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Ecological implication of the spatio-temporal changes in the mangroves of Imo River estuary in Southern Nigeria

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ABSTRACT

The study investigated mangrove forest cover change over a 30 year period in the Imo River estuary. Satellite remotely-sensed data of Akwa Ibom State (Landsat TM image 1986, 2003 and 2016) were acquired from the United States Geological Survey (USGS). Additional information was equally obtained from ground-truthing and Focus Group Discussion. The images obtained were processed using Erdas Imagine 9.2 and enhanced for proper visual interpretation using Principal Component Analysis Algorithm. Land cover and use classes were categorized based on their spectral signatures on the images using unsupervised classification algorithm in Erdas Imagine. During the first 17-year study period (1986-2003), analysis of the satellite imageries showed four major land use classes; three (3) of which spatially decreased significantly - mangrove forest 33.46% (3026.92ha), bush fallow 2.68% (242.01ha) and farmland 15.75% (1,424.41ha) while built-up areas increased by 25.8% (2,334.02ha).There was an increase in the size of mangrove forest by 14.78% (67.6ha) between 2003 and 2016 due to effective legislation by the traditional authorities in some communities. The 30 year period (1986-2016) under assessment showed a decline of 19.07% of the mangrove forest. Arising from the above observation, provision of alternative livelihood options is proposed to limit population influx into mangrove communities with strict/implementable legislative provisions. Mid and long term resource management measures in forms of enlightenment, accountability by resource managers, involvement in community forest management among others are to be considered in future plan of action to enhance resource efficiency and economic development.

Keywords: Land use, spatiotemporal, livelihood, economic development, community forest management

INTRODUCTION

Mangroves are areas covered with unique vegetation which are located between land and ocean. The vegetation comprises trees, herbs and shrubs which are very productive. Mangroves are ecologically important in that they trap sediments which help to increase vertical land development and provide shield against storm which reduces the impact of coastal erosion (Lee *et al*., 2014; Doughty *et al*., 2017).They also intercept land-derived nutrients and sediments making them bio-geochemically important (Kamel *et al*., 2017). Furthermore, mangroves are noticeably salient in the provision of nurseries for shrimps, habitat for crabs, oysters, endangered species such as crocodiles and monkeys and sequestering of carbon (Kelleway *et al*., 2016; Yando *et al*., 2016; Benzeev *et al*., 2017). Equally, rural livelihoods are sustained by the provision of timber, fuel wood, food, tannins and dye obtained from estuary resources (Palacios & Cantera, 2017).

Notwithstanding the outlined importance of mangroves, their decline continues to occur globally. This forest system has therefore become one of the most threatened habitats (Valiela *et al*. 2001). Estimated annual rate of loss of over 2 percent has been reported for global mangroves (Hamilton and Casey, 2016; Thomas *et al*., 2017). Observed trend shows that the loss of mangroves exceeds that of the tropical rainforest (Polidoro, 2010). There is the prediction that by 2025 mangrove loss in the developing countries will reach 25 percent.

Nigeria was known to have had the third largest mangrove forest in Africa some years back (Spalding *et al*., 2010). However, recent report shows that its coverage area has reduced to about 6908 km^2 (Hamilton and Casey, 2016). Between 1986 and 2003, Nigeria lost 21, 342 ha of mangroves due to various anthropogenic activities (Adedeji *et al*., 2012). The Niger Delta mangrove is regarded as Africa's second most sensitive ecosystem and a global hotspot, yet the most exploited globally (FAO, 1997). Of the above area coverage, the Niger Delta within which Akwa Ibom State falls however has the largest stretch of mangroves (6000 km^2) in Nigeria according to a study by Anderson (1997) but has also been observed to reduce in size over the years. Some studies have shown slow decline in the total area of mangroves of the Niger Delta (James *et al*., 2007; Wang *et al*., 2016). In their different independent studies, a 5% loss was observed by James *et al*. (2007) while Wang *et al*. (2016) observed a 4% rate of loss. The assessment of mangroves in the Niger Delta between 1984 and 2007 by Wang *et al*. (2016) showed no major change in the total area occupied by mangrove but observed a decline in the biomass of mangroves. Nonetheless, another study carried out by Hula and Ituen (2015) to analyze the spatio-temporal change in mangrove forest in Akwa Ibom revealed that mangrove forest covered an area of 114103.8 ha representing 17.2% of the entire area of Akwa Ibom in 1986. However, in 2003, mangrove forest reduced from its initial area coverage to 107669.7ha (15.3%). This change observed from 1986 to 2003 (i.e. 17 year period) resulted in the loss of 6434.1 ha (1.9 %) of mangrove forest to other land use/cover in Akwa Ibom State.

