Unprecedented rates of deforestation in Menabe Antimena: Can we halt this catastrophic damage?

DURRELL

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Conservation Importance

Madagascar is famous for its rich biodiversity and unparalleled levels of endemism. High numbers of these unique plant and animal species are found in the dry deciduous forests of western Madagascar, making this habitat one of the island's top conservation priorities.

The central western region of Menabe holds one of the largest remnants of dry forest in Madagascar. This area has experienced a long history of deforestation (Zinner et al. 2014) and its forests are facing increasing anthropogenic pressure. The Menabe Antimena new protected area, 210,312 hectares (MEEF, 2015), is home to over 227 species of animal: 34 mammals, 49 reptiles, 128 birds and 16 amphibians (IUCN Red List of Threatened Species) and over 200 species of tree (Rakotonirina, 1996). Of the animals, 19 are globally threatened, 12 are regionally endemic and two are site endemic; the giant jumping rat (*Hypogeomys antimena*) and Madame Berthe's mouse lemur (*Microcebus Berthae*). The site endemic mammal species are obligate forest dwellers and rely on undisturbed primary rainforest for survival. Menabe is also important for plant conservation by sheltering endemic tree species such as *Hazomalania voyroni*, *Dalbergia greveana*, *Diospyros perrieri* and three baobabs species including *Adansonia grandidieri*, *Adansonia rubrostipa* and *Adansonia za*. The area is well known for its richness in wild edible yam including *Dioscorea bako* which is native to the region but threatened to extinction.

Menabe is a popular tourist destination due to its easily accessible wildlife and world famous Avenue of the Baobabs. Local NGO Fanamby, responsible for managing the protected area, specialises in developing partnerships between the tourism sector and local communities, creating eco-tourism projects that benefit people and biodiversity.

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Conservation Action

Durrell Wildlife Conservation Trust has been working in Menabe since 1997. Durrell worked alongside Fanamby, the Regional Ministry of Environment, Ecology and Forests (DREEF) and the National Centre for Training and Research in Environment and Forestry (CNFREF) to establish the Menabe Antimena new protected area, which was given temporary protection by the Madagascar Government in 2005 and permanent protection in 2015. As a Category V protected area (Managed Landscape), Menabe Antimena includes areas of human inhabitation as well as roads and agriculture.

Durrell works closely with local communities living within and around the protected area, working towards effective, sustainable solutions that work for people and biodiversity. This approach includes community forest management and participatory ecological monitoring. There are 19 legally recognised forest management associations (11 for dry forest and eight for mangrove) responsible for managing the sustainable use of forest resources and conducting forest patrols to deter and report illegal activities. These associations receive training to strengthen management capacity. Local communities are also trained in ecological survey techniques and are involved in collecting data on some of the areas threatened species. To encourage participation and biodiversity conservation, communities have received support to improve their standard of living, including the provision of wells, school materials and bicycles. This community-led approach has proved to be highly successful and popular across the region.

Forest Loss

Drivers of Forest Loss

There has been a rapid increase in the deforestation rate in Menabe Antimena since 2011. Previously, deforestation was primarily driven by; slash and burn agriculture for maize crops (at least in part for use in domestic and international beer brewing) and grazing land for livestock, uncontrolled fires spreading from outside the protected area and illegal logging primarily for building timbers (Vieilledent et al. 2016). In recent years, there has been a rapid increase in the destruction of forest for the production of cash crops, specifically peanut and maize. It is believed that the peanuts are grown to produce peanut oil which is being exported to overseas markets, predominantly China (Vieilledent et al. 2016).

Recently, drought may have contributed to an increase in illegal maize and peanut farming within Menabe Antimena through a decline in water regime from the dam of Dabara (Mahabo district) reducing irrigation for the rice fields south of the protected area. With no perceived alternatives, the local communities have turned to maize as a substitute food and income source inside the protected area. Maize can be grown on an area of land for only three to six years before the land becomes unproductive, meaning new areas of forest are cleared regularly.

Additionally, immigration from the South driven by regional droughts and famine has increased the pressure on the land inside the protected area.

