and the cross-year comparability was improved through radiometric and geometric correction, spatial sub-setting to the same study area, use of a consistent land-cover classification scheme, supervised classification, and accuracy assessment for each year.

The process began with radiometric and geometric corrections, applied to standardize the datasets and eliminate sensor-related and atmospheric distortions to ensure that the pixel values were consistent and comparable across the different time periods, followed by band composition. Pan sharpening techniques were employed particularly for SPOT 3 and Landsat 7 imagery to enhance spatial resolution by integrating high-resolution panchromatic data with multispectral images to allow for clearer delineation of land cover boundaries and to improve the accuracy of classification. Subsequently, layer stacking was performed Using ENVI 4.5 to compile selected spectral bands into a single multi-band composite image for each year. The images were then spatially subset by extracting the study area, which was defined based on Research Area interest and environmental features relevant to the research scope. A Region of Interest (ROI) was delineated to focus the analysis on areas experiencing significant anthropogenic or ecological change, through a combination of field surveys, historical documentation, and visual interpretation of high-resolution satellite imagery (Findi & Wantim, 2022).

The core classification process was conducted using a supervised classification approach, specifically employing the Support Vector Machine Algorithm (SVMA). Accuracy metrics were derived by constructing confusion matrices comparing classified outputs with independent ground-truth data. These validation datasets were obtained through field verification using GPS-located ground control points (GCPs), high-resolution reference images, and expert knowledge. The overall accuracy, user's and producer's accuracies for each class, and the Kappa coefficient were calculated to quantify the reliability of the classification. An overall accuracy above 85% and a Kappa value greater than 0.75 were targeted as benchmarks for acceptable classification performance (Findi & Wantim, 2022). This was then followed by change detection analysis using a post-classification comparison method. The accuracy assessment of this Images was tested using the Ground Control Points and Pixel classified using the Envi 4.5 software (Butt et al., 2015), while Change Detection and Landcover and Land uses were calculated using the ArcGIS 10.8 and Envi 4.5 Respectively.

2.3. Data Analyses

Responses of the questionnaires were keyed in Microsoft Excel (version 13) and descriptive statistics involving frequencies and cross tabulations as well as chats were used to express the ethnographic dependence results using R-Studio (version 4.1). The questionnaire responses were summarized using frequencies and cross-tabulations, while the focus-group discussions were used to clarify, validate, and contextualize the quantitative patterns. The Kappa Coefficient was used to summarize the results of the accuracy assessment for LULCC.

3. Results

3.1. Demographic Characteristics of Respondents

From the study, males and females constituted 60% and 40% respectively of the respondents from all four communities of Black Bush, Ekondo-Titi beach, Matutu 1, and Matutu 2. A majority of the respondents (40%) belonged to the 18 - 30 years category, followed by 31 - 50 years (38%). The old were also represented (12%) while the <18 years (10%) group was the least. Most of the respondents were married (60%).

3.2. Perception of Mangrove Resources Exploited

Results of the respondents' perception on the presence, type and use of mangrove are presented in **Table 1**. All respondents (100%) in the four communities acknowledged haven seen a mangrove tree and are aware of their presence in their communities. Based on the direct type of mangrove resources being used, 41% of the respondents were involved in fuel wood harvesting, while 34.1% and 9.3% used it for the construction of houses and for the building of boats (**Figure 2** and **Figure 3**). Only (0.4%) used it for traditional uses.

Table 1. Respondents' Knowledge, type and frequency of mangrove resources being exploited.

Variable	Description	Percentage of respondents (%)
Knowledge of ever heard of or seen a Mangrove tree	Yes	100
Perceived uses of mangrove resources	Fuelwood	41.4
	Construction of houses	34.1

Continued

	Build boats	9.2
	Catch fish	0.7
	Timber	6.5
	Build bridges	2
	Use as medicine	5
	Furniture	0.7
	Use for tradition	0.4
Frequency of mangrove resource collection	Daily	26
	Weekly	38
	Monthly	14
	Seasonal	12
	Rarely	10

Figure 2. Different uses of mangrove wood in the area (**A**—canoe carving, **B**—building of thatched houses, **C**—Fuelwood, and **D**—for constructing bridges).

Based on the frequency of use, a majority (38%) of the respondents exploited mangrove resources on a weekly basis, some on daily basis (26%) whilst 1% of the respondents rarely exploited mangrove resources.