Reports on the cause of mangrove losses in Nigeria present a multiplicity of factors ranging from subsistence human activities to large scale commercial production activities (Ekpenyong, 2015). Increasing population appears to be responsible for this especially in the coastal areas resulting in the increasing pressure on mangroves ecosystem (Feka and Morrison, 2017). This has been noted as a major reason for the demand for timber, fuel wood and even space for human settlement across coastal regions.

Notwithstanding the above evidences, several mapping techniques have been employed to provide updated information on the extent and status of the mangroves. Such a mapping (survey) will potentially serve a useful, reliable tool for policy and decision making regarding conservation and management of the mangrove ecosystem (FAO, 2007). Hence, assessment of mangrove forest globally and locally in recent times has been made possible by using both remote sensing data and existing field maps. Remote sensing ensures the availability of photographs and satellite imageries from which information on land cover could be extracted for use while GIS provides new sets of analytical tools that is capable of integrating and handling simultaneously multiple sets of data from different sources (Ituen *et al*., 2008).

As mangrove forest area continues to decrease in size, important ecosystem goods and services provisioning have become a great concern to livelihood experts, resource managers and planners. Consequently, further mangrove degradation could be particularly severe for the wellbeing of coastal communities in developing countries especially where people rely heavily on mangrove goods and services for their daily subsistence and livelihood. The trend of the changes in the ecosystem structure will provide evidence-based tool to calibrate and justify (if any) community conservation awareness programmes.

STUDY AREA

The study area is the Imo River estuary located in the southern part of Akwa Ibom State (Fig. 1) and is situated between latitudes 4°32' and 5°53'N and longitudes 7°30' and 8°25' E with a population figure for 2018 put at 271,149. The mean annual temperature of the study area is 27°C according to some reports credited to Akwa Ibom State Statistical Year Book (ASSYB), (2014). The area is characterized by two seasons namely the wet and dry seasons. The wet season prevails between mid-March to mid-November and the dry season starts from mid-November and ends mid-March of each year. The annual total rainfall is 3,000mm along the coast. The relative humidity ranges between 75% and 95% and is relatively common across the State according to the technical report of the Akwa Ibom State Government (2014). High and low tides alternate twice daily causing an inflow of sea water to the estuaries.

The climatic condition in the study area favours the growth and spatial distribution of mangrove vegetation along the coast as observed in most tropical coastlines of the world. The prominent plant species which occur in the area include: *Rhizophora racemosa, R. mangle, R. harrisonii*, *Avicennia africana* and *A. nitida*, *Conocarpus erectus* and *Nypa fruticans* (Ukpong, 1991).

MATERIALS AND METHODS

For mangrove cover change detection, Landsat Thematic Maps (TM) captured in Dec 1986, 2003 and 2016 were acquired from United State Geological Survey (USGS) website. Each of the maps had a spatial resolution of $28.5m^2$ and 1986 as the base year. The data availability was guided by the months and years without cloud cover within the period (1986, 2003 and 2016). An existing land use cover map of the study area was also acquired from Cross River Basin Development Authority (CRBDA) and utilized as an auxiliary data for training sets and accuracy assessment of the 1986 classified images.

The image interpretation processes and change detection were carried out using Erdas Imagine 9.2 software while mapping was completed within ArcGIS 9.2 software environment. Supervised classification techniques were applied in the image interpretation to derive meaningful classes from the image. A supervised signature extraction was adopted in conjunction with a maximum likelihood algorithm. In order to assess the accuracy of the classified image, 1986 classified images was compared to a land cover map of CRBDA published in 1986 while the 2016 classified image was compared with ground truth data that captured the latitudes and longitudes of points randomly taken through the use of Geographical Positioning System (GPS) in May 2018. A combination of these methods proved reliable in generating valid land use/cover categories for the study. Additionally, Focus Group discussion (FGD) was used to further validate the results generated from the change detection study.