Mapping Forest Loss

Figure 1 shows the extent of deforestation within Menabe Antimena between 2000 and 2015. The majority of deforestation occurred between 2011-2015 and has been focused around the most accessible forest areas; near villages and areas of zero to low tree cover. The official strict conservation zone has remained relatively intact but with areas of deforestation fast approaching its boundary. Areas of the strict conservation zone managed by local communities (SCZ management transfers) have seen less deforestation than areas outside of the strict conservation zone.

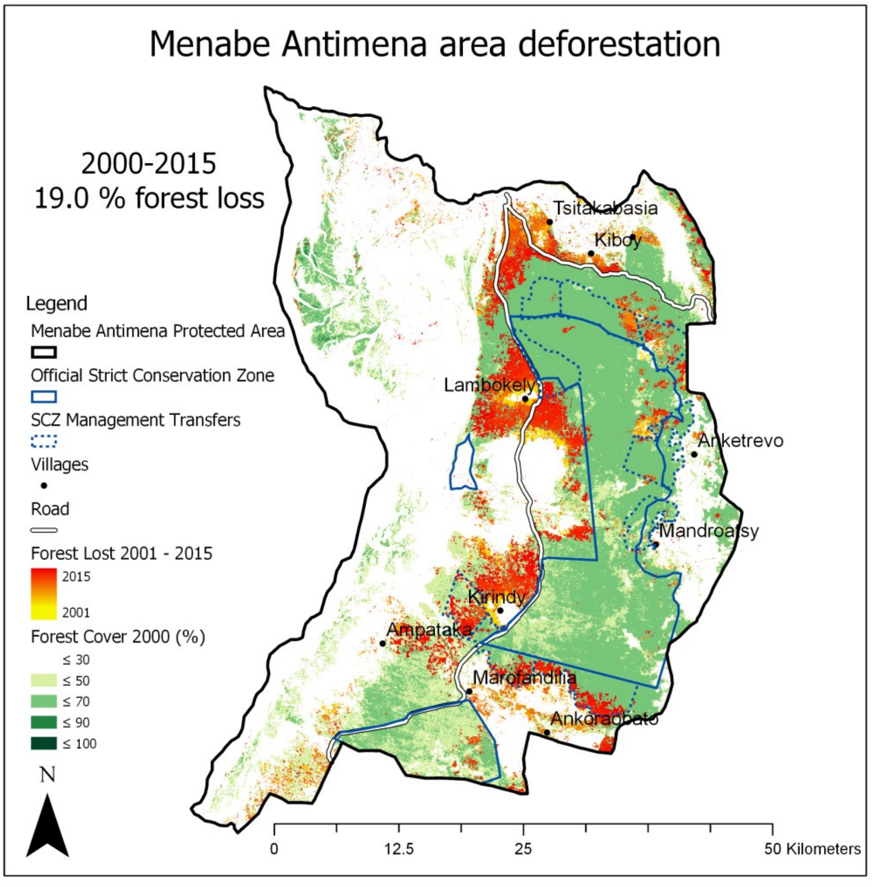

Figure 1. Map of forest loss between 2000 and 2015 in Menabe Antimena.

Graphs of Forest Loss

Figures 2 - 5 are plots of the area of land deforested each year from 2000 to 2015 in Menabe Antimena, the official strict conservation zone and SCZ management transfer areas. All three show an overall increase in the area of land deforested each year. Please note: the y-axis scales on these graphs are different.

Annual forest loss within Menabe Antimena:

Between 2000 and 2009 the area of land deforested within the boundary of Menabe Antimena remained at or below 1000ha per year. Since 2010 the area of new land that has been deforested each year has risen dramatically, reaching over 4000ha per annum in 2014.

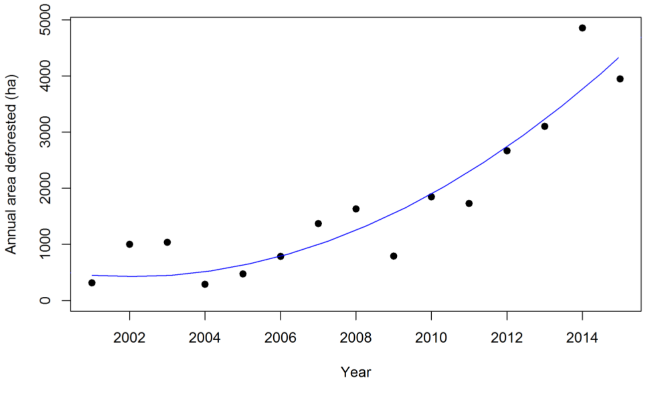

Figure 2. Annual area deforested within Menabe Antimena fitted with a best fit, second order polynomial trend line in R.

