Chapter

A Visual Assessment Scale for Rapid Evaluation of Mangrove Degradation, Using Examples from Myanmar and Madagascar

Christoph Zöckler, Dominic Wodehouse and Matthias Markolf

Abstract

Mangroves are globally threatened, disappearing and degraded. They are lost due to land use changes, mostly agricultural expansion and aquaculture, but also degraded by cutting by villagers and logging and timber extraction for domestic and economic purposes. Extent and conversion of mangroves can usually be estimated by applying remote sensing and modern drone technology, but the scale of degradation of mangrove habitats is not easily detected by such methods. In this paper we propose an assessment tool for a rapid evaluation on the degradation, using examples from different regions in Myanmar and Madagascar. We propose a visual and practical guide listing a range of 1–6 to identify and quantify the level of degradation. We demonstrate the application by displaying various examples from Myanmar and Madagascar and how this tool can be used for wider applications, discussing advantages scope, and limitations.

Keywords: Mangroves, Myanmar, Madagascar, degradation, scale, restoration

1. Introduction

Globally mangroves are one of the most threatened ecosystems. In 1980 there were globally 198,000 km^2 of mangroves [1], but by 2003 this had reduced to 154,000km^2 [2]. By 2010, 38% of the global mangrove cover had been lost and for Asia the figure is over 50% [3] and the trend is still continuing [4]. The main drivers are agricultural expansion and aquaculture, while a growing rural population increasingly encroach remaining areas [5]. Moreover, the remaining mangroves are widely subjected to degradation, threatened by legal and illegal logging for domestic and commercial use, consequently reducing the ecosystem services that they provide as summarised for Myanmar [6].

In 2000, Myanmar still had the seventh highest mangrove forest cover in the world, but between 2000 and 2012 had lost mangroves at a much faster rate than almost any other country [5–7]. Myanmar continues to have a relatively high rate of loss of 0.8% per annum (p.a.) in the 21st century [7]. Specifically, 1924–1999, 83% of the mangroves in the Ayeyarwady Delta in Myanmar were cleared [8, 9]. While this central delta area has suffered most of the losses, the southern region of Taninthary still holds vast swathes of pristine mangrove.

Madagascar still holds large areas of mangrove forests, but many of them are also subjected to pressures from a growing local population. In 2013, the total area of mangroves for the country, situated almost exclusively on the West coast, was estimated at 303,000 ha. From 1990 to 2010 Madagascar experienced a net loss of about 21% of its mangroves, a total of 2,868 ha per year [10, 11]. These losses are mainly due to the massive exploitation of mangroves for firewood, charcoal and timber (housing and fencing), the development of aquaculture, cyclones and other causes [11, 12].

However, the rate of loss declined in recent years and globally mangroves have become prime conservation targets [13]. While in the period from 1990 to 2000 there was a net loss of almost 12% (or 34,418 ha) of Madagascar's mangroves, the net loss in the period of 2000–2010 was estimated at 22,941 ha or 8.6%), the most significant of which is in the Tsiribihina Delta (4,177 ha/25.5%) [11]. The mangroves of the area, however, are still one of the largest remaining dense mangroves in Madagascar [10].

Restoration and rehabilitation efforts have largely focused on areas previously covered by mangroves (e.g. Lewis et al., [14]), but little attention has been paid to rehabilitating degraded mangrove areas. It is important to be able to describe degraded mangrove areas that would benefit from improvement activity such as the enhancement of hydrological connectivity and protection measures. Rehabilitation will increase their ability to provide the full range of ecosystem services as well as preserve the whole ecosystem integrity. Therefore, the proposed degradation scale can also provide a reliable and cost-effective methodology to accurately describe mangrove conditions, also in recently restored mangroves.

Despite constantly improving technologies, remote sensing and more recently drone-based surveys, have struggled to depict accurately the condition of mangroves [7, 15]. Although mangrove conversion and deforestation can be reliably monitored using such techniques, mangrove loss is only one indicator of mangrove status. The importance of mangrove degradation has gained considerably less attention [16]. Modern technologies still fail to reveal the scale and the extent of forest degradation and hence poorly describe the state of the remaining forest [10, 17]. While it is acknowledged that there have been great strides in the development of remote sensing and drone/LIDAR capability, this technology will not be available to local NGOs, government mangrove agency field offices and village conservation groups until it becomes much cheaper and simpler.