RESULTS

The result of the changes in land cover of the study area revealed five (5) land cover classes/uses: Open water, Mangrove forest, Secondary forest/ bush fallow, Farmland and Built-up/bare land (Table 1, Figs 1, 2 and 3). For the 17-year period (1986-2003), land cover analysis showed a decrease in area occupied by mangrove forest, secondary forest/bush fallow and farmland at 33.46% (3026.92ha), 2.68% (242.01ha) and 15.75% (1,424.41ha) respectively while open water and built-up areas increased by 22.31% (2017.78ha) and 25.80% (2,334.02ha) respectively (1986-2003). The greatest rate of decrease in land cover was recorded for mangrove forest (178.05ha per year) while the greatest expansion rate was observed in the built-up area (137.30ha per year).

Between 2003 and 2016, mangrove forest showed a slight increase of 879.15ha (14.78%), translating to only 67.6 ha per year. Also, Secondary forest/bush fallow and built-up areas increased at 37.17% and 0.05% respectively more than other land uses in the study area. However, built-up area showed the lowest increase in area occupied (56.2ha). In contrast, open water and farmland reduced by 57.13ha per year at 12.49 % and 158.31ha per year at 34.61% respectively during the13 years (2003-2016).

During this period of assessment, the trend showed a reduction in mangrove forest area by over 19% and farmland by almost 31% while open water, secondary forest/bush fallow and built-up area experienced an expansion. Built-up area had the highest expansion within the 30 year period by21.22%.

Table 1: Magnitude, Rate and Direction of Land cover change (1986-2016)

S/N	Land Cover Classes	1986 (Ha)	2003 (Ha)	2016 (Ha)	1986-2003 Change (Ha)	2003-2016 change (Ha)	1986-2016 Change (Ha)	1986-2003 change (%)	2003-2016 change (%)	1986-2016 change (%)	1986-2003 change/yr (Ha)	2003-2016 change/yr (Ha)	1986-2016 change/yr (Ha)
1	Open water	2,772.99	4,790.77	4,048.14	+2,017.78	-742.63	+1,275.15	22.31	12.49	11.32	118.69	57.13	42.51
2	Mangrove forest	8,355.63	5328.71	6,207.86	-3,026.92	+879.15	-2,147.77	33.46	14.78	19.07	178.05	67.6	71.59
3	Secondary forest/bush fallow	20,246.79	20,004.78	22,214.86	-242.01	+2,210.08	+1968.07	2.68	37.17	17.47	14.24	170.01	65.60
4	Farmland	11,288.4	9,863.99	7,805.95	-1,424.41	-2,058.04	-3,482.45	15.75	34.61	30.92	83.79	158.31	116.08
5	Built-up /bare land	5,133.61	7,467.63	7,523.83	+2,334.02	+56.2	+2,390.22	25.80	0.95	21.22	137.30	4.32	79.67
Total		**47,797.42**	**47,455.88**	**47,800.64**	**9,045.14**	**5,946.1**	**11,263.66**	**100.00**	**100.00**	**100.00**			

