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Effects of salt making on growth and stocking of mangrove forests of south western Indian Ocean coast in Tanzania

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Abstract: Sustainability of mangrove forest is threatened by the ongoing high extent of degradation due to salt extraction. Information is lacking on the impact of degradation on growth and stocking of the mangrove forests in the tropical region including Tanzania. A study was carried out to identify destructive activities due to salt production and their effects on growth and stocking of mangrove species in Lindi municipality along the southern coast of the western Indian Ocean coast in Tanzania. Semi-structured interviews were randomly administered among 123 randomly selected salt pan owners and salt workers to identify the activities involved in salt making. Effects of salt making activities on growth and stocking of mangrove species were assessed using a transect walk. Results revealed that the most involved activities in salt production were construction of ocean water reservoirs (21.14%), salt pans (35.8%) and salt pans pathways construction (15.45%), salt storage area (14.63%) and huts construction (13.1%). Mangrove basal area and stocking were lower in areas with salt making activities with 0.74 m2/ha and 110 m^2/ha respectively compared to areas without salt making activities (4.1m2/ha) and (266 m^2/ha). We can conclude that salt making poses threat on the sustainability of mangrove forestry ecosystem.

Keywords: West Indian Ocean Coast, Mangrove forest, Salt extraction, salt pans Tanzania.

Introduction

Since 2002, all Tanzania mangrove forests have been gazetted and categorized as forest reserves in which no human activities were allowed to take place [1].This was to offer environmental and socio-economic benefits, and ecosystem services such as carbon stocks, coastal protection, conservation of biological diversity habitat, spawning grounds and nutrients for a variety of fish as well as wood and non-wood products [2- 4].. However, this ecosystem decreased with years due to the anthropogenic activities such as salt extraction carried out along the coast of Tanzania. According to FAO, 2010 Global resource assessment report, mangrove forests cover in the world continues to decline from 16.1 to 15.6 million(ha) in 1990 and 2010 respectively [5]. The same was observed also in Tanzania where a mangrove stocking has known a declining trend for a decade between 1990 and 2000 in districts of Rufiji, Kilwa, Kisarawe and Lindi with approximately a total area of 3254 ha covered by salt pans [6], moreover, between 1980 and 2010 Tanzania mangrove forest has lost about 44,000 ha due to the anthropogenic activities like salt production [7].

Salt production using solar salt pans are common in Lindi municipality, local salt industries around the mangrove forests areas are legally owned and managed by individuals and different groups. This activity offers important incomes to local communities living adjacent the coastal areas [8], yet it has negative impacts on growth and stocking of mangrove forest due to clear-felling of mangrove forest for salt pan allocation [7], [9, 10], thus reducing number of mangrove species [11,12].

Most studies that have been done had focused on other effects of human activities on mangrove forest such as conversion to agricultural lands in Rufiji Delta [13], conversion to aquaculture ponds in Bagamoyo especially prawn farming [14, 15]. Other drivers include clearance for urban and industrial development in Dar es salaam [10, 13]. Little has been reported on the effect of salt making on mangrove forests.

Therefore a study was carried out to explore the effects of salt making on mangrove forest based on specific objectives: (1) To identify the main activities involved in salt production in mangrove forest 2) To assess the stocking and growth of mangrove forest areas under and without salt extraction activities.

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Materials and methods

Study area

The study was carried out at Machole and Mtange village, Lindi municipality, its geographical position is (09°58'S, 39°38'E) adjacent to the Indian Ocean shoreline. The weather in Lindi municipality is tropical and humid which temperature; moderated by sea breeze especially on the islands; ranges between 25 and 29°C [16]. The total rainfall per year ranges from 700 mm to 1000 mm.The town is characterized with Mangrove forests forming important vegetation along the coast. The mangrove forests are characterized with animals such crabs and other of different species. Lindi municipal mangrove forest covers about 4500 ha with *Avicennia marina and Rhizophoramucronata* being common mangrove species. Fishing, salt making and farming in small scale represent main economic activities of Lindi municipality. A study was conducted in these sites representing important salt-production areas, especially Machole, Mtange, Tulieni and Ngongo streets.

Socio-economic survey

Influence of salt making processes on degradation of mangroves was assessed using structured questionnaire. The household heads were selected purposely on the basis of their involvement in salt making activities. With the help of village government officials, a total of 123 households were selected to be included in the study.

Mangrove inventory

Two mangrove areas were purposely selected to assess the effect of salt making on mangrove growth and stocking. A site of mangrove forest without salt making was chosen as a positive control. The two mangrove areas were systematically surveyed through transects and plots. A total of 10 m radius circular plots were adopted. In each plot mangrove trees were counted, recorded for estimation of stocking density in terms of tree stems per hectare and tree diameter at breast height (Dbh). This latter was measured using tree calliper for later estimation of other forest standard parameters such as basal area.

The two sites were preferred based on existing management practices of salt making in mangrove forests established and allowed by government. All areas categorized are protected areas under Forest Act No. 4 of 2002. The legislation prohibited any human intervention although salt extraction activities are old as the Germany colonial government. Salt extraction has also been legalised whereby individuals have an opportunity to extract salt.

