Title - Rural livelihoods and mangrove degradation in southwestern Madagascar: Lime production as an emerging threat

Journal - Oryx

Word count - 1996

This paper was accepted for publication by Oryx on 22nd November 2016.

This is an uncorrected pre-proof version.

Abstract

Mangroves are heavily threatened globally, with fuelwood harvesting and charcoal production a growing threat in low income nations. However, the socio-ecological dynamics of mangroves are poorly understood, especially the roles of poverty and wealth in shaping resource use. This is particularly the case with Madagascar's mangroves, which contribute 2% of global mangrove cover. We report on the use of and threats to mangroves in the Bay of Assassins in southwestern Madagascar. We document the production of 'sokay' - a sea shell based lime produced in mangrove wood kilns and used as a render on houses to improve their durability. Lime rendered houses are considered a status symbol. Growth in the use of lime is related to a rise in income in some households, which is partly a result of the increased commodification of marine products such as sea cucumber, seaweed and octopus. These products have experienced rapid commercialisation over the last decade, with fishers now supplying global markets. We also document evidence of the emergence of larger-scale lime production. The growth of lime production has major ramifications in terms of mangrove cover. We have observed a worrying development in mangrove harvesting patterns tied to lime production, where mangrove ecosystems are cleared instead of selectively cut. We consider the implications of our findings for broader debates about the relationship between conservation, poverty and natural resource use. We highlight research priorities and discuss the policy implications of our research, especially the need for the integrated management of different ecosystems.

Introduction

Globally, mangrove ecosystems are heavily threatened (Duke et al. 2007). While aquaculture has been the biggest proximate driver of mangrove loss in many regions (Walters et al., 2008; Richards & Friess, 2016), mangrove harvesting for fuelwood and charcoal production is a growing threat in low income nations (UNEP, 2014). Mangrove deforestation and degradation have serious socio-economic implications linked to the loss of important ecosystem services, including the provision of building materials, fuel wood, charcoal and (shell)fish (Barbier et al., 2011; Walters et al., 2008). Other services include storm protection, carbon storage and a range of cultural services (Barbier et al., 2011; Costanza et al., 2014).

Despite their importance, the socio-ecological dynamics of mangroves are poorly understood (Bandaranayake, 1998; Walters et al. 2008). Madagascar's mangrove ecosystems, which make up 2% of global cover, remain particularly understudied (Giri and Mulhausen, 2008; Harris, 2011). They are increasingly threatened by conversion to agriculture and charcoal production (Giri and Mulhausen, 2008; Jones et al. 2016), although there are considerable geographical variations in socio-ecological dynamics (Jones et al. 2016). Given the central role mangroves play in the livelihoods of many coastal communities in Madagascar, there is an urgent need to better understand the drivers of coastal resource use and the socio-ecological dynamics of the island's mangroves. In this short note we document preliminary research on an emerging threat to mangroves in the Bay of Assassins in southwestern Madagascar (Figure 1), namely the production of 'sokay' - a sea shell based lime render produced in mangrove wood kilns and used to improve the durability of houses. This paper is based on data from a vegetation survey carried out in August 2015; 15 semi-structured interviews with key informants (including six involved in lime production)

undertaken in four villages (Ampasimara, Lamboara, Tampolove and Vatoavo) in August 2015; and data from surveys and interviews carried out in 2006 (Epps, 2007) and 2014 (Blue Ventures, 2015).

The Bay of Assassins

The Bay of Assassins (*Helodrano Fanemotra* in Malagasy) is a coastal inlet in southwestern Madagascar located 180km north of the regional capital of Toliara. The inlet is fringed by ~1300 hectares of mangrove (Jones et al., 2016), dominated by *Ceriops tagal* and *Rhizophora mucronata.* There are 10 villages around the bay, with a total human population of ~3000 (Peabody and Jones, 2013). Small-scale fisheries generate over 80% of household income in these communities (Barnes-Mauthe et al., 2013).

Figure 1. The Bay of Assassins, southwestern Madagascar (mangrove cover data from Blue Ventures Conservation)

Coastal areas in Madagascar are increasingly experiencing in-migration, as poor agricultural households move to the coast in an attempt to find more secure livelihoods (Bruggemann et al., 2012). While data are scarce, there is evidence that the Bay of Assassins is experiencing significant in-migration. For example, in the villages of Lamboara and Ampasilava fewer than 30% of inhabitants were born in those settlements (Epps, 2007). The region's arid climate and the growth in marketing opportunities for marine produce have encouraged people to turn from inland agriculture to coastal fishing (Aina, 2010). Coastal in-

migration and the commodification of marine resources in southwestern Madagascar have in turn led to increasing pressure on fisheries (Aina, 2010; Barnes-Mauthe et al., 2013).