Figure 3. Provisioning Ecosystem Services from the Rio Del Rey Estuary (**A**—Pile of periwinkle, **B**—Mangrove snail, **C**—Bags of periwinkle, **D**—Uca tangeri used in fishing by the locals, **E**—*Callinectes sapidus*, **F**—Shrimps, **G**—Mangrove alligator, **H**—Mangrove monkey, **I** to **N**—Some varieties of smoked fish and crayfish derived from the study area).

3.3. Economic Dependence on Mangroves

The economic activities of respondents during the study period are presented in Table 2. Gathering of fuel wood was opined by (35%), fishing (25%), and crap/periwinkle gathering (23%) of the respondents. Evidence of these activities is presented in Figure 4. Timber exploitation was the least activity as opined by 14% of respondents. Generally, respondents depended more on mangroves for fuel wood (50%), fish and seafood (37%), medicinal plants (7%), and timber (6%). A total of 55% used it just for subsistence while 34 used it commercially.

Table 2. Economic dependence on mangrove resources by respondents.

Variable	Description	Percentage of respondents (%)
Activities engaged by respondents	Gathering fuelwood	35
	Fishing	25
	Crap/periwinkle	23
	Timber	14
	Others	3
Activities most engaged in	Fuelwood	50
	Fish and Seafood	37
	Medicinal Plants	7
	Timber	6
Purpose of using mangrove resources	Subsistence	55
	Commercial	34
	Craft and construction	11

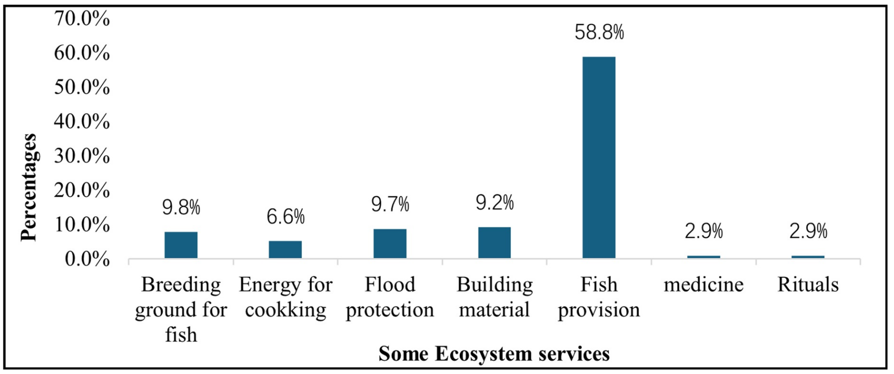


Figure 4. Some perceived ecosystem services offered by mangrove in the eastern Rio del Rey.

Also, majority of the respondents perceived the economic importance of mangrove resources to be very high (57%), whilst the least respondents (4%) perceived its importance to be low.

3.4. Respondents' Perception on the Socio-Cultural Importance of Mangrove Forest

A majority of the respondents (78%) had no traditional knowledge or beliefs attached to the use of mangrove resources. However, 21% of respondents had some knowledge of the cultural values attached to mangrove forest whilst the least (1%) had no idea at all. With respect to the role or use of mangroves in culture, only 17% reported that some rituals were carried out using mangroves (Table 3).

Table 3. Respondents' perception on the socio-cultural services offered by mangrove forest.

Variable	Description	Percentage of respondents
Role Mangrove plays in Cultural Practices	Rituals	17%
	Community Gathering	15%
	Other	5%
	None	63%
Perception of any Traditional knowledge on the Use of mangrove Resources	Yes	21%
	No	78%
	None	1%

3.5. Respondents' Perception on the Ecosystem Services Derived from the Mangrove Ecosystem in the Study Area

Three categories of ecosystem services were identified during the study. Half of the respondents (58%) identified different types of fish, the extraction of seafood, periwinkle and clams as top provisioning services. Some of these fish types are presented in Figure 3. Building materials recorded (9.2%), while fuel wood was the second least perceived provisioning service (6.6%). As for source of medicine as a provisioning service, just 2.9% of the respondents reported this service as being provided by the mangrove. However, from further discussions with the respondents, it was acknowledged that mangrove leaves were being used as tea to treat stomach issues, the sap stops bleeding, and the barks as well were used as fishing net dyes to make them last longer. For the supporting services, the respondents cited the mangrove as being a breeding ground for fish (9.8%), and flood protection (9.7%) as presented in Figure 4.