Therefore, we propose here a rapid assessment tool that is ground- or boat-based, which uses visible features of the mangrove forest structure. This is a simple tool to describe and categorise mangrove forest degradation for Indo-West Pacific non-arid areas, using photographic examples from Myanmar and Madagascar. Comments and suggestions from the mangrove community are welcome to improve this degradation scale.

There is an increasing need to identify the real status of a mangrove, its ecosystem health and the scale of degradation. Degraded mangroves can give a false impression of being superficially healthy but might no longer fully provide the full range of expected ecosystem services, such as the buffering of storm surges, benthic biomass production and others [18].

2. Methodology

The authors visited several different sites between 2013 and 2019 in SE Asia and Africa to assess their conservation status and degree of degradation. The mangroves of Taninthary in southern Myanmar were visited eight times between Dec 2013 and Nov 2019. Mangroves further north on the west coast of Myanmar in the Ayeyarwady Division were surveyed in January and February 2016, [19, 20].

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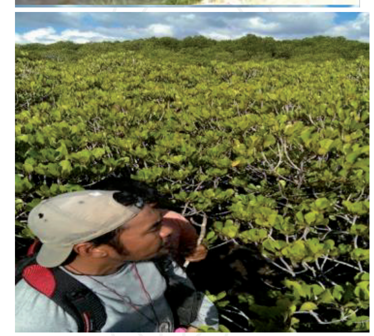
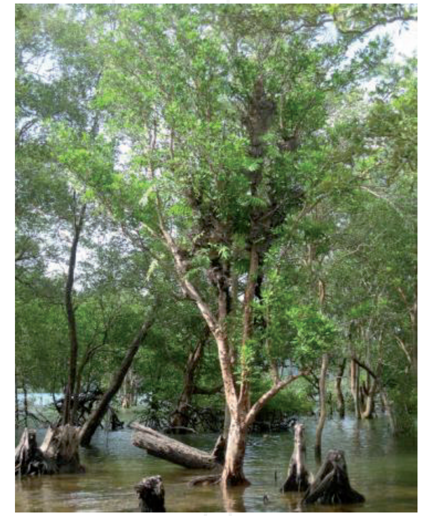
Scale			
1	**Shape**: Very low / very few mangroves. **Height**: <1 m due to possible presence of ferns, herb layer or climbers (e.g. *Acrostichum*, *Acanthus*, *Finlaysonia, photos on right side, which can block natural regeneration.)* **DBH of remaining mangroves**: NA **Logging**: Everything cut. Visible stumps, clearly cut by blade. **Light to Floor**: 100% **Notes**: Reliant on external seed / propagule sources. Ensure area was originally mangrove. Substrate might be eroding, revealing dead mangrove roots. In extreme cases the area might erode so much as to be below an elevation suitable for mangrove growth.		
2	**Shape:** Low. Bushes, establishing seeds and propagules, saplings, regenerating stumps, dead stumps and roots possibly still visible. **Height**: <2 m **DBH of remaining mangroves**: Could be large if species like *Xylocarpus* present, otherwise small (<5 cm DBH) **Logging**: Mangrove has been clear cut of everything but low bushes. Some stumps might be growing back, if species 'coppice', e.g. *Sonneratia*, *Heritiera*, *Avicennia*, *Laguncularia* and *Xylocarpus*, sometimes creating a 'bonsai' effect, lowest left photo. (N.B. *Rhizophora* and *Ceriops* will not grow back as they have no reserve meristem.) **Light to Floor**: 95% **Notes**: Ensure area used to be mangrove. Few or no seeding trees. Reliant on external supply of seeds / propagules.		 

Scale		
3	**Shape**: Low forest. Dense, bushy vegetation. Young trees, saplings. Often a heterogeneous mix of gaps and a few young trees. **Height:** 2-5 m. Very few trees taller than 5 m / 20 cm DBH. **DBH of Remaining Mangroves**: <15 cm DBH. **Logging:** Larger trees (>15 cm DBH) were removed, stumps of which might be visible. Gaps might also have been produced by logged trees damaging neighbouring trees / saplings when felled. **Light to floor**: 25–75% **Notes**: Forest will have a lot of gaps, but is likely to have enough seeding trees to regenerate. (Difficult to depict as similar to level 4, but overall tree height lower and less homogeneous in structure.)	  