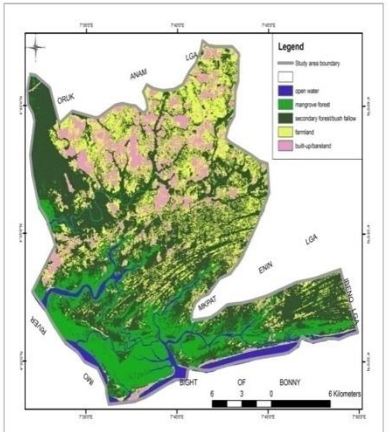

Fig 1: Land cover status of Imo River estuary for 1986

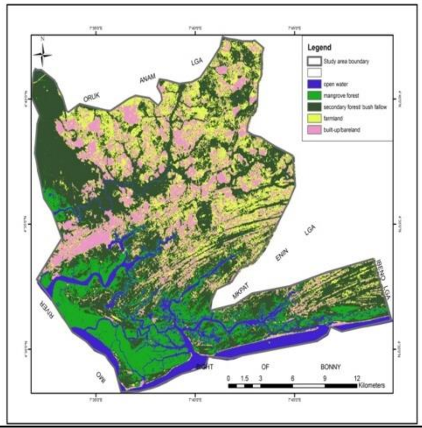

Fig 2: Land cover status of Imo River estuary for 2003

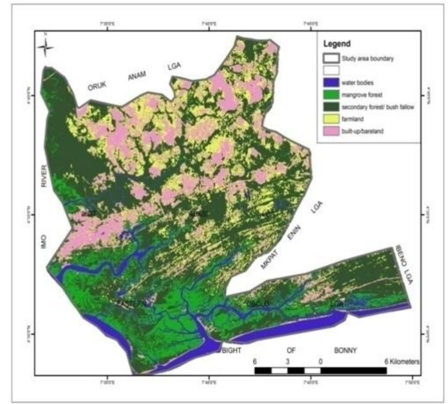

Fig. 3. Land cover status for Imo River estuary for 2016

Plate 1: Degraded mangrove area with few *Nypa fruticans* seedlings present

Plate 2: Overexploited area of the estuary showing decaying stumps of Rhizophora spp.

As shown in the Table 2, FGD results showed decreases in the population of sclater's monkey (70.4%) and dwarf crocodiles (55.5%) due to hunting indicative of the effects of human influences on biodiversity. Crustaceans such as oyster that live on the props of *Rhizophora* species were absent as signified by 48.1% of the discussants especially in areas such as those that were over-exploited compared to areas where tall *Rhizophora* trees were found in which the latter was observably in decreasing trend were up to about 81.5%. Again, crabs were conspicuously absent from such areas. However, small- sized periwinkles were found in the muddy substrates as in Kampa.

Table 2: Status of some Mangrove Wildlife Species following FGD with some Respondents in the Study Area (N=27)

Species	Status reposed by Respondents	Frequency	Percentage
Sclater's Monkey (*Cercopithecus sclateri*)	Increased	-	-
	Decreased	19	70.4
	Absent	5	18.5
	Do not know	3	11.1
Dwarf Crocodile (*Osteolaemus tetraspis*)	Increased	-	-
	Decreased	15	55.5
	Absent	7	25.9
	Do not know	5	18.5
Crabs	Increased	-	-
	Decreased	5	18.5
	Absent	14	51.9
	Do not know	8	29.6
Oysters which are found on props of *Rhizophora*	Increased	-	
	Decreased	4	14.8
	Absent	13	48.1
	Do not know	10	37.0
Oysters which are found on tall *Rhizophora*	Increased	-	-
	Decreased	22	81.5
	Absent	2	7.4
	Do not know	3	11.1
Periwinkles now occurring in small sizes	Yes	2	7.4
	No	20	74.1
	Do not know	5	18.5

DISCUSSION

For the 17-year period (1986-2003), changes were observed to occur in all the land cover classes represented in the study area. The observation of the study presents evidence of human-induced land cover and land-use change which has led to a decline of forested areas across the study area. Hence, the observed reduction in the area for secondary forest/bush fallow and farmland could have arisen from their conversion to residential and industrial areas. This is reflected in the expansion of the built-up area (1986-2003). This period witnessed the construction of

Aluminium Smelting Company of Nigeria in Ikot Abasi LGA established in the 90's. Built-up areas also tended to increase to cater for the housing needs of the growing population. Moreover, the continuous conversion of forested areas to built-up area will continue to exacerbate pressure on the mangrove and its resources.

The decrease in the area of farmland may have been due to fallowing on some farmland for a certain period of years to recuperate and improve the fertility of the soil for future high yield of crops especially as shifting cultivation is still a common practice in the study area. This increased the area of secondary forest/ bush fallow. Again, some area of farmland may have been converted to residential/ commercial accommodation thereby increasing the extent of land area utilized for built-up (1986-2016).

Open water increased by 2,017.78ha between 1986 and 2003 at a rate of 22.31% translating to 11.32 ha per year. A reduction in open water (742.63) occurred between 2003 and 2016 at a rate of 12.49% which translated to 118 ha per year. The 30-year period under assessment witnessed an increase in the area covered with open water.