Annual forest loss within the official strict conservation zone of Menabe Antimena:

The area of land deforested each year within the official strict conservation zone has been considerably lower than in the surrounding protected area. The annual area deforested has fluctuated between 2000 and 2015 but has seen a steady overall increasing trend, reaching a high of over 250ha per annum in 2014.

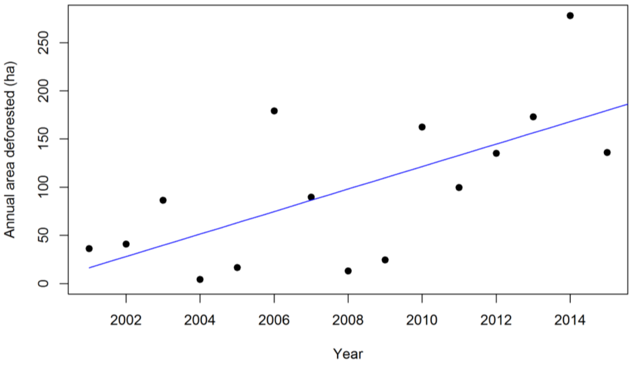

Figure 3. Annual area deforested within the official strict conservation zone fitted with best fit trend line in R.

Annual forest loss within the management transfer strict conservation zones (SCZ) of Menabe Antimena:

A comparatively small area of 491 of 47,000ha within the SCZ management transfer areas was deforested between 2000 and 2009, with only one peak in 2007. Since 2010 the area of land deforested each year rapidly increased, reaching a high of almost 1500ha in 2015. Deforestation in the management transfer strict conservation zones was much greater than in the official strict conservation zone (Figure 3) and it is increasing at a greater rate. This suggests that the management transfers, which are closer to villages and roads, have been more heavily targeted by illegal slash and burn agriculture, and local associations have been weakened by the situation resulting in reduced motivation and effectiveness in protecting their own forests.

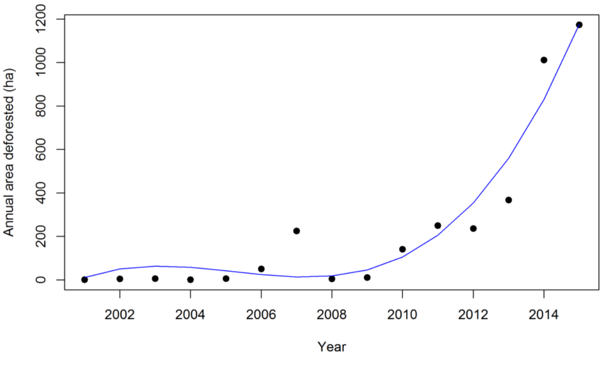

Figure 4. Annual area deforested with the management transfer strict conservation zones (SCZ) fitted with a best fit, third order polynomial trend line in R.

Forecasting future forest loss within Menabe Antimena:

Forecasts of forest loss in Menabe Antimena were created by modelling continued deforestation across all zones in the protected area at the observed rate for 2015. Projected forecasts were modelled by adding new deforested pixels to a radius surrounding each deforested pixel from 2015 such that the total area deforested (2015 pixels plus the new deforested pixels) matched the figure predicted. Two scenarios have been modelled: the 'current scenario' - constant loss of forest across the protected area at the rate recorded in 2015 and the 'worst-case scenario' - increased loss as predicted by the following graphs based on lines of best fit for the existing data.

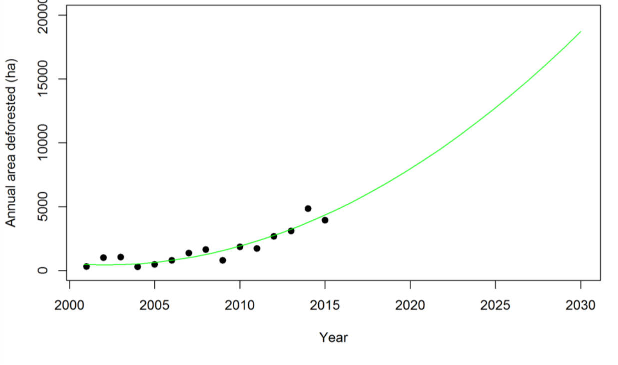

Figure 5. Annual area deforested within Menabe Antimena fitted with a best fit, second order polynomial line in R. This line has been extended to predict future loss under the 'worst-case scenario'.