Data analysis

Socio-economic data were analysed using Statistical Package for Social Sciences (SPSS 16) to generate simple descriptive statistics (means, mean Bar graph drawn in percent) used to rank destructive salt making activities carried in the areas. Mangrove tree parameters, stocking parameters (tree stems per hectare, Dbh, basal area m^2/ha) were analysed into means and standard errors using M-excel and SPP statistical package.

Results

Salt-making related activities

As was expected among 123 interviewees, 35.8% were of the opinion that pans construction are the most destructive activities in salt production on the area, followed by construction of ocean water reservoir say 21.14% of interviewees, then construction of salt pans pathways for 15.45% , constructions of salt storage areas for 14.63% and hut construction for 13.01%**(Fig. 1).** Old mangrove stumps were found along the salt farms, which means that mangroves were present and eliminated for pan construction. In additional to that huts; used to store salts before going to market; were found in mangrove areas. People said that, these huts (small buildings) were constructed by Germany colonialists since 1920s and till now are managed and used for storing salts.

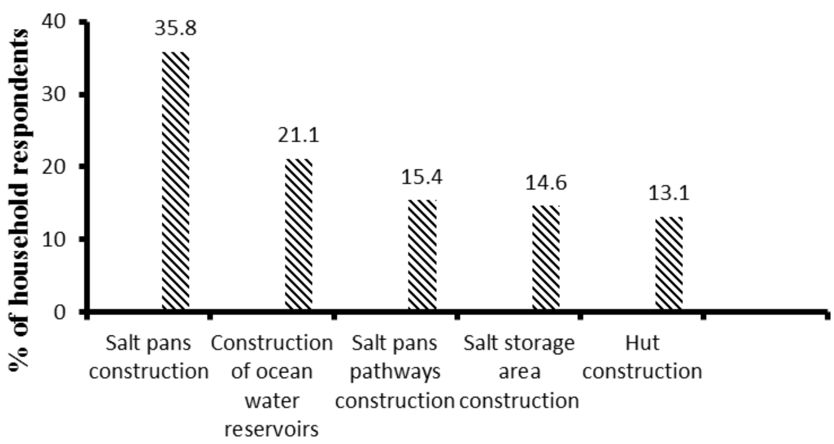

Figure 1: salt making related activities on area.

Effect of Salt making on stocking of mangrove

Generally mangrove tree species were counted along the nearest land sides of the ocean water in both areas of salt farm and non-salt farm, the results revealed that, there was significance difference between numbers of mangrove trees found in the two studied areas **(Table 1).**

Table 1: Number of stem per hectare of mangrove forests in salt and non-salt farm areas

SPH(m2/ha)	Squares	Df	Mean Square	F-Value	P-value
Non-salt farm area	139574.802	1	139574.802	20.981	0.000**
Salt farm area	984565.867	148	6652.472		
Total	1124140.669	149			

** Denotes significant difference at 0.05 level
SPH=Species per hectare, Df=Degree of freedom,

In salt farms areas, lower number of stem per hectare (110 m^2/ha) was noted respect to (266 m^2/ha) non-salt farm areas. Furthermore, the number of stems per diameter class increased in non-salt farm respect to salt farm area. Equally we observed that, the mean of tree in diameter class of less than 10cm dbh was dominating on the salt farm areas while in non-salt farm area above 10cm dbh was dominating **(Fig 2).**

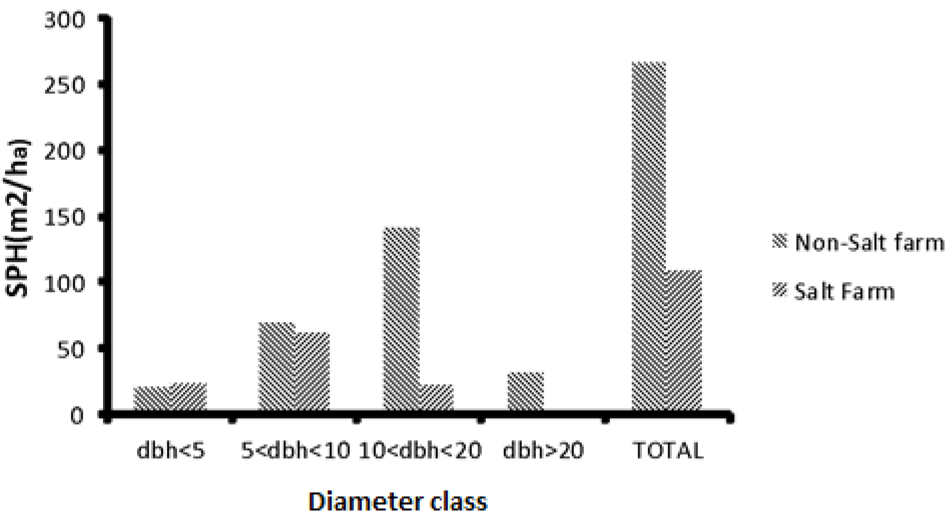

Figure 2. Number of stem per hectare in area with and without salt making activities

Effect of Salt making on mangrove diameter

Overall the basal area distributions of mangrove species such as Avicennia *marina and Rhizophora mucronata* for various dbh classes in these two sites were significantly different (Table 2).