Scale			
4	**Shape**: Mangrove clearly defined in the shape of forest with gaps in between few larger trees, but more even canopy than in Level 3. **Height**: > 6-12 m **DBH of Remaining Mangroves**: 20 cm and larger unless a densely stocked plantation. **Logging**: All the very big trees have been logged as well as some of the mid-sized trees. **Light to Floor**: 25–75% **Notes**: In a plantation forest, the majority of trees are in place, but some stems have been removed (<30%). If the planting density was high, there will be little light to the forest floor.	 	
5	**Shape**: High forest with large trees. Plantations will have an even height canopy. Limited understory. Canopy undisrupted. **Height**: > 12 m **DBH of Remaining Mangroves**: Up to 1 m DBH **Logging**: Only a few trees extracted and few cut stumps evident. **Light to Floor**: <25%. Canopy largely closed. **Notes**: Mature mangroves, particularly *Sonneratia* / *Avicennia*-dominated can be naturally quite open forest.		

Scale			
6	**Shape**: Tall forest. Limited to no understory. Continuous cover except for natural disturbance or gaps. **Height**: >12 m. **DBH of Remaining Mangroves**: Up to and over a 1 m. **Logging**: N/A. Trees intact. Very limited extraction. **Light to Floor**: <25%. Canopy largely closed. **Notes**: Likely to have limited understory where canopy is closed. As in 5, areas at the front low zone and back can be naturally quite open, with significant spaces between trees, and tree form very open, e.g. *Avicennia*, *Sonneratia*.		

Table 1.
Mangrove degradation scale 1–6, based on mangrove forest structural features such as shape, height, visible logging, light reaching the mangrove floor and stem diameter of the remaining trees. This scale is not applicable in northern latitudes where cryptic mangrove stands are reaching their limits of range, such as in southern China, North Vietnam, the Red Sea and North Africa. This scale is also not relevant within arid mangrove zones.

Most of the surveys were conducted using small boats, but many mostly non-estuarine mangroves were surveyed on foot and some even accessed by motorbike. These ground surveys were essential to access the interior of mangrove areas [21].

Georeferenced point assessments were conducted using a specifically designed KOBO smart phone app that uses our proposed mangrove degradation scale from 1 (very poor) - 6 (excellent), see **Table 1**. Inevitably the GPS point taken with the smart phone app is likely to be several meters up to 200 m distant from the actual observed mangrove stand providing inaccuracies that can be ignored as they give a rough first assessment of the mangrove nearby. However the GPS points do not allow accurate analysis using remote sensing tools. Where possible, visible additional information on the causes of mangrove loss were noted. The app is designed to be simple and user friendly.

3. Selected examples of application

Myanmar has suffered large losses of mangroves and the remaining forest has been subjected to many pressures. While huge areas have been lost or been