Mapping Projected Forest Loss

Figures 6 - 9 show projected deforestation in 2020, 2025, 2030 and 2035 if deforestation occurs at the same rate as in 2015 (approximately 3947 ha / year) - the 'current scenario'. Figures 10 and 11 are maps of the projected deforestation in 2020 and 2025 if the rate of deforestation increases in line with the above graph - the 'worst case scenario'.

Projected forest loss under the 'current scenario':

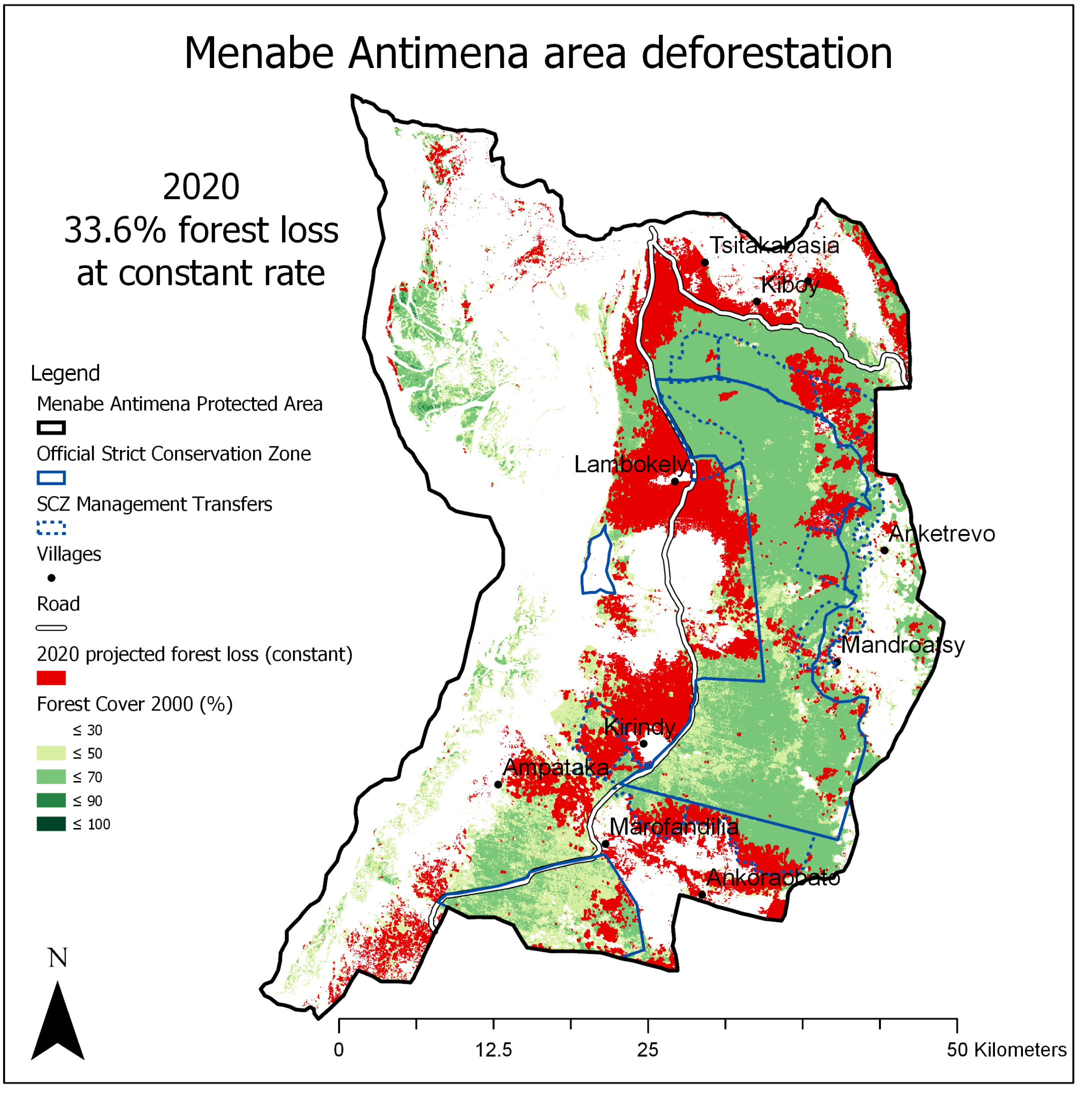

Figure 6. Map of projected forest loss by 2020 under the 'current scenario', assuming forest loss continues at the rate observed in 2015.