3.6. Perception of Respondents' to Changes Observed in the Availability of Mangrove Resources

Results of the perception of respondents' to changes observed in the availability of mangrove resources are presented in Table 4. Seventy-one (71%) of the respondents agreed there has been a tremendous change in mangrove resources when compared to the past years, while 29% of the respondents reported there was no change in mangrove resources. With regards to some of the changes observed, majority (61%) of the respondents reported there has been a reduction in the mangrove forest, followed by an increase in invasive species (18.7%), reduction in fish population (8.8%), with the least being pollution (5.2%).

Table 4. Respondents' perception to changes in mangrove resources.

Variables	Category	Respondents and their percentages
Changes to mangrove resources	Yes	(71%)
	No	(29%)
Types of changes observed	Fish reduction	(8.8%)
	Increased flood	(6.3%)
	Increased Invasive species	(18.7%)
	Pollution	(5.2%)
	Mangrove Reduction	(61%)

Based on the challenges faced in accessing mangrove resources, a majority (50%) of the respondents reported there have been some legal restrictions with regards to mangrove resource harvesting. This was followed by lack of knowledge on sustainable practices (25%), with environmental degradation being the least (6%) as seen in Figure 5.

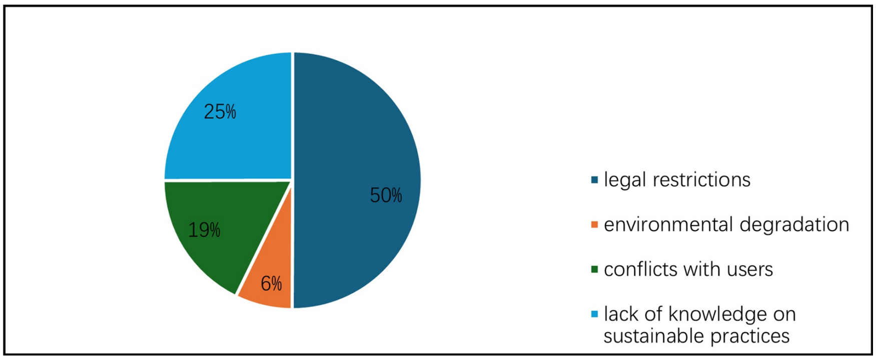


Figure 5. Challenges faced in accessing mangrove resources in the area.

3.7. Drivers of Change Affecting Mangrove Resources

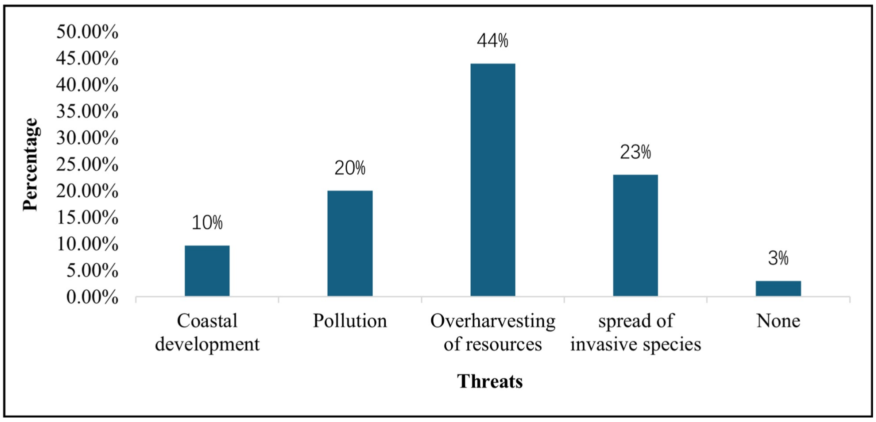


Figure 6. Perception of primary causes of mangrove degradation.

From the survey, respondents were asked to rank some of the threats affecting mangrove ecosystem in the area. Based on the perceived threats (Figure 6), overharvesting of resources ranked the highest with 44%, second by the spread of invasive species with 23%, directly followed by pollution with 20% and coastal development with 10% (**Figure 7**). However, 3% of the respondents reported there were no threats noticed or observed in the area.

Figure 7. Anthropogenic activities and invasive species posing threats to mangrove ecological health and biodiversity in Rio Del Rey estuary (**A**—transportation of fuel at Ekondotiti beach, **B**—Nypa palm Invasion, **C**—Fishing nets with very small pore sizes, **D**—Logged mangroves for fish smoking, **E** and **F**—Settlement expansion within mangrove areas.

