American Journal of Geophysics, Geochemistry and Geosystems
Vol. 6, No. 3, 2020, pp. 74-81
http://www.aiscience.org/journal/aj3g
ISSN: 2381-7143 (Print); ISSN: 2381-7151 (Online)

Vulnerability of Coastal Vegetation to Human Activities in Tanzania

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Abstract

The current study assessed the vulnerability of mangrove forests to human activities in the coastal areas of Ununio, Mbweni and Pemba Mnazi in the United Republic of Tanzania. Land use changes in mangrove area were identified during transact walks on the fields before they were validated in Google Earth (GE) images. Major human activities affecting the study area were described associated with their influence on mangrove forests. GE images of 2003, 2010 and 2018 were analyzed in ArcGIS for mangrove area change detection and the extent of change was determined. The major human activities at Ununio and Mbweni were salt works, settlements, and trampling whereas at Pemba Mnazi, they were mangroves clearing for charcoal, timber, poles and building materials production. The analysis of the 2003 images indicated that Ununio, Mbweni and Pemba Mnazi had 104 ha, 75ha and 178 ha of mangroves, respectively. However, due to human encroachment, about 72%, 65.3% and 63.4% ha of the mangroves at Ununio, Mbweni and Pemba Mnazi, respectively, were cleared and converted to other land uses. The study concludes that mangroves are highly vulnerable to human activities in the study area, and recommends that effective conservation and management of mangrove habitats should be considered in association with local community participation.

Keywords

Vulnerability, Coastal Vegetation, Mangrove Forests, Tanzania

Received: May 14, 2020 / Accepted: June 3, 2020 / Published online: July 7, 2020

1. Introduction

Mangroves are a unique type of forest growing at the interface of land and sea throughout the tropics and subtropics. Although mangroves constitute only 0.5 percent of the global forest area, they play crucial ecological and socioeconomic roles in coastal areas. Mangrove forests are not only the natural guardians of tropical coastlines against erosion by waves, currents, and winds, they also provide fertile nursery grounds for fish and invertebrate species that later move into marine ecosystems [1]. In addition, the mangrove forests regulate water chemistry in coastal zones. More recently, it has become evident that mangroves play an important role in climate change mitigation, holding up to 50 times more carbon sequestration potential than other tropical forests, and storing up to five times the amount of carbon per unit area compared to upland tropical forests [1; 2].

Although, mangroves occupy only 0.5 percent of the global coastal area, they store 10-15 percent of all coastal sediment carbon globally [3]. Despite their ecologic, social and economic functions, these ecosystems are continuously under anthropogenic threat and climatic vulnerability. Millions of people living in and around mangrove ecosystems in the tropics rely heavily on mangroves for their food and income, as well as protection of their settlements and agricultural land. Coastal area is one of the rapidly developing areas in

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the world [4; 5]. Many activities have been running in this area such as fisheries, aquaculture, transportation, tourism and others. Those activities have impacts on the coastal ecosystems (salt marshes, mangroves, wetlands, estuaries, and bays), either directly or indirectly, causing destruction and disruption to the ecosystems. One of the coastal ecosystems that have been changing in different parts of the world are mangrove forests [6].

As a consequence, the species diversity index of mangroves is gradually decreasing in many areas [7]. Loss of mangroves throughout the world may reach up to 60% by 2030 [8; 9; 10; 11]. Mangrove forests are continuous declining at a speedy rate (1 to 2% per year), however, at a threatening level in the developing countries where they are found in abundances [12; 13]. During the last decade, mangrove forest was reduced by ~15 sq. km in Tanzania due to land reclamation [14]. A later study of African mangroves utilizing satellite imagery from 1999 to 2000 indicated that there were only 80,900 ha of mangroves in Tanzania [15]. Mangroves were gazetted as forest reserves in Tanzania from 1928, and therefore a culture of use perpetuated. Mangrove degradation and loss has occurred, but at much lower levels than most other countries in the region. Tanzania led the region in its approach to mangrove protection and sustainable use through the Mangrove Management Project (MMP) which was initiated in 1988 [16].

Figure 1. A map of Dar es Salaam indicating the location of the study sites. Source: NBS Database and Google Earth.