The substantial loss of mangrove between 1986 and 2003 is a pointer to the extent of long-term anthropogenic activities and the impact it had created on the ecosystem. Of all the land cover classes, mangrove forest experienced the most considerable change where 3026.92ha (representing over 33.46% of the total change) was lost within this period. This loss agrees with the observation of Vo *et al*. (2013) that the last few decades have been characterized by overexploitation and conversion of large areas of mangroves to other land uses. Wells *et al*. (2006) had observed in his work within similar period under review, a higher percentage loss (80%) for some countries. In the Niger Delta, a similar trend had earlier been reported for other locations in the region (James *et al*., 2007; Wang *et al*., 2016). Equally, the findings of this study tend to be in agreement with that of Ntuk *et al*. (2018) who observed a similar trend within the same period in Uruan Local Government Area of Akwa Ibom State as a result of socioeconomic activities. This loss seems not surprising especially because the social, cultural and economic lives of the people are centred around mangrove resources (Gideon and Onyema, 2020). The mangroves provide a wide range of products such as wood for housing and other construction works, fuelwood (for which the people depend on as their major source of energy), medicine, food such as crabs, oyster, fish and periwinkle. More so, the use of the mangrove resources prior to this period (before 1986) by communities was relatively minimal due to the availability of primitive implements such as machete used only to cut small- sized vegetation which were few at the time compared to large-sized trees.

Most importantly, the loss of mangroves was greatest within this period due to the activities of oil and gas exploration companies which started prior to this period under assessment, specifically in 1976, in the area with the use of advanced technology such as bulldozer and chainsaw. The availability of these equipments allowed for large expanse of the mangrove forest to be cleared at a time for oil exploration activities, construction of oil production facilities and subsequently for dredging. The period under assessment is closer to the period of establishment of facilities of different multinational oil companies in the area. For instance, the operation of Shell B. P in 1976 in Eastern Obolo changed the mangrove landscape with the clearing of pristine mangrove forest for oil exploration activities. Iko community alone has about thirteen (13) oil wells (even though corked) within mangrove forest lands. The initial clearing of the mangroves by oil companies paved way for community members to access areas that were inaccessible before this period. Utilization of mangrove resources and change in land use has been observed to be one primary reason for the decline in mangrove size across many regions (Thomas *et al*., 2017).

In contrast to the observation made between 1986 and 2003, mangrove forest increased slightly by 14.78% (879.15ha) between 2003 and 2016. The increase of 67.6ha per year is not comparable to the loss of 178.05ha per year observed for 1986-2003. This slight increase in the area occupied by mangroves may have been due to the effective legislation by the traditional authority especially the Paramount ruler of Eastern Obolo L.G.A. (whose reign spanned between 2003 and 2016) with subsequent sanctions on erring village heads who granted permission to prospective commercial harvesters of matured mangrove stands of *Rhizophora* species and *Avicennia africana* (Okonko, per.comm, 2018). Consequently, this study observed from the discussion sessions with the respondents that in the past, three erring village heads were dispossessed of their certificate of recognition to discourage such actions. Unfortunately, the effort of the former monarchy has not been sustained in the area nor in other part of the study area, except in Iko which through the effort and enforcement of laws by the village head and the punishment meted to erring offenders, commercial exploitation of wood using chain saw except for fuel wood harvesting for domestic use has not been carried out since 2016 till date. Jiménez (2004) and Krüger (2005) had observed that implementing of laws that encourage ecosystem conservation is effective in discouraging mangrove loss. Observably, mangroves found closer to residential areas were not only stunted but were small in diameter. Mangroves are slow-growing species and requires low disturbance to attain maximum size for sustainable harvesting. Notwithstanding the loss and degradation of the mangroves, Eastern Obolo section of the estuary still holds the most substantial extent of mangrove forest comprising tall standing mangrove species such as *Rhizophora recemosa*, *Avicennia africana* and *Laguncularia racemosa* in Akwa Ibom State till date (Fig. 3).

In summary, the thirty- year (30) period under assessment (1986 – 2016), evidently shows that 19.07% of mangrove area has been lost to mostly human activities. This is equivalent to 71.59ha per year. This declining trend is consistent with the observations of James *et al*. (2007), Giri *et al*. (2011), Abd. Rasiyd *et al*. (2016) and Thomas *et al*. (2017). This continuous pressure on mangrove forest for wood is due to the durability of the wood and the decline in lowland rainforest wood resources either as a result of wood harvesting or conversion to agricultural land and built-up areas. Most importantly is the indirect influence of human population in the coastal areas. Increase in the number of people in the coastal communities implies increase in utilization of resources for their wellbeing. Considering the fact that the mangroves provide ecosystem services (most of which cannot be valued monetarily) to humans, their loss invariably will impact on the environment and well-being of humans. The quantification of the extent of mangrove forest and the assessment of those driving forces inducing the decline give insight into understanding the impact such activities could eventually have on the provision of ecosystem services by the mangrove forest in Akwa Ibom State. Therefore, the decline in mangrove forest extent is of enormous consequences on the biodiversity of the ecosystem.