Mangrove use in the Bay of Assassins

Mangrove wood is harvested for two main purposes, namely the construction of houses and as a fuel in the construction of kilns to produce lime render. To estimate the effects of harvesting on mangroves we conducted measurements of canopy cover, structure and species composition of 60 randomly selected 7 metre radius circular plots around the bay. We counted and identified to species level every tree (non-harvested and harvested) and measured its diameter at breast height. From our vegetation survey we found that every plot contained harvested trees, even those that were densely vegetated and relatively difficult to access. We found that the majority of tree harvesting involves the select felling of trees within mangrove stands, rather than clear cutting larger areas. Our mangrove plots had a mean canopy cover of 73.5% (S.E. ±3%), with a mean of 28.7 % of trees (>5cm dbh) harvested (S.E. ±2.5%). While harvesting involves mostly cutting trees at the trunk and thus killing the tree (as Rhizophoraceae do not coppice or re-sprout), the forest is generally cut in a way that leaves the majority of trees intact.

Lime production and use

During our visits to four villages we observed that houses in the Bay of Assassins are made from a wide range of materials, including reeds, wooden planks, corrugated iron sheets, and lime render over a wooden frame (Figure 2). Our interviewees stated that lime render is the

preferred wall material due to its relative durability. However, lime production is a time consuming process, requiring kiln makers to cut a large volume of mangrove wood and collect sacks of sea shells. This means that the use of lime is limited to wealthier households who can afford to pay others to produce it.

Figure 2. A house wall with wooden frame and lime render

We came across 10 kilns in four villages at various stages of construction and measured a sample of 30 poles. A lime kiln (Figure 3) measures approximately 260cm in length, 230cm in width and 120cm in height and using mangrove poles of approximately 10cm diameter. Layers of sea shells are sandwiched between layers of wood. Favoured sea shells are those from gastropods such as 'tsakodia' (*Terebralia palustris*) and 'bozike' (*Murex ramosus*) (Epps, 2007). However, kiln makers we interviewed reported that these species were increasingly difficult to obtain and that they are reliant on bivalves such as 'divike' (*Donax faba),* which are considered inferior due to their smaller and thinner shells.

Figure 3. A lime kiln in the Bay of Assassins

The preferred species of mangrove wood for kiln construction is 'tangandahy' (*Rhizophora mucronata*)*,* due to its high calorific value, although we noted that other species such as 'tangambavy' (*Ceriops tagal*) were also used. Kiln construction requires around 120 poles of mangrove wood, with a total volume of approximately 2.5 m^3. A typical

kiln produces between 35 and 40 rice sacks of lime. An average sized house requires around 70 sacks to render. Each sack of lime sells for approximately 1000 Ariary (US$ 0.3). A house thus costs around 70,000 Ariary ($US 20) to render. To put this in perspective, the average income in southwestern Madagascar is less than US$ 200 per person per year (INSTAT, 2010) and households spend more than 70% of household income on food (WFP, 2011).

As well as improving the durability of houses, lime render is also considered a status symbol. Interviews with key informants suggest that lime use has increased over the last decade. This is supported by previous household surveys. In 2006, 28% of households in Lamboara village owned buildings with lime render invested in their construction (Epps, 2007). By 2014 this figure had gone up to 65% (Blue Ventures, 2015). Furthermore, interviews revealed that over the last five years lime producers have sold lime to individuals from outside the villages in the Bay of Assassins. There is thus evidence of a lime commodity network that extends beyond the bay.

Key informants suggest that growing wealth from sea cucumber (*Holothuria spp.*) and seaweed (*Kappaphycus alvarezii*) aquaculture, along with octopus (*Octopus cyanea*) fishing, have contributed to growing demand for lime as some households can afford to pay others in the village to produce it. All three of these marine products have experienced rapid commodification over the last decade, with fishers now supplying global markets. For example, commercial trade in octopus only started in 1994 in the region, with export trade starting in 2003 and middlemen visiting villages to collect fresh octopus for export (Aina, 2010).