Together with other projects, the MMP has helped to reduce illegal cutting and clearance and has encouraged replanting of large degraded areas [17]. However, widespread over-exploitation of mangroves for timber, fuel and tannin

continues and some forests are considered degraded and at risk. As the urban zone expands, mangroves around Dar es Salaam are prone to clearing [18]. Mangrove forest in Dar es Salaam was estimated to be 21.7 km^2 in 1991 [19] and few changes were reported between 1990 and 2000 [14]. But, the impact of mangroves destruction on livelihood of coastal community as manifested by the frequency of coastal erosion and reduction of coastal fishery in different areas of Dar es salaam City, has reached to a point that could no longer be ignored [20].

In this paper, the authors analyzed and validated the vulnerability of mangroves to human activities in the peri-urban mangroves of Ununio, Mbweni and Pemba Mnazi in Dar es Salaam, Tanzania. This would provide up to date information on mangrove status in re-designing of the existing mangrove management plans for the sustainability of the mangroves in the areas and elsewhere.

2. Materials and Methods

2.1. Study Site Description

This study was conducted in Dar es Salaam, the major economic hub of Tanzania. It is also the most populous city in Tanzania growing at a rate of 5.6% per year and it harbors about 5.82 million people, equivalent to 10% of the country's population [19]. This high population has attracted ever-increasing demand for socio-economic services including infrastructures and property development and has exerted multiple pressures on its coastal and marine resources including mangrove forests.

Mangrove forests in these areas are one of the key components of the Dar es Salaam seascape [21]. They are distributed in four districts of Dar es Salaam which are Ilala, Kinondoni, Temeke and Kigamboni. Mangroves of Ununio and Mbweni lay on the northern outskirts of Dar es Salaam in Kinondoni district and Pemba Mnazi mangroves lay on the eastern outskirts of Dar es Salaam in Kigamboni District (Figure 1). These areas experience high rates of settlements expansion and development of coastal infrastructure and properties than most of the other parts of Dar es Salaam.

2.2. Data Collection and Analysis

2.2.1. Land use Change and Its Influence on Mangroves Forests Distribution

Transect walks and interviews with selected informants were conducted with the aim of capturing information about the causes and effects of mangroves cover change in the study sites. Few questions were prepared for interviews with the informants who were purposefully selected to represent stakeholder groups in mangrove use and conservation. A content analysis was employed to summarize the information obtained from observations and interviews and it helped in interpretation of satellite images.

2.2.2. Mangrove Cover Change

The GE historical imagery tool was used to explore the imageries availability, coverage, and quality to capture a near decadal change in mangrove extent. The mangrove boundaries themes of 2003, 2010 and 2018 were visually inspected and digitized following the maximum boundary of the mangrove extent. In order to quantify the mangrove cover change, the GE digitized mangrove boundaries themes of the three year period were overlaid in ArcGIS 10.2 according to [22]. Thereafter, mangrove losses were validated in the GE imageries.

3. Results

3.1. Land use Change and Its Influence on Mangrove Distribution

Table 1. Summary on types of human land use change and their impacts to mangroves.

Site	Type of land use change	Human activities	Influence to mangroves
Ununio	Mangrove clearance	Construction of residential houses/settlements, estates	Loss and modification of mangroves through clearance and land reclamation
	Salt pans	Salt production works	Loss/modification of mangroves through clearance and obstruction of water flow.
	Paths /Streets	Trampling	Modification of mangrove vegetation structure through death of seedlings/ tree pruning
Mbweni	Mangrove clearance	Construction of residential houses/settlements, hotel, firewood collection	Loss and modification of mangroves through clearance
	Paths/streets	Trampling	Modification of mangrove vegetation structure through death of seedlings/tree pruning
	Waste dumping sites	Domestic waste dumping	Mangrove Pollution
Pemba Mnazi	Mangrove clearance	Charcoal production, fishing	Loss and modification of mangroves through clearance
	Paths/ streets	Trampling	Modification of mangrove vegetation structure through death of seedlings/tree pruning

Source: Field visit

3.2. Mangrove Cover Change

The results in Figure 2 indicated that at Ununio, the analysis of the 2003- 2018 GE satellite images for mangrove cover change indicated a loss of 75 ha. Field observations indicated salt pans and buildings within the mangrove area as well as scattered mangroves with big bare land, caused by human encroachment and natural events. The GE- based validation of loss for some selected covers of the mangrove forest at Ununio is presented in Figure 2. It was noted that salt works coverage recorded 18 ha and up to 4.3 km of the salt works perimeter directly bordered by the mangrove forest.