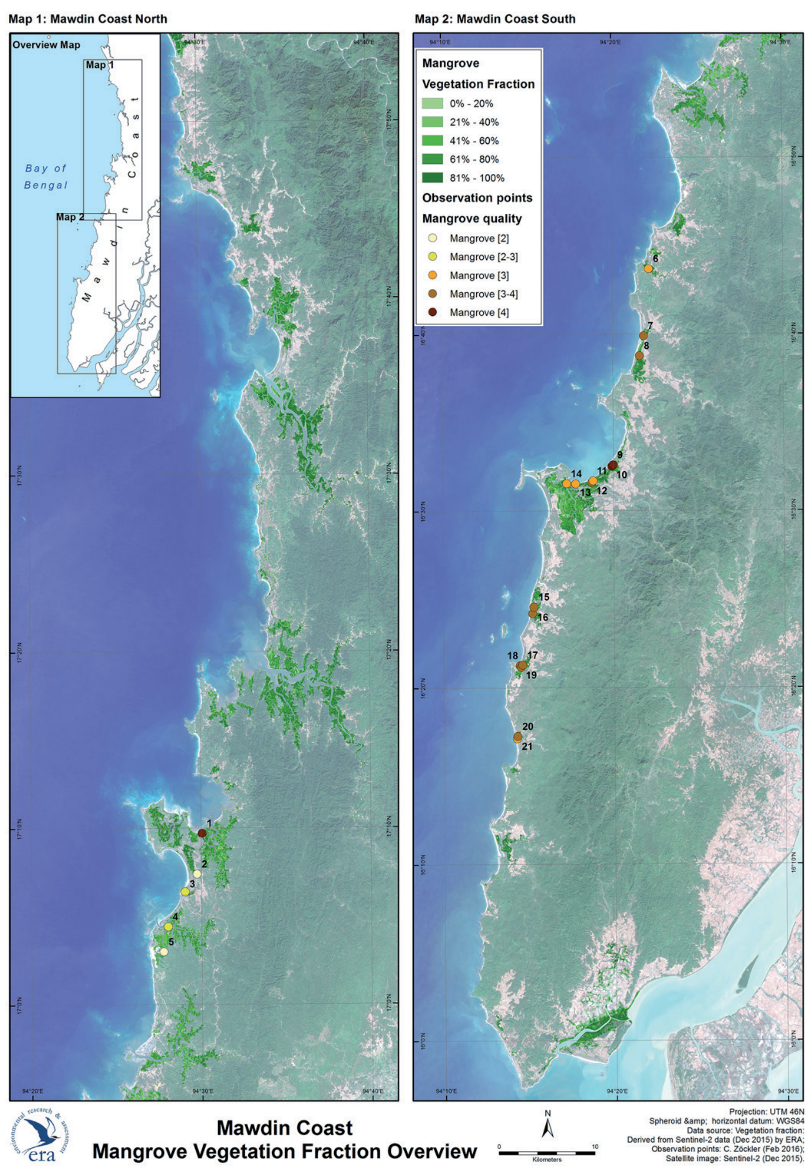


Figure 1.
Mangrove status of non-estuarine mangrove stands on the Mawdin coast in the Ayeyarwady Region on the west coast of Myanmar [22]. Each symbol represents an assessment point (21).