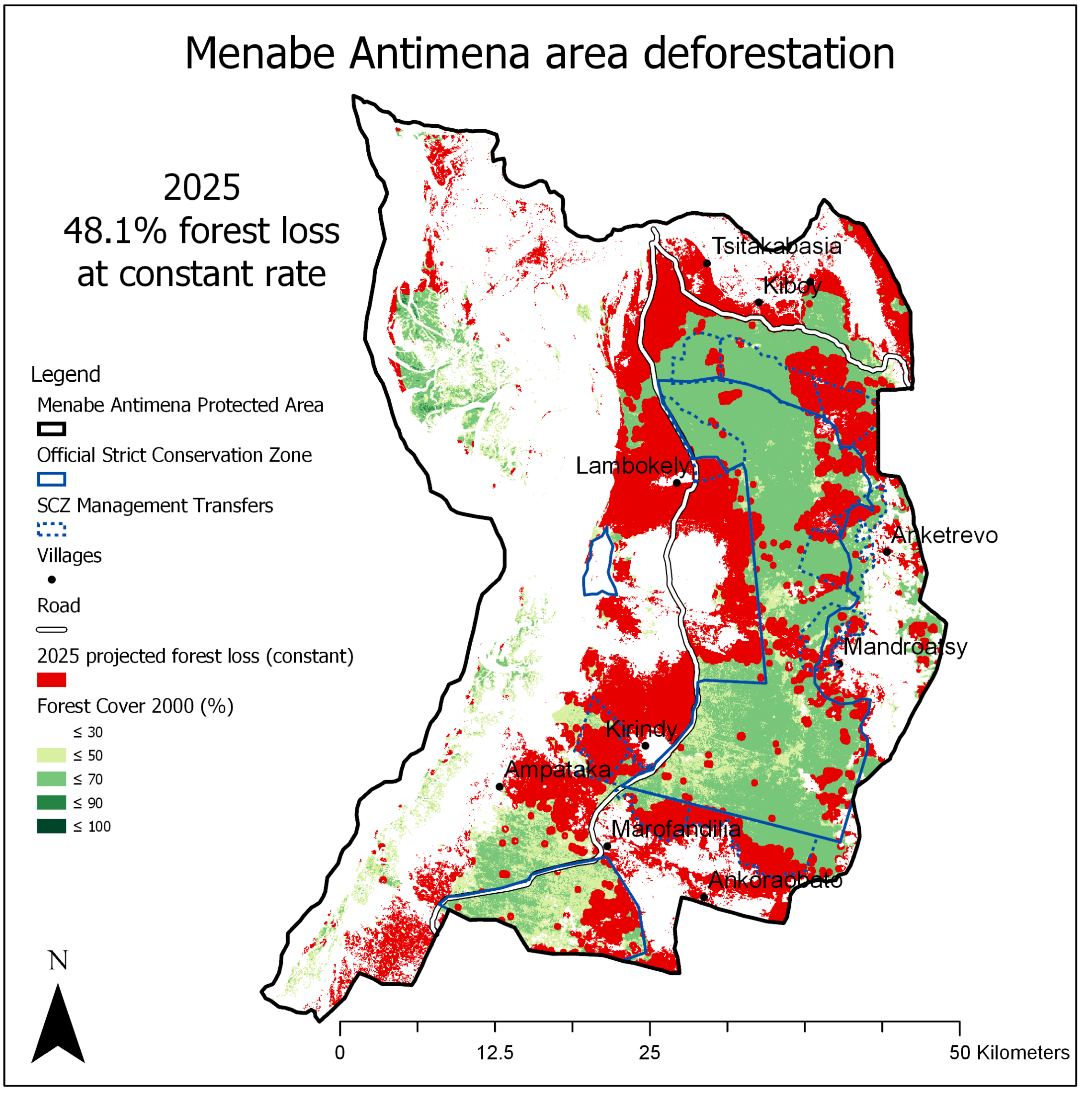

Figure 7. Map of projected forest loss by 2025 under the 'current scenario', assuming forest loss continues at the rate observed in 2015.