3.8. Perceived Factors Driving Changes to Mangrove and Impact of Those Drivers on the Ecosystem

The analysis in **Figure 8(A)** and **Figure 8(B)** revealed the most significant driver identified by the respondents was lack of awareness and education as cited by 40.5% of the respondents and this highlights a critical gap in understanding sustainable practices likely fueled by low formal education levels. Also, policy and government related issues were the second most cited driver of change with 22%

response, followed by population growth (19%), land use changes (16%), and economic development, which was a minor concern (2.5%).

The most severe impact reported as a result of the drivers mentioned above was fish stock reduction (50% respondents), second by overuse of resources (23% respondents), mangrove reduction noted by 20.5%, land degradation (1.4%), and unknown effects (5.1%) suggesting some respondents were either unaware of some specific consequences or less tangible factors like climate change.

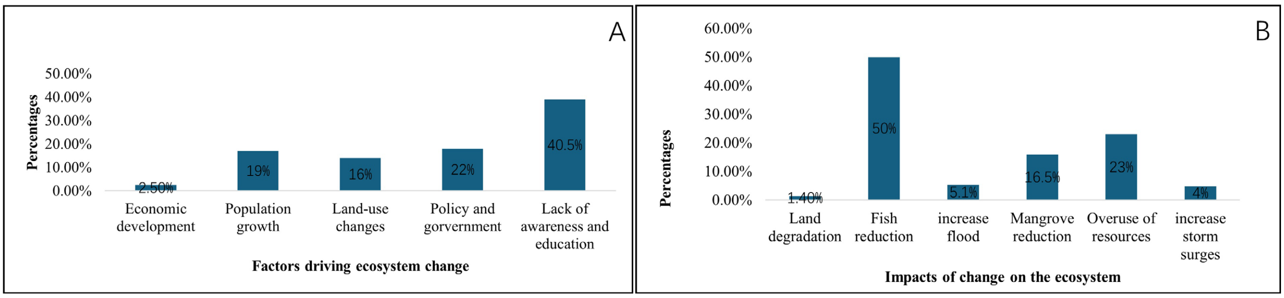


Figure 8. (A) and (B): Perceived drivers of change to mangrove and their impacts on the ecosystem.

3.9. Land Use Land Cover Change (LULCC) Analysis

By comparing the user accuracy with the producer accuracy for all class types, the overall accuracy was 99.6, 97.9, and 99.4 in 1995, 2010 and 2025 respectively while the Kappa coefficient was 1.0, 0.9 and 1.0 in 1995, 2010 and 2025 respectively (Table 5).

Table 5. Overall accuracy and Kappa coefficient of land cover classification of 1995, 2010 and 2025.

Class types	1995		2010		2025	
	Prod. Acc (%)	User Acc (%)	Prod. Acc (%)	User Acc (%)	Prod. Acc (%)	User Acc (%)
Cropland	99.5	98.4	95.0	98.2	98.9	98.1
Degraded Mangrove	97.8	98.6	91.7	98.7	98.4	94.7
Dense Mangrove	99.9	98.9	93.2	99.9	98.9	93.6
Dense Terrestrial Forest	98.8	98.9	93.0	55.5	75.7	96.3
Secondary Terrestrial Forest	100	98.5	99.2	87.1	98.0	98.0
Settlement/Bare soil	98.9	100	86.9	100	89.9	99.9
Waterbodies	99.9	99.9	100	100	100.0	100
Overall Accuracy	**99.6**		**97.9**		**99.4**	
Kappa Coefficient	**1.0**		**0.9**		**1.0**	

From 1995 to 2010, degraded mangroves, secondary terrestrial forest, and settlement/bare soil increased by 2498.3 ha (7.4%), 8168.8 ha (24.3%), and 6.1 ha (0.0%) respectively, while cropland, dense mangrove, dense terrestrial forest, and water bodies decreased by −822.2 ha (−2.4%), −1587.8 ha (−4.7%), −7894.9 ha

(−23.4%), and −282.6 ha (−0.8%) respectively.

From 2010 to 2025, cropland, degraded mangrove, settlement/bare soil increased by 4463.5 ha (13.3%), 1160.8 ha (3.5%), and 3364.9 ha (10.0%) respectively, while dense mangrove, dense terrestrial forest, secondary terrestrial forest, and water bodies decreased by −2672.0 ha (−7.9%), −1375.5 (−4.1%), −4931.4 ha (−14.6%), and −5.2 ha (−0.0%) respectively.