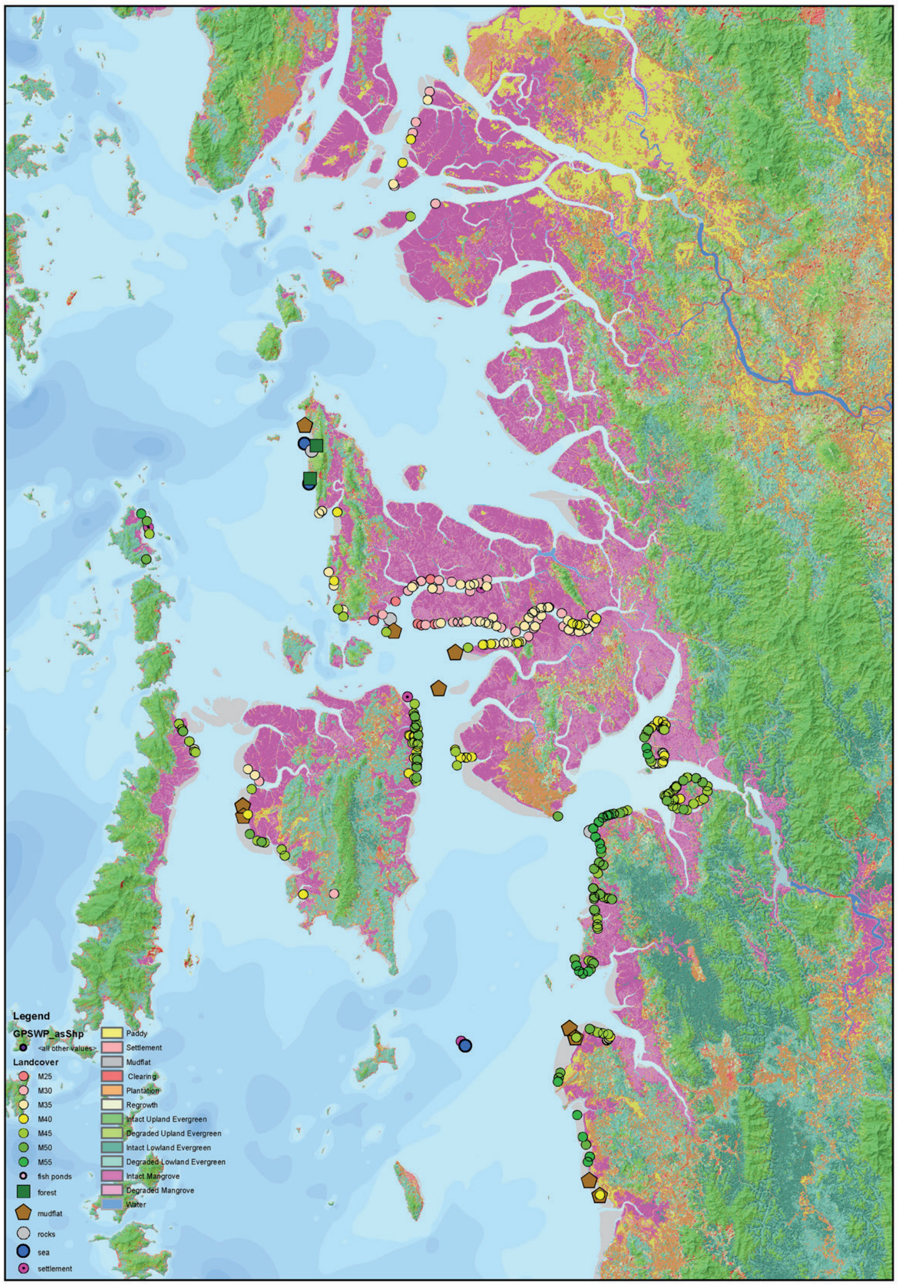


Figure 2.
*Mangrove distribution (pink) and status of the mangroves within the Myeik archipelago, Taninthary, Myanmar in 2016, based on our scale with symbols from 2.5 (pale pink) to 5.5 (dark green) and based on 282 assessment points (100 in the northern part and 182 in the southern part, [19]). See also **Table 2**.*

converted to agricultural land or aquaculture, many of the remaining areas have been heavily degraded by local logging and timber harvesting for building materials. Recently and with increasing severity, mangroves have been extensively harvested for charcoal production [6]. Our degradation scale has been applied to several mangrove sites in Myanmar in 2016 and 2017. **Figures 1** and **2** show the results mapped at two distinct coastal areas. **Figure 1** shows the Mawdin shoreline on the west coast in the Ayeyarwady Division which has only marginal and often small coastal mangrove areas. This region also includes minor areas that have been recently selected for small-scale mangrove restoration. **Figure 2** depicts the mangrove rich region of southern Taninthary, south of Myeik town. These large estuarine mangroves contain mature mangrove stands of well over 150,000 ha. Although most of the mangroves are still in good condition, recent increased usage and harvesting by local communities have left signs of degradation which this rapid assessment tool has depicted.