Table 2. Basal area (BA) of mangrove forests in non-salt farm area and salt farm area

BA/ha(m^2/ha)	Squares	Df	Mean Square	F-Value	P-value
Non-salt farm area	73.682	1	73.682	32.613	0.000**
Salt farm area	334.376	148	2.259		
Total	408.058	149			

*.Denotes significant difference at 0.05 level
BA=Basal area , Df=Degree of freedom

Total basal area in the salt farm was lower (0.74 m2/ha) than those not under salt making activities (4.1m2/ha) **(Fig. 3).** Moreover, mangrove forest in non-salt farm area had better basal area distribution than salt farm area except for mangrove species with dbh between 5cm and 10cm which were the same in the both sites (non-salt farm and salt farm) **(Fig. 3).** Additionally, the largest tree dbh were found at mangrove areas without salt making activities while in salt farm we observed small trees. This indication of replanting strategies of mangrove species had took place in recent years,

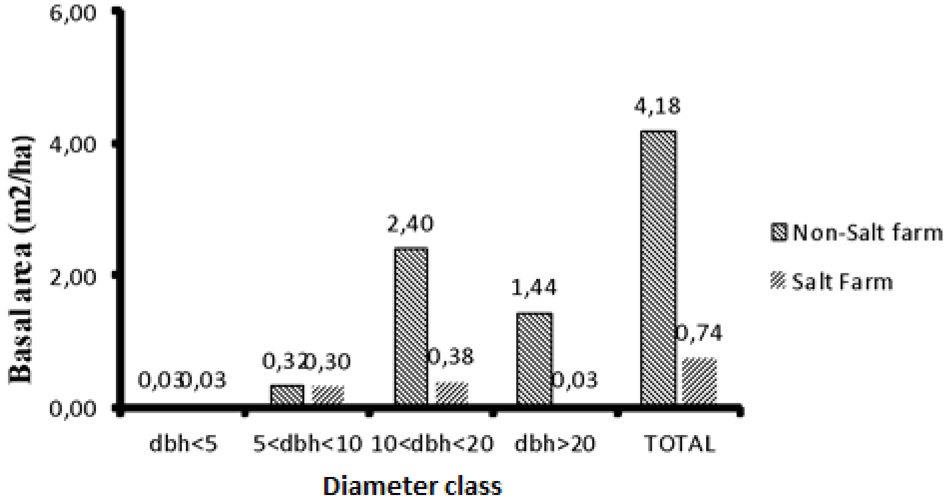

Figure 3. Basal area (m^2/ha) in mangroves with and without salt making activities

Discussion

People were involved in salt pan construction as basic activities in salt using solar energy. Mangrove species near the salt farms were probably undercut to get space for salt pans allocations and some were used as pegs to anchor the lining of pre-harvesting and harvesting pans [8, 7]. The construction of salts pans under mangrove forests areas hinder mangrove trees regeneration.

Furthermore, mangrove forests under salt making were used to build huts for storing salt on site and as a source of firewood to use at home or at the salt farm for cooking lunch. These activities involved clear felling of mangrove forests which led to the reduction of both mangrove forest and mangrove ecosystem [7, 16], [18, 19]. In addition to that, highly repeated activities in the same areas created impeding layer, elevated local salinity and increased the soil temperature as a result of hard pans formation which prevented infiltration or mixing up of water. The hard pan created adverse environmental conditions that impair growth, regeneration and development of mangrove ecosystem [9].

Low number and poor basal area distribution of mangrove species per hectare in salt farm areas was observed. These areas are characterized with small trees with diameter class of less than 10cm; this was probably attributed to the fact that mangrove areas were converted into salt pans [20]. During mangrove forest assessment, in salt farms areas, many young trees were found, this justify that, in previous years the areas had mangrove trees, but had been destroyed and encroached by man through establishment of salt pans, and in time some of mangrove trees above 20 cm were used as a facility in making salt linings and were undercut for salt pans allocations [21]. Lower than 20cm of dbh class in mangrove forest in salt farm was probably due to five usages of mangroves reported by UNEP in 2003. Since then, mangrove replanting strategies are encouraged in mangrove forests, and established in recent decade for coastal forests restoration in all destructed areas under mangrove in Tanzania. Although all areas have been secured and replanting initiatives have been undergone, mangrove in Tanzania still lose areas and salt pans were found intact with mangrove stands, which indicates further mangrove forest exploit [22]. According to Natural resource officer in Lindi Urban District, high dbh tree class of 5cm and 5-10cm were due to the mangrove replanting strategies initiated in recent years.

Conclusion

There was remarkable difference in basal area distribution and stocking of mangrove forest between the areas with and without salt making activities. We concluded that, even if salt making activities can increase income for local communities around mangrove ecosystem, they have negative influences on mangrove growth and stocking, especially solar pans construction that destruct and impair mangrove species growth and development of other ecological functions.

Other methods like thermal evaporation of brines should be adopted and implemented for mangrove conservation since salt pans construction involves clear felling of mangrove forest.

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