The mangrove forest hosts several wildlife species e.g. dwarf crocodiles, sclater's monkeys and birds (heron, kingfisher). Recent report shows that there are evidences of some mangrove primates (e.g. monkeys) being severely threatened (Nowak *et al*., 2019). The decline in the extent of mangrove forest area of the estuary tends to have its root in anthropogenic activities. Varied implications arise from the observed destruction and decline in the extent of mangrove forest area. Firstly, the degradation/loss of habitat of animals will encourage their migration to other estuaries which are already threatened by human influences, exposure to hunting and/or eventual death of these animals in the face of unabated human activities.

Periwinkles are adapted to muddy conditions but some species of crabs do not withstand prolonged inundation but require harder substrate with less frequent inundation. Specifically, loss of mangroves ecosystem will imply loss of nurseries and breeding grounds for fish and other species. Furthermore, destroying the mangroves also threatens the aquatic food chain which many animal species depend on the ecosystem for such as fish, some reptiles, birds, insects and amphibians among others.

Secondly, the forest structure is affected by indiscriminate harvesting of large-diameter mangrove trees for house construction in some parts of the estuary. While some areas totally lack vegetation cover except for the regeneration of few *N. fruticans* seedlings (Plate 1) others are dominated by younger, shorter and small-sized diameter trees, which in some communities are harvested and utilized as fuelwood. Only areas with difficult and inaccessible terrain and where community laws are effective are spared of mangrove mature trees. In some other area (especially those closer to residential areas) where fuelwood harvesting and yearly *chikoko* harvesting was carried out as observed in Okorombokho, out of the twenty seven (27) discussants in Okorombokho community, FGD results showed that nineteen (19) respondents (representing 70.4%) reposed that mangrove species within their area were stunted. Again, twenty two (22) of these respondents (representing 81%) had observed the invasion of *Nypa fruticans* as well as decaying stumps around the mangrove. Invasion of *N. fruticans* is encouraged by the destruction of the mangroves. Their buoyancy encourages and increases their ability to float and travel long distances and get established where space has been created. Regeneration and restoration of degraded areas require propagules which are usually gotten from matured mangrove trees and carried by tidal waves to other parts of the mangrove ecosystem. Undisturbed areas of mature mangrove plants are therefore crucial to this ecosystem productivity and restoration.

Furthermore, the absence of protection of shorelines against storms by the mangroves in communities is a consequence of their destruction that the communities are facing and may continue to face in the future if this goes unchecked. As such, cases of storms as gathered from FGD are not surprising. For instance, in Emeroeke and Okorombokho, several houses have been lost to continuous storm actions and flooding resulting from mangrove degradation. The impacts of mangrove disturbances on the mangrove forest as revealed in the FGD shows that strong and destructive storms never experienced in the upland communities are becoming prevalent and destroying houses, for example, in Agasa. Erosion/ flooding were also observed to have washed off the

foundation of a house in Emeroeke. FGD revealed that four houses had already been washed off as the rivers are extending their bounds into the communities. The massive roots of the mangrove trees are very effective in dispersing wave energy away from the shoreline (Massel *et al*., 1999). The mangroves roots silt the sediments hence create a fertile environment suitable for the aquatic marine. They also reduce the accumulation of sediments in the surrounding marine environments in addition to the protection of the coastal shoreline.

CONCLUSION

The 30 years of mangrove assessment showed a decline of mangrove areas with associated ecological implications. However, effective legislation by traditional authorities can boost increase in mangrove areas. In view of the observed decline, there is need for regular and effective monitoring of the mangrove forest of the Imo River estuary to ascertain the extent of mangrove and the status of its biodiversity periodically. Additionally, provision of alternative livelihood options which discourage population influx to mangrove rural communities could divert attention and dependence away from the mangrove forest. The effectiveness of relevant community laws made between 2003 and 2016 needs to be strengthened by the government to reduce depletion of mangrove cover and promote sustainable conservation and climate change adaptation.

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