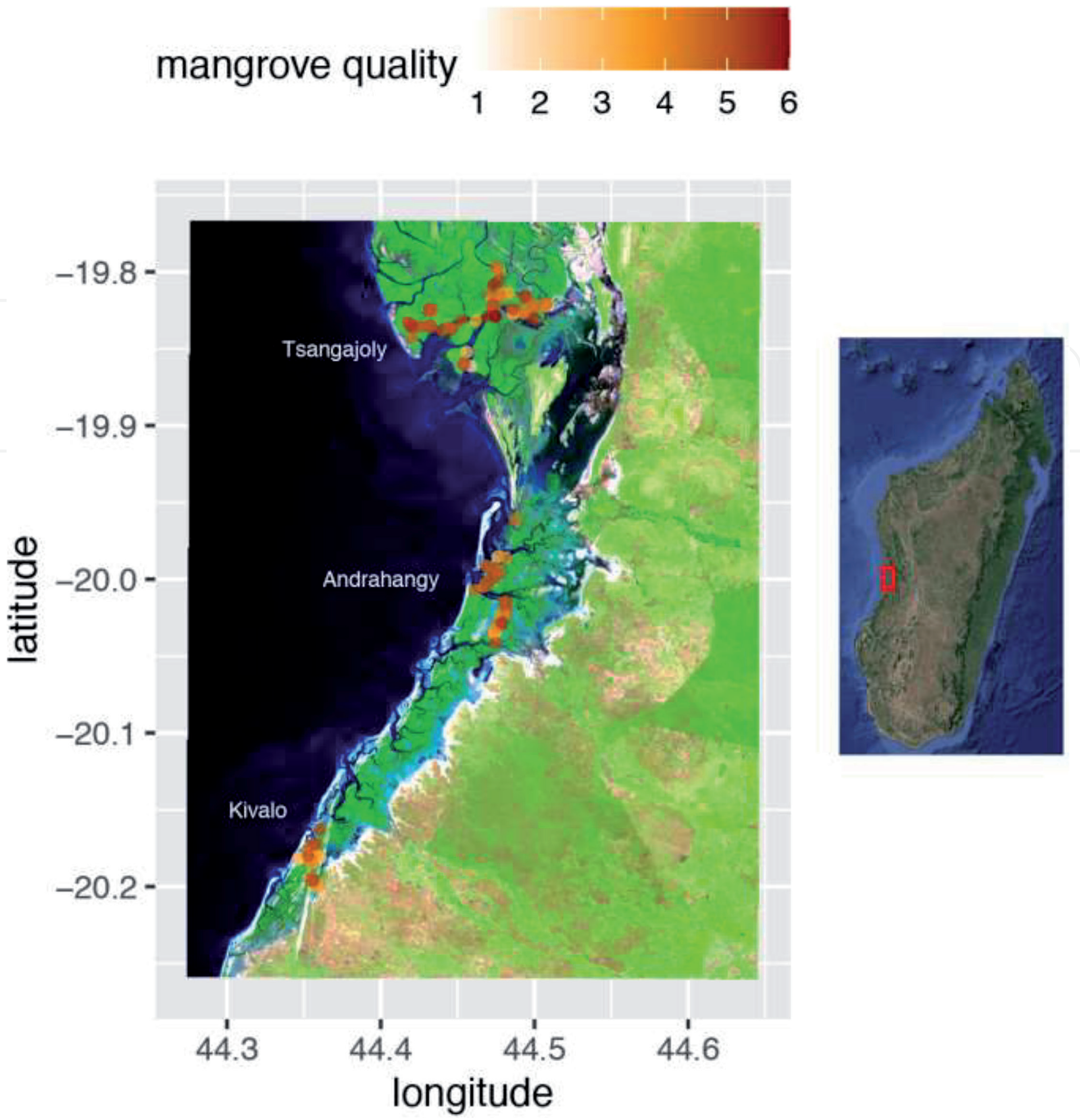


Figure 3.
Left: Landsat 8 image with remaining vegetation and the mangrove degradation status in three sub-regions in the Menabe Antimena protected area, Western Madagascar. A total of 114 assessment points were taken across all three areas. Right: Location (red square) of surveyed area in Madagascar.

No	Site	Average mangrove quality and range of assessments	No of mangrove assessment points
	Myanmar (see Figures 1, 2)		
1	Mawdin Coast, Ayeyarwady Division	3.2 (2.0–4.0)	21
2	North of Myeik, Taninthary	3.4 (3.0–5.5)	100
3	South of Myeik, Taninthary	4.5 (3.5–5.5)	182
	Madagascar (Menabe) (see Figure 3)		
1	Tsangajoly/ Baie de Borongeny	4.0 (3.5–5.0)	58
2	Andrahangy	3.8 (3.0–4.5)	29
3	Kivalo	3.3 (3.0–4.5)	27

Table 2.
Average mangrove degradation (range from 1 = much degraded to 6 = intact, high-quality) at selected sites in Myanmar and Madagascar between 2016 and 2019 [6, 19, 20].

Examples from Madagascar, show similar patterns and demonstrate the value of a scale that can be widely applied across the Indian Ocean. **Figure 3** shows the results of the application of this degradation scale in 2019 on the western coast within the Menabe Antimena Protected Area. **Table 2** shows the average assessment scale as a measure of the overall status of the mangrove quality in each region or sub-region.

4. Summary assessment of selected mangrove areas

Table 2 shows the average degradation levels observed in different coastal regions in Myanmar and Madagascar. The first area on the Mawdin coast was based on a small sample size (n = 21). It suggests a relatively low average of just over 3, reflecting the wide-scale destruction and degradation of mangroves in the region as well as early stages of rehabilitation efforts.