Therefore from 1995 to 2025, cropland, degraded mangrove, secondary terrestrial forest, and settlement/bare soil increased by 3641.3 ha (10.8%), 3659.1 ha (10.9%), 3237.4 ha (9.6%), and 3371.0 ha (10.0%) respectively, while dense mangrove forest, dense terrestrial forest, and water bodies decreased by −4259.8 ha (−12.7%), −9270.4 ha (−27.5%), and −287.76 ha (−0.9%) respectively (Table 6).

Table 6. Magnitude of LULC Change of the Ekondo-Titi mangrove stretch.

LULC Classes	1995-2010 (Ha)	% cover Δ 1995-2010	2010-2025 (Ha)	% cover Δ 2010-2025	1995-2025 (Ha)	% cover Δ 1995-2025
Cropland	822.2	2.4	3641.3	10.8	4463.5	13.3
Degraded Mangrove	2498.3	7.4	1160.8	3.5	3659.1	10.9
Dense Mangrove	−1587.8	−4.7	−2672.0	−7.9	−4259.8	−12.7
Dense Terrestrial Forest	7894.9	4.1	−1375.5	−4.1	−9270.4	−27.5
Secondary Terrestrial Forest	8168.8	24.3	−4931.4	−14.6	3237.4	9.6
Settlement/Bare soil	6.1	0.0	3364.9	10.0	3371.0	10.0
Water bodies	−282.59	−0.84	−5.17	−0.02	−287.76	−0.85

(−) sign indicates a decrease of change; (Δ) sign stands for change.

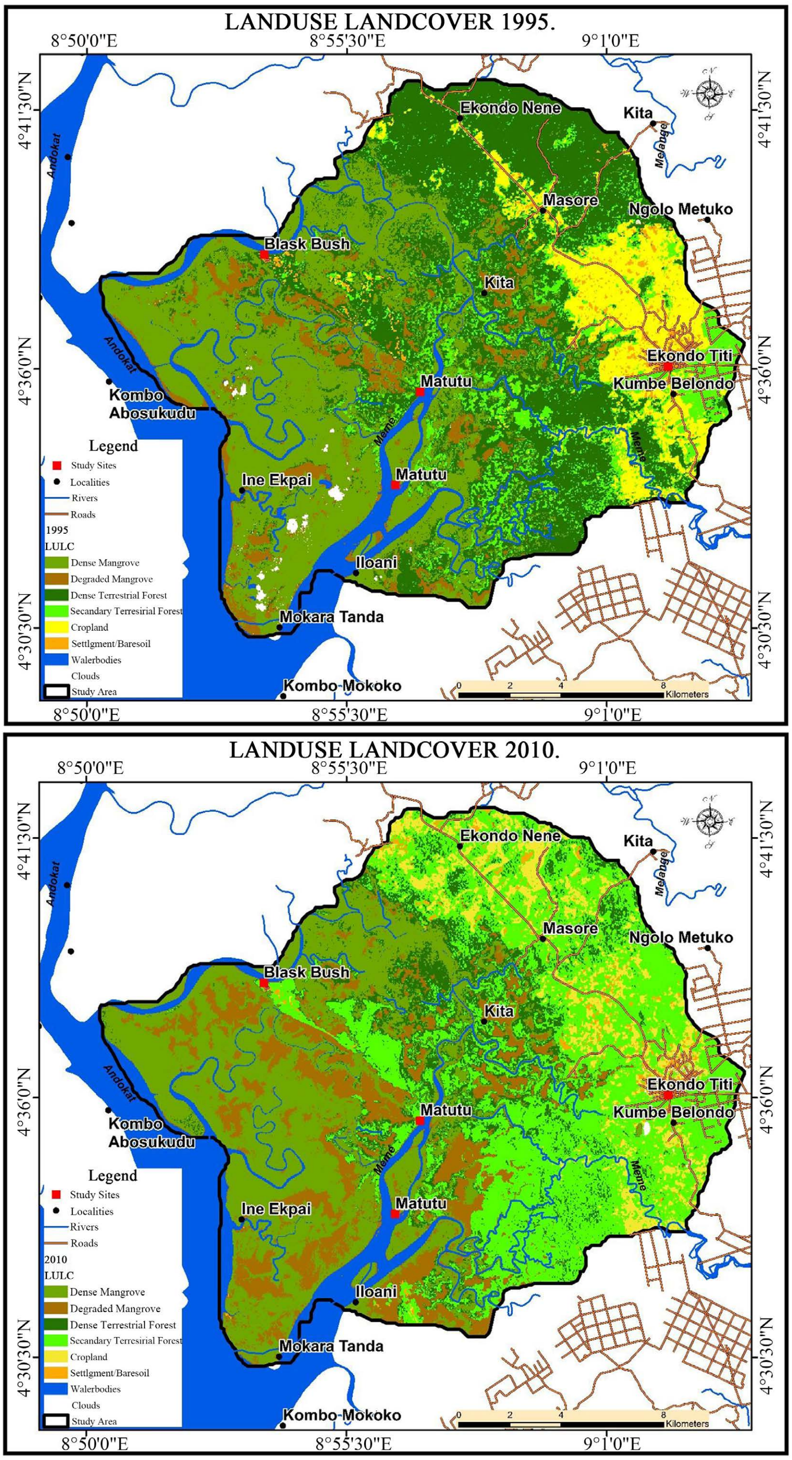
Table 7. Landsat classification area statistics for 1995, 2010 and 2025.