Lime production as a threat to mangrove quality and quantity

Changes in lime production and use have important implications for mangroves. Our vegetation surveys show that while the mangroves of the Bay of Assassins are heavily harvested, this mostly involves selective cutting, resulting in low level disturbance. However, recent lime production has led to the clear cutting of mangrove forest in some instances (Figure 4). The area shown in the photograph was cleared in 2013 to satisfy a large commercial order from outside the villages. A total of 1.5 hectares were cleared. While this is a small area, there are long term implications for the site as canopy clearance has resulted in substantial surface subsidence (*sensu* Lang'at et al., 2014; Sasmito et al., 2014) limiting seedling regeneration, even after 3 years.

Figure 4. *Clear cutting of Rhizophora mucronata and Ceriops tagal in response to demand for lime in 2013.*

Mangrove use and environmental policy in the Bay of Assassins

In this short communication we have documented lime production and consumption and how it relates to mangrove forests in the Bay of Assassins. Socio-economic surveys (Epps, 2007; Blue Ventures, 2015) and interviews with key informants, suggest that the use of lime render has increased over the last 10 years as a result of a rise in the income of some households. This relates in part to new sources of income that have been created as villages in the Bay of Assassins have become connected to global commodity chains for sea cucumber, seaweed and octopus.

Our research has highlighted the complex relationship between poverty, income growth and resource use. Our findings suggest that it is not simply poverty that drives patterns of mangrove use and change in the Bay of Assassins. Rising incomes have created new pressures in the form of demand for lime render which is met by other households who produce it commercially. While research on charcoal production in communities inland has found that it is carried out primarily by poor households who have abandoned farming (Gardner at al., 2016), the socio-economic characteristics of lime producers is not yet known. Mangrove wood use needs to be quantified through a comprehensive household survey and particular attention needs to be paid to differences between households in lime production and consumption, for example according to wealth and migration status. If migration into coastal villages continues, incomes rise, and demand for building timber and lime render grows, how can mangrove harvesting patterns and rates be managed in such a way as to allow mangrove regeneration?

Secondly, we have found that lime commodity chains extend outside the villages of the Bay of Assassins. External demand has been particularly important since it has led to different harvesting patterns, with mangrove clearance rather than selective cutting. The extent of lime commodity chains and the size of the market for lime is unknown. There is also a need for research on the the socio-ecological dynamics of seashell collection, particularly the quantity and species of molluscs targeted; how shell collectors are responding to scarcity; and the ecological impacts of shell collection.

Finally, our findings suggest that mangroves must be managed as part of broader landscape based approaches. There is now abundant research showing that mangroves are interlinked with other ecosystems in important ways, for example mangroves acting as

hatcheries for coral reef and pelagic fish species (Nagelkerken et al., 2008). Our documentation of lime production shows that links between ecosystems are also socio-economic. Changes in one system (e.g. growing income from aquaculture) can affect another (e.g. loss of mangrove cover through increased demand for lime). In turn, the loss of mangroves has implications for fisheries due to the role of mangroves in the life-cycle of fish and other marine fauna important to the livelihoods of rural households in fishing communities (Duke et al., 2007; Nagelkerken et al., 2008). In the Bay of Assassins livelihoods draw on coral reefs, sea grasses, mangroves and terrestrial dry forests (Epps, 2007; Peabody and Jones, 2013; Cripps and Harris, 2009). It is therefore crucial that environmental policy considers marine resources (fisheries and aquaculture), terrestrial forests, and mangroves at the same time and examines links between them.

References

Aina, T.A.N. (2010) *Management of octopus fishery off south west Madagascar*. United Nations University Fisheries Training Programme, Iceland.

Bandaranayake W.M. (1998) Traditional and medicinal uses of mangroves. *Mangroves and Saltmarshes,* 2, 133-148.

Barbier, E.B., Hacker, S.D., Kennedy, C., Koch, E.W., Stier, A.C., Silliman, B.R. (2011) The value of estuarine and coastal ecosystem services. *Ecological Monographs*, 81, 169-193.

Barnes, D.K.A. and Rawlinson, K.A. (2009) Traditional coastal invertebrate fisheries in south-western Madagascar. *Journal of the Marine Biological Association of the United Kingdom*, 89, 1589–1596

Barnes-Mauthe, M., Oleson, K. L., & Zafindrasilivonona, B. (2013) The total economic value of small-scale fisheries with a characterization of post-landing trends: An application in Madagascar with global relevance. *Fisheries Research*, 147, 175-185.

Blue Ventures (2015) *Mangrove use in the Bay of Assassins*. Blue Ventures Conservation, London.