On the other hand, the length of settlements bordering mangroves was recorded to cover 5 km**.** The extent continues up to the year 2018, where the mangrove area reduced up to 29 ha due to land use change (Table 2).

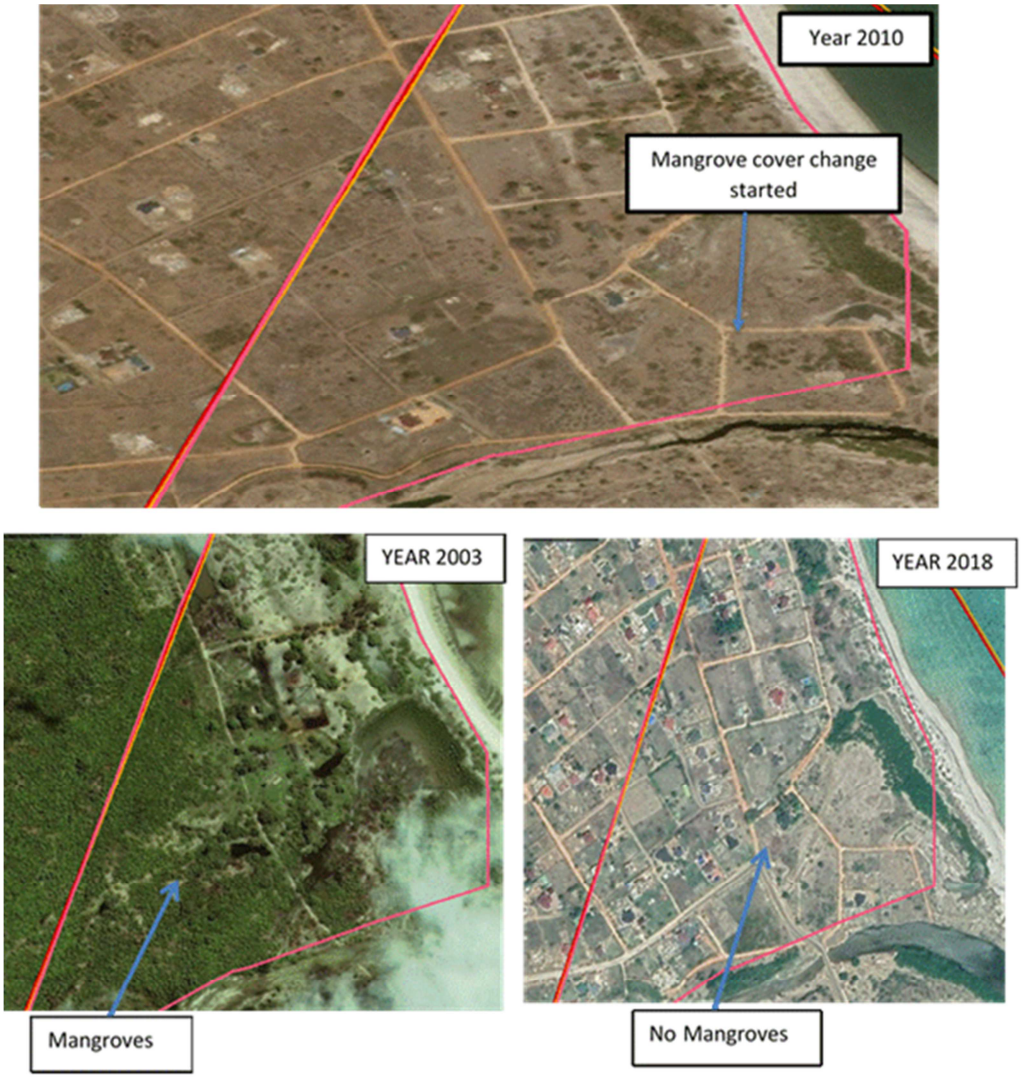

Figure 2. Google Earth images validating loss of mangroves at Ununio due to human settlement development and Salt works.

Table 2. Extent of mangrove cover change in Ununio area.