Landcover types	1995		2010		2025	
	Area (ha)	%	Area (ha)	%	Area (ha)	%
Cropland	3004.3	6.5	2182.1	8.9	6645.6	19.7
Degraded Mangrove	2052.3	6.1	4550.6	13.5	5711.4	17.0
Dense Mangrove	11425.1	34.0	9837.3	29.2	7165.3	21.3
Dense Terrestrial Forest	11250.9	33.4	3356.0	1.0	1980.4	5.9
Secondary Terrestrial Forest	3186.0	9.5	11354.8	33.7	6423.4	19.1
Settlement/Bare soil	532.7	1.6	538.8	1.6	3903.8	11.6
Waterbodies	2098.2	6.2	1815.6	5.4	1810.4	5.4

The results showed a great increase in land area in cropland from 3004.3 ha (8.9%) in the year 1995 to 6645.6 ha (19.7%) in 2025, degraded mangroves from 2052.3 ha (6.1%) in the year 1995 to 5711.4 ha (17.0%) in 2025, and settlement/bare soil from 532.7 ha (1.6%) in the year 1995 to 3903.8 ha (11.6%) in 2025 (Table 7). On the other hand, dense vegetation dropped significantly from 11425.1 ha

(33.9%) in 1995 to 7165.3 ha (21.3%) in 2025. These given data therefore states that the increase in cropland, degraded mangrove, settlement/bare soil, and the decrease in dense mangroves are mostly as a result of deforestation, which means some of the mangrove areas were cleared off and converted to agricultural land and settlements.

Maps showing the LULCC from 1995 to 2025 are presented in **Figure 9**.



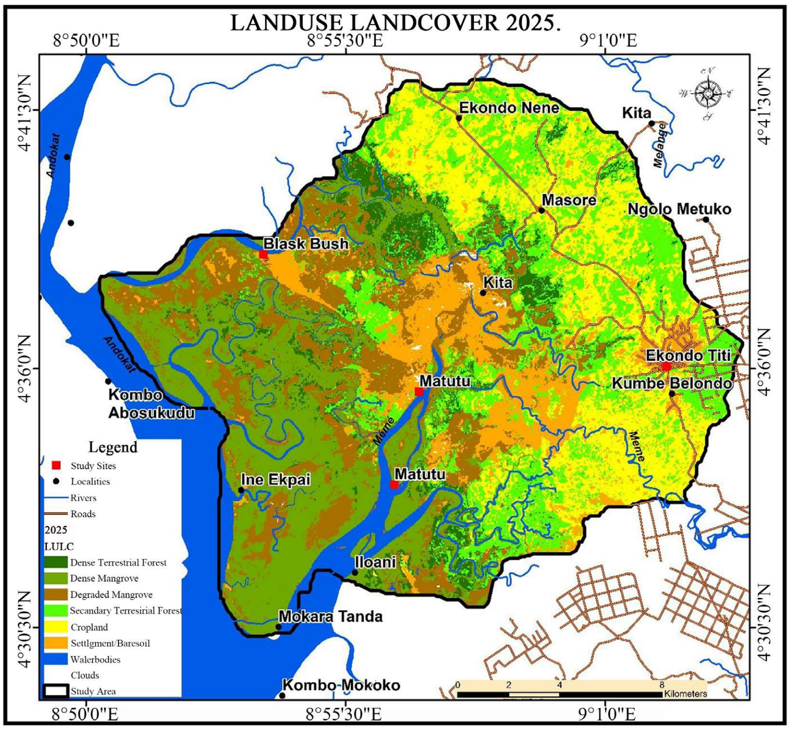


Figure 9. Maps showing the LULCC from 1995 to 2025 in the eastern Ekondo-Titi stretch of Rio del Rey estuary.