In the Taninthary region, the northern side, closer to the business capital Myeik, appears to have suffered more mangrove losses and disturbances, the degradation is lower with a score of 3.4 than the southern more remote mangroves around Whale Bay and Kan Maw island which averaged over 4.5 (see **Figure 3**). This suggests that the southern mangroves are healthier than the northern mangroves of Taninthary.

Madagascar also displayed differences in mangrove status in the three selected sub-regions (see **Table 2** and **Figure 3**). Kivalo, followed by Andrahangy and Tsangajoly/Baie de Borongeny showed the highest overall degradation. Although this was not specifically tested, it might well be due to higher population densities in the southern areas, which are closer to the biggest regional city of Morondava. All three areas show significant signs of degradation of which most are rather unlikely to be detected using remote sensing methods. Most signs of degradation were spatially associated with local communities depicting increased pressure on the mangroves mainly due to logging for fire wood and construction material. Over-exploitation of mangrove wood in the region by local fisherman for cooking, treatment of fishery products, and construction of boats and houses was already described by Rasolofo [23]. In some surveyed areas, grazing of zebu or goats also present increasing threats to mangroves.

5. Discussion

This simple, rapid degradation assessment tool allows the assessment of the present status and degree of degradation of a mangrove forest, but it also demonstrates the state of forest succession and rate of restoration after intervention and restoration activities have taken place. The tool is applicable over at least the Indo-West Pacific and West-Indian Ocean regions in non-arid situations, where high salinity is not the limiting factor. In the northern margins of the mangrove belt, mangroves develop much smaller 'dwarf' versions, which do not allow the application of the full range of the degradation scale, particularly the assessment of height. We hope that beyond these areas, where similar species at genus level provide comparable forest structures, this assessment tool will also allow comparisons across regions and possibly also for mangroves across the Pacific, Caribbean and South America.

Like any tool this degradation scale approach has its limitations. It only provides a restricted window from the sea front or from a boat, at best within navigable channels or small access roads, excluding large areas of the inner part of the mangroves, which are often, especially in levels 3 and 4, inaccessible on foot. While this is certainly a restriction, this rapid assessment tool is only meant to provide an initial, qualitative assessment of damage by logging and cutting or other degrading activities. We are encouraging assessors to get out of survey boats as much as possible to provide additional survey points on foot. In addition, assessments might be hampered by observer bias or difficulty in allocating local degradation to the appropriate class.

This degradation scale has not been tested and verified, but initial comparisons by different observers using the same locations did not indicate a significant difference in the assessment results. This first draft would benefit from further testing in other mangrove systems including non-deltaic mangroves to develop a more robust scale of degradation. Later on, a combination of this rapid assessment tool together with drone surveys would provide a more accurate scale of degradation and present status of any chosen mangrove forest. Repeated surveys are encouraged as they could reveal changes in the status of a mangrove stand over time. This would be particularly valuable to assess the effectiveness of in-situ protection measures, community forest agreements and active restoration schemes if baseline data is collected before, and then at intervals afterwards. Additionally, it is hoped that the scale can be tested and used on its own by community groups and government mangrove agency field officers to assess and rank their mangroves in order to prioritise rehabilitation and protection measures. Being simple and cheap the proposed rapid assessment tool has major advantages in comparison with remote sensing and LIDAR approaches and could provide substantial benefits to community-based mangrove conservation projects.

The tool offers the identification of degraded areas that have not appeared to be in need for restoration based on superficial consideration or often remote sensing. In addition, the tool can also be applied in recently restored mangroves and plantations and could also provide a good measure for success of restoration projects and activities, whereby the age of the restoration activities needs to be taken into consideration. It also allows comparisons and can point to errors and failures of the restoration efforts and highlights mitigation measures required.

In comparison to deforested mangroves, areas with reversible mangrove degradation represent opportunities for rapid and effective conservation interventions, and thus can substantially facilitate mangrove restoration initiatives [24]. The tool provides rapid and effective identification of sites most suitable for mangrove rehabilitation.

We would welcome input, comments and improvements, including extra photos, particularly from groups that have tried to use this scale. Eventually it will be available for download and printing as well as a smart phone app. It is suggested that a version of it is laminated for use in the mangrove while conducting surveys.

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