Land cover/use	Land cover/use (ha)		Change 2003-2018 (ha)	%	Average annual change
	2003	2018			
Mangrove forest	104	29	75	72	4.8

For Mbweni site, results from GIS analysis of the 2003 mangrove coverage revealed that the area occupied by mangrove was 75 ha. This area recorded decreasing trend from 67 ha to 26 ha in 2010 and 2018, respectively (Figure 3). Like Ununio, field observations of the mangrove forests showed mangrove cover change at Mbweni as presented in Figure 3, based on GE validation of loss for some selected covers of the mangrove forest in the area.

Figure 3. Google Earth images validating loss of mangroves at Mbweni to due settlement, dumping site, fish auction area and trampling.

Table 3. Extent of mangrove cover change in Mbweni area.

Land cover/use	Land cover/use (ha)		Change 2003-2018	%	Average annual change
	2003	2018			
Mangrove forests	75	26	49	65.3	4.3

At Pemba Mnazi site, results from GIS analysis of the 2003 mangrove coverage presented 178 ha as mangrove area. However, clear cutting has reduced this area of mangrove cover up to 174 ha and 65 ha in the years of 2010 and 2018, respectively. Images from GE displays mangrove cover change during the period of 2003-2018 as illustrated in Figure 4.

Table 4. Extent of mangrove cover change in Pemba Mnazi area.

Land cover/use	Land cover/use (ha)		Change 2003-2018	%	Average annual change
	2003	2018			
Mangrove forests	178	65	113	63.4%	4.2