4. Discussion

Coastal inhabitants depend greatly on mangroves to meet their livelihood and other economic and cultural needs. Based on the perception of mangrove resources exploited, majority of the respondents (41%) were involved in mangrove exploitation for fuel wood. This is because mangrove wood is highly utilized for cooking and smoking purposes and this is linked to the central activity of coastal communities. Respondents also exploited other mangrove products for purposes such as construction of houses, fishing and building of boats. These results are in line with (Bissonnette et al., 2024) who demonstrated that mangroves are utilized for a variety of purposes within communities, including construction and energy production, as well as fishing equipment manufacturing. Overall, majority of the respondents (38%) exploited mangrove resource on a weekly bases and daily bases (26%). This implies that local communities within the Ekondo-titi mangrove stretch are highly dependent on mangrove resources as their main source of livelihood, corroborating findings by (Bissonnette et al., 2024) who suggested an over-exploitation of mangrove resources by users.

As per the socio-cultural importance of mangrove forest, majority of the respondents (78%) had no traditional knowledge or beliefs attached to the use of mangrove resources. This is probably due to the fact that most of the inhabitants of these coastal communities are mostly made up of Nigerians, who focus mainly on mangrove resource exploitation and trade. However, there were some respondents (21%) who had some cultural values attached to the use of mangrove. Some reported that, the mangrove forest (also called "*Ndongore*" *in the Oroko clan*) serves as a spiritual realm where some rituals are performed, consulting the "gods" for village developmental issues or certain sacred village affairs. Also, from the findings, traditional knowledge might be limited possible due to generational shift or modernization (Fongnzossie, 2022).

Based on the Ecosystem services, provisioning services was the most important service (58.8%), derived from mangroves in the area, with fishery products and other sea foods being the most dominant activity in the area. This is because fishery products serve as the main source of income and protein for the local communities. However, other provisioning services such as fuel wood, building materials and medicine were also gotten from the mangrove ecosystem in the study area. Some respondents acknowledged the use of mangrove leaves to treat stomach issues and the barks to stop bleeding as well as dyes for their fishing nets. These results show the high level of dependence of these communities on mangrove resources, also confirmed by Goldberg et al., 2020.

Based on the perceived changes observed in the availability of mangrove resources in the area, majority of the respondents (71%) reported there have been tremendous changes in mangrove resources with reduction in mangrove forest being the highest (61%) observed change, followed by increased invasive species (18.7%), colonising and threatening mangrove ecological health. Some of the changes noticed in the mangrove ecosystem were a reduction in mangrove forest cover (61%) due to overharvesting of resources, increase in invasive species such as Nypa palm (*Nypa fruticans*) and reduction in fish population. A majority acknowledged that environmental changes such as climate change could possibly exacerbate these observed changes as purported by (Goldberg et al., 2020).

As concerns the drivers of change to mangrove ecosystem, overharvesting was the most frequently perceived threat (44%), indicating unsustainable resource extraction practices. Invasive species at 23% and pollution at 20% are also of significant concerns. While coastal development (10%) was less perceived as a threat, possibly due to limited infrastructure. Also, lack of awareness and education as cited by 39% of respondents, highlights a critical gap in understanding sustainable practices, likely exacerbated by low formal education levels in the community (only 6.5% had higher education). Without proper knowledge, communities may unintentionally engage in harmful practices like overharvesting or deforestation. In addition, policy and government-related issues were also cited as a driver of change (18%), indicating perceived weakness and inadequate enforcement of conservation laws in this area. Population growth was also reported as a driver of change (17%), reflecting increase pressure on mangrove resources due to higher demand for food, fuel and land. Meanwhile, economic development was a minor concern (2.5%), likely because large scale economic activities are limited in the area (Enoh et al., 2024).