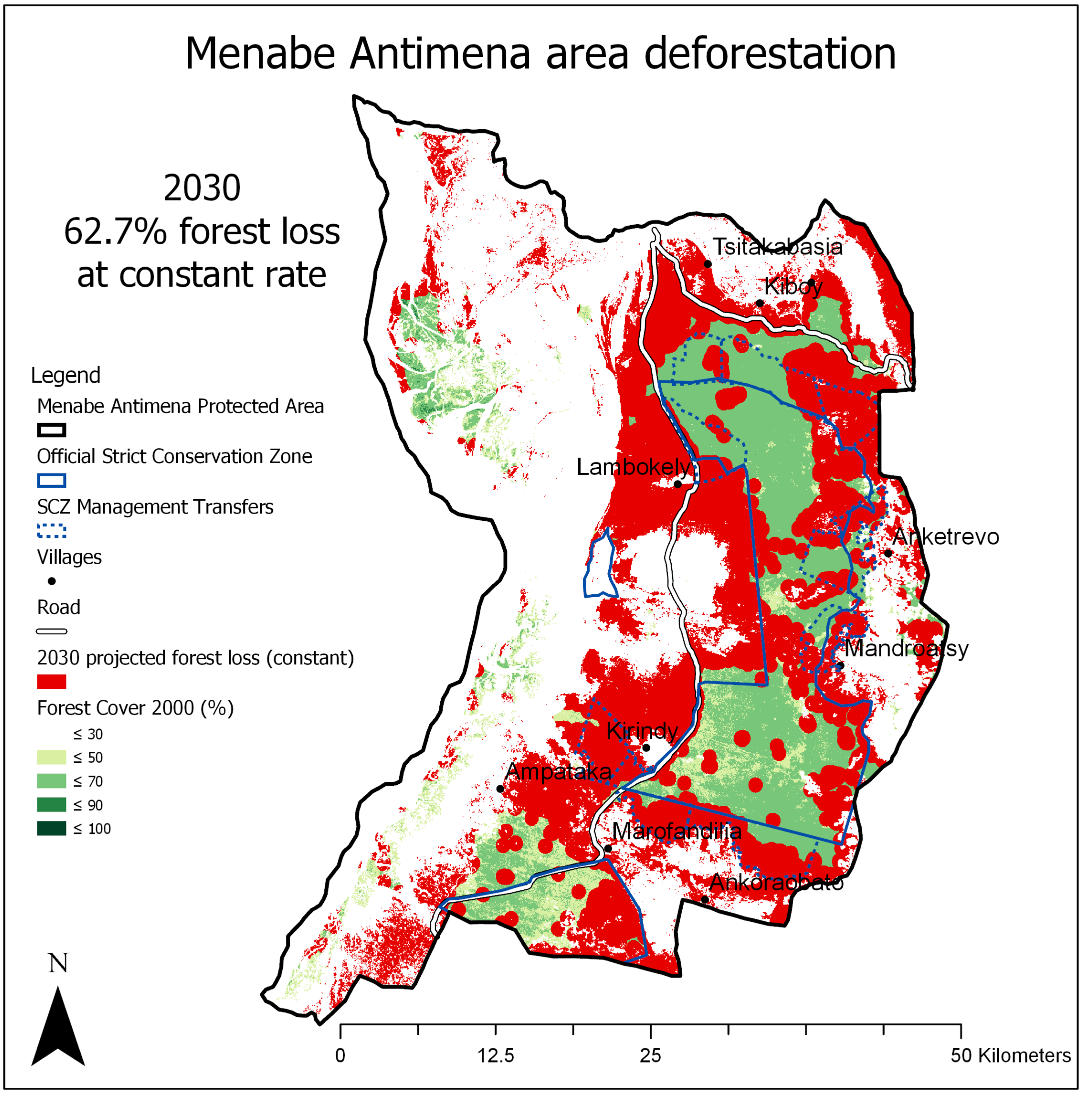

Figure 8. Map of projected forest loss by 2030 under the 'current scenario', assuming forest loss continues at the rate observed in 2015. At this point, the forest has become severely fragmented and is now three distinct areas of forest, which would have catastrophic impacts on the gene flow between animal populations in the segments, increasing likelihood of extinction.