Bruggemann, J.H., Rodier, M., Guillaume, M.M.M., Andréfouët, S., Arfi, R., Cinner, J.E., Pichon, M., Ramahatratra, F., Rasoamanendrika, F., Zinke, J. & McClanahan, T.R. (2012) Wicked social-ecological problems forcing unprecedented change on the latitudinal margins of coral reefs: the case of southwest Madagascar. *Ecology and Society* 17: 47

Costanza, R., de Groot, R., Sutton, P., Sander van der Ploeg, S., Anderson, S.J., Kubiszewskia, I., Farbere, S., Turner, K.R. (2014) Changes in the global value of ecosystem services. *Global Environmental Change, 26*, 152-158.

Cripps, G. and Harris A. (2009) *Community creation and management of the Velondriake marine protected area*. Blue Ventures Conservation, London.

Duke, N.C., Meynecke, J.O., Dittmann, S., Ellison, A.M., Anger, K., Berger, U., Cannicci, S., Diele, K., Ewel, K.C., Field, C.D., Koedam, N., Lee, S.Y., Marchand, C., Nordhaus, I. and Dahdouh- Guebas, F. (2007) A World without Mangroves? *Science*, 317(5834), 41-42.

Gardner, C.J., Gabriel, F.U.L., St John, F.A.V. and Davies, Z.G. (2016) Changing livelihoods and protected area management: a case study of charcoal production in south-west Madagascar. Oryx, 50(3), 495-505

Giri, C. & Mulhausen, J. (2008) Mangrove forest distribution and dynamics in Madagascar. *Sensors*, 8, 2104-2117.

Epps, M. (2007) *A Socioeconomic Baseline Assessment: Implementing the socioeconomic monitoring guidelines in southwest Madagascar*. Blue Ventures Conservation, London.

Harris, A.R. (2011) Out of sight but no longer out of mind: a climate of change for marine conservation in Madagascar. *Madagascar Conservation and Development*, 6, 7-14.

INSTAT (2010) *Enquête Periodique aupres des Menages 2010*. Institut National de la Statistique, Republique de Madagascar, Antananarivo.

Jones, T.G. (2013) Shining a light on Madagascar's mangroves. *Madagascar Conservation and Development*, 8, 4-6.

Jones, T.G. , Glass, L., Gandhi, S., Ravaoarinorotsihoarana, L., Carro, A., Benson, L., Ratsimba, H.R., Giri, C., Randriamanatena, D. and Cripps, G. (2016) Madagascar's Mangroves: Quantifying Nation-Wide and Ecosystem Specific Dynamics, and Detailed Contemporary Mapping of Distinct Ecosystems. *Remote Sensing*, 8, 106.

Lang'at, J.K., Kairo, J.G., Mencuccini, M., Boullion, S., Skov, M.W., Waldron, S., Huxham, M. (2014) Rapid losses of surface elevation following tree girdling and cutting in tropical mangroves. *PloS One*, e107868.

Lau, W.Y.Y. (2012) Beyond carbon: Conceptualizing payments for ecosystem services in blue forests on carbon and other marine and coastal ecosystem services. *Ocean & Coastal Management*, 83*, 5-14*

Nagelkerken, I., Blaber, S.J.M., Bouillon, S., Green, P., Haywood, M., Kirton, L.G., Meynecke, J.O., Pawlik, J., Penrose, H.M., Sasekumar, A. & Somerfield, P.J. (2008) The habitat function of mangroves for terrestrial and marine fauna: A review. *Aquatic Botany*, 89, 155-185.

Peabody, S. and Jones, B. (2013) *Plan d'Amenagement et de Gestion de la NAP Velondriake*. Blue Ventures Conservation, London.

Richards, D.R. and Friess, D.A. (2016) Rates and drivers of mangrove deforestation in Southeast Asia, 2000-2012. *Proceedings of the National Academy of Sciences*, 113, 344-349.

Sasmito, S.D., Murdiyarso, D., Friess, D.A., Kurnianto, S. (2016) Can mangroves keep pace with contemporary sea level rise? A global data review. *Wetlands Ecology and Management,* 24, 263-278.

UNEP (2014) *The Importance of Mangroves: a call to action*. United Nations Environment Programme World Conservation Monitoring Centre, Cambridge, United Kingdom.

Walters, B.B., Rönnbäck, P., Kovacs, J.M., Crona, B., Hussain, S., Badola, R., Primavera, J.H., Barbier, E. and Dahdouh-Guebas, F. (2008) Ethnobiology, socio-economics and management of mangrove forests: A review. *Aquatic Botany,* 89, 220-236

WFP (2011) Rural Madagascar Comprehensive Food and Nutrition Security and Vulnerability Analysis. World Food Programme, Antananarivo