Based on the perceived observed impacts of the drivers of change on mangrove resources, a reduction in fish stock was reported by 50% of the respondents, thus emphasizing the ecological consequences of overharvesting and habitat destruction. The community's heavy reliance on fishing makes this impact particularly devastating for livelihoods. Also, overuse of resources was the second most reported impact (23%) and this is directly tied to high dependence on mangrove for income. Other minor impacts included land degradation (1.4%). These observed impacts noticed in the area indicates that mangrove resources were being overused and this posed a lot of threats not only to the mangrove forest cover but also to the ecosystem services as well (Enoh et al., 2024).

Results on LULCC revealed a significant change within the study area from 1995 to 2025. Over the 30-year period, the most striking change was seen in the reduction of dense mangrove forest cover, which decreased by 12.7% accounting for 4259.8 ha. This loss can be attributed to the high rate of deforestation likely for agriculture, fuel wood, timber and construction of houses with evidence seen by an increase in cropland of 10.8% accounting for 3641.3 ha and increase in degraded mangroves of 10.9% accounting for 3659.1 ha. The significant increase in degraded mangrove can also be attributed to ecological degradation possibly due to pollution and unsustainable resource extraction. The results also showed a dramatic decline in dense terrestrial forest cover of 27.5% accounting for 9270.4 ha which can still be attributed to expansion of farm lands due to the fact that most of this communities were very far from cities where they could access other food sources, coupled with the very poor nature of the roads linking these communities to the city, thus making them to be heavily dependent on their own local produce.

Furthermore, the expansion of cropland and settlement/bare soil can reflect socio-economic drivers such as the agricultural demand caused by population growth. Cropland nearly doubled, rising from 8.9% (3004.3 ha) in 1995 to 19.73% (6645.6 ha) in 2025, indicating intensive farming activities as it is the most reliable and lucrative activity nowadays. Settlement/bare soil areas also expanded by 10.0% (3371.0 ha) which correlates with some infrastructural development in the area as more foreigners are immigrated to the area for economic gains. These changes also suggest a transition from the natural land cover to human-dominated landscapes, with potential implications such as biodiversity loss, soil erosion, and reduced carbon sequestration in alignment with (Ajonina et al., 2013).

The results also showed secondary terrestrial forest changing with an initial increase of 24.3% (8168.8 ha), from 1995 to 2010, likely due to regrowth in abandoned farm land areas. However, this gain was later offset by a 14.6% accounting for 4931.4 ha decline from 2010 to 2025 possibly due to renewed land clearance for agricultural purposes. On the other hand, water bodies and cloud cover showed minimal changes indicating that these features were less affected as compared to vegetation, cropland and settlement. Based on the results, the conversion of natural dense mangrove forest cover and dense terrestrial forest cover aligns with global patterns of land-use change in tropical and coastal region where economic development often outweighs environmental conservation (Ajonina et al., 2013). These trends or changes highlight the ecological pressures existing in the area and the consequences of human encroachment on natural ecosystems which, could have a significant impact on the ecosystem services of the area and local livelihood of the people in the long run.

5. Conclusion

Mangroves remain critical ecosystems as they serve as a major source of livelihood for people residing along the coastline. Within the Ekondo-Titi mangrove stretch, mangrove resources serve as the main source of livelihood of inhabitants of the coastal communities. Communities within the Ekondo-Titi mangrove stretch depend highly on mangrove provisioning ecosystem services for their livelihood, with fish smoking and periwinkle gathering, being their main source of income. However, the mangroves in this area were under threat from overexploitation for uses, such as fuel wood, building of houses and canoes, and *Nypa* palm invasion, thus resulting in a continuous decline in mangrove forest cover from 1995-2025. This has had a great impact not only on the livelihoods of the local communities but on the biodiversity as well. With the current rapid rate in degradation of coastal ecosystems, particularly mangrove forests, continual monitoring and evaluation of the socio-ecological characteristics of the mangrove forests is necessary and should be incorporated in the current management strategies, to ensure their sustainability. As such, existing laws should be re-enforced to curb illegal logging and unsustainable fishing practices, ensuring the sustainability of mangrove ecosystem services. Moreover, other sustainable and eco-friendly alternative sources of income such as but not limited to eco-tourism, mangrove bee keeping, poultry farming etc. could be introduced to divert the attention of these communities from mangrove resources, thereby ensuring their sustainability.

Conflicts of Interest

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

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