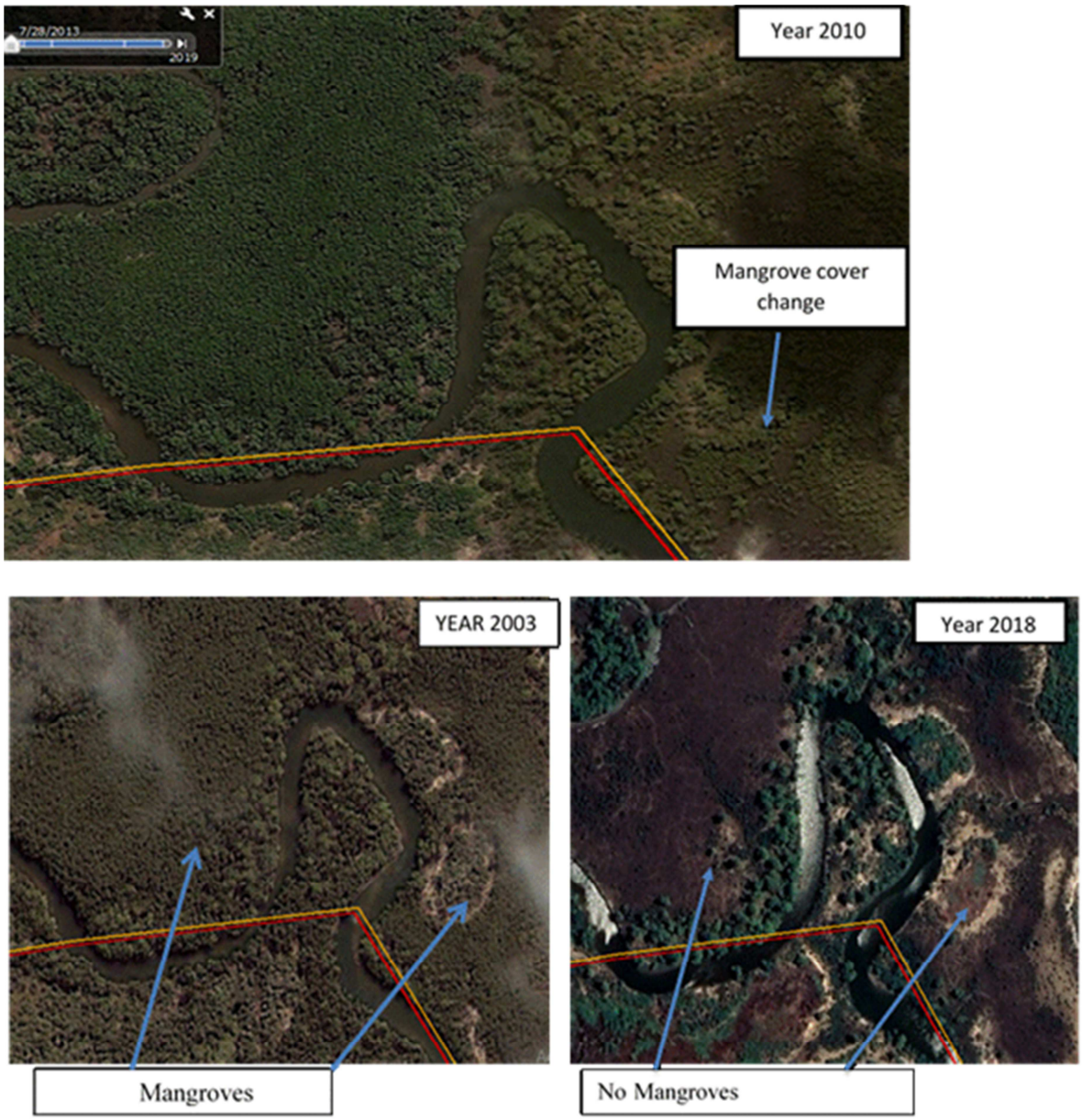

Figure 4. Google Earth images validating loss of mangroves at Pemba Mnazi due to Mangrove clearing.

4. Discussion

Despite the conservation efforts by the Community Based Organizations (CBOs), government and non-government actors, mangroves in these areas are still vulnerable to degradation as a result of human activities. Major human activities are associated with coastal property development for both residential and commercial investments propelled by the fast-expanding tourism industry in these coastal areas of Tanzania.

As recently reported by the study of Makemie *et al*. [23], per-urban mangroves of Dar es Salaam continue to face degradation as a result of salt works, urban expansion, pollution and unsustainable fishing practices. However, as shown by the results in this study in Table 1 and Figures 2, 3 and 4, efforts made by Tanzania Forest Service Agency (TFS) to install signposts for the public awareness on the conservation status of mangroves have not spared the mangrove forests from human encroachment.

This implies that, mangroves have not been practically managed despite their legal protection by the instruments such as Forest Act, 2002, Environmental Management Act, 2004 (subsection 57 (1)) and the Tanzania coastal tourism development guidelines, 2003. As [23] reported, the continued degradation of mangroves through anthropogenic pressures can be viewed as a result of institutional failure, caused by the absence of a central authority to coordinate the conflicting interests concerning licenses for land titles. Private investors have therefore

taken this failure as a window of opportunity to violate regulations in favor of short-term profits, but at the expense of the long-term society's interests in mangrove resources [24].

Mangroves in the study sites have been altered by increased human activities. The observed loss of mangroves particularly in the forest margins, suggests a high vulnerability to human pressures than those in the interior of the forests (Figures 2, 3 and 4). Interview with key informants in the sites revealed mangrove species that have become more vulnerable: In ununio and Mbweni areas, the major mangrove specie altered is *Avicenia Marina* (Mchu), as it is the main mangrove specie occupying the areas.

For Pemba Mnazi site, Mangroves species like *Arvicennia Marina* (Mchu), *Rhizophora mucronata* (Mkoko or mkaka) and *Ceriops tagal* (Mkandaa) have been affected. This is due to their very good quality in producing timber, poles used in making boats for fishing and building materials.

Although the main focus of the present study was on human activities drivers, mangrove losses in the Mbweni were observed to be contributed by coastal erosion. The mangrove trees, particularly those located along the side of the Mpigi River, were lost as a result of continued erosion. The losses of mangroves along the river banks were also reported by Makota *et al*. [21]. Previous investigations [25; 26] on the nature and cause of coastal erosion in this area indicated aggravation of the problems by human activities involving sand mining and removal of protective mangroves. Moreover, human activities involving unplanned settlement construction were reported to obstruct natural waterways leading to water accumulation in certain covers of the mangrove forest.

5. Conclusion

The study assed the vulnerability of mangroves forests to human activities by using transect walks and GE images. The results indicated that about 72%, 65.3% and 63.4% ha of the mangroves at Ununio, Mbweni and Pemba Mnazi, respectively, were cleared and converted into salt works, urban expansion, pollution and unsustainable fishing practices. The study concludes that mangroves are highly vulnerable to human activities in the study area. The findings provide explanations for the current mangrove status as well as the extent of human impacts on these fragile mangrove forests. Therefore, effective control measures are required to regulate human pressures and protect these mangroves. Promotion of incentive based conservation schemes like community-based payment for ecosystem services is one of the plausible options to explore.

Acknowledgements

The authors owe special thanks to Tanzania Forest Service Agency (TFS) staff for their support during data collection of this study.

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