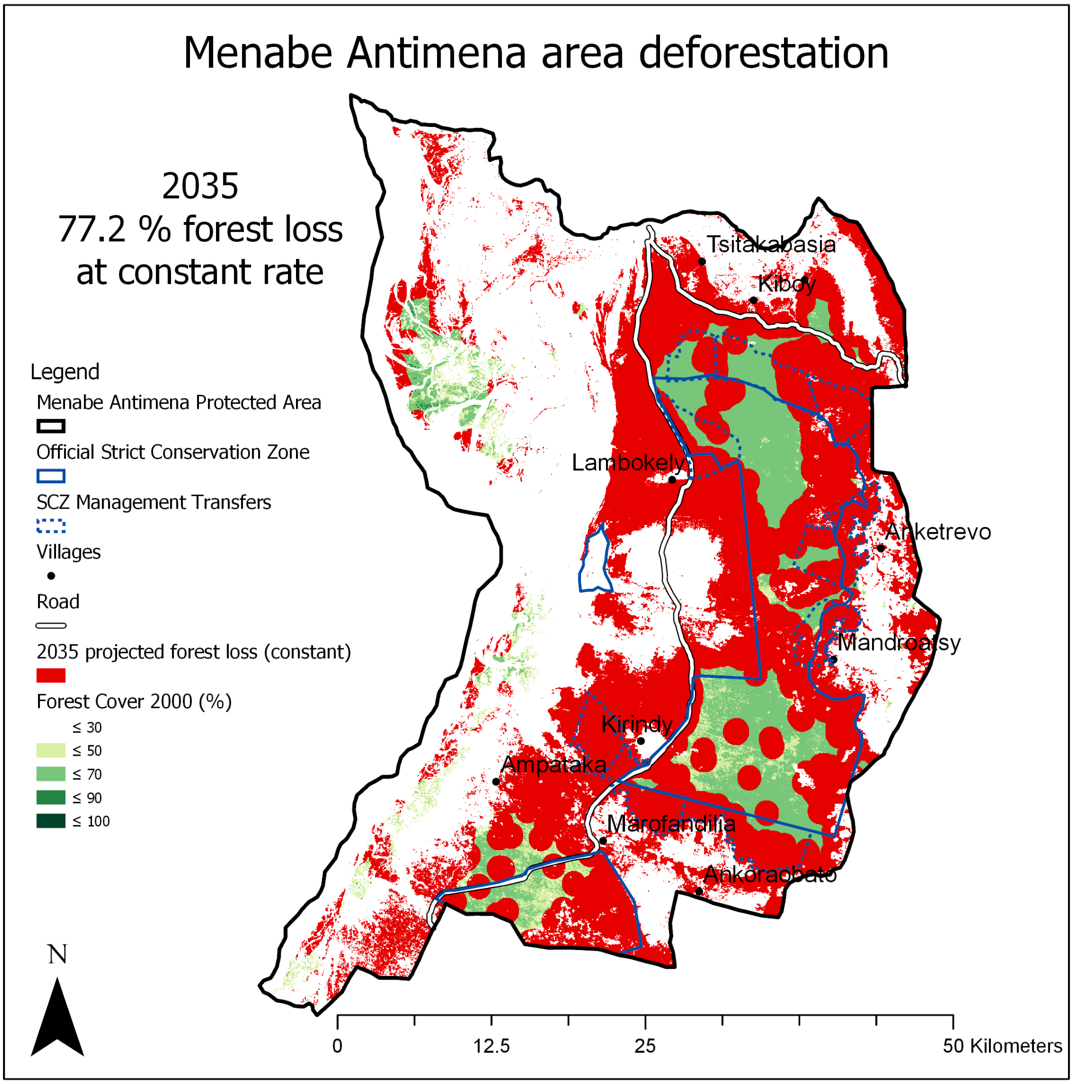

Figure 9. Map of projected forest loss by 2035 under the 'current scenario', assuming forest loss continues at the rate observed in 2015.

Projected forest loss under the 'worst-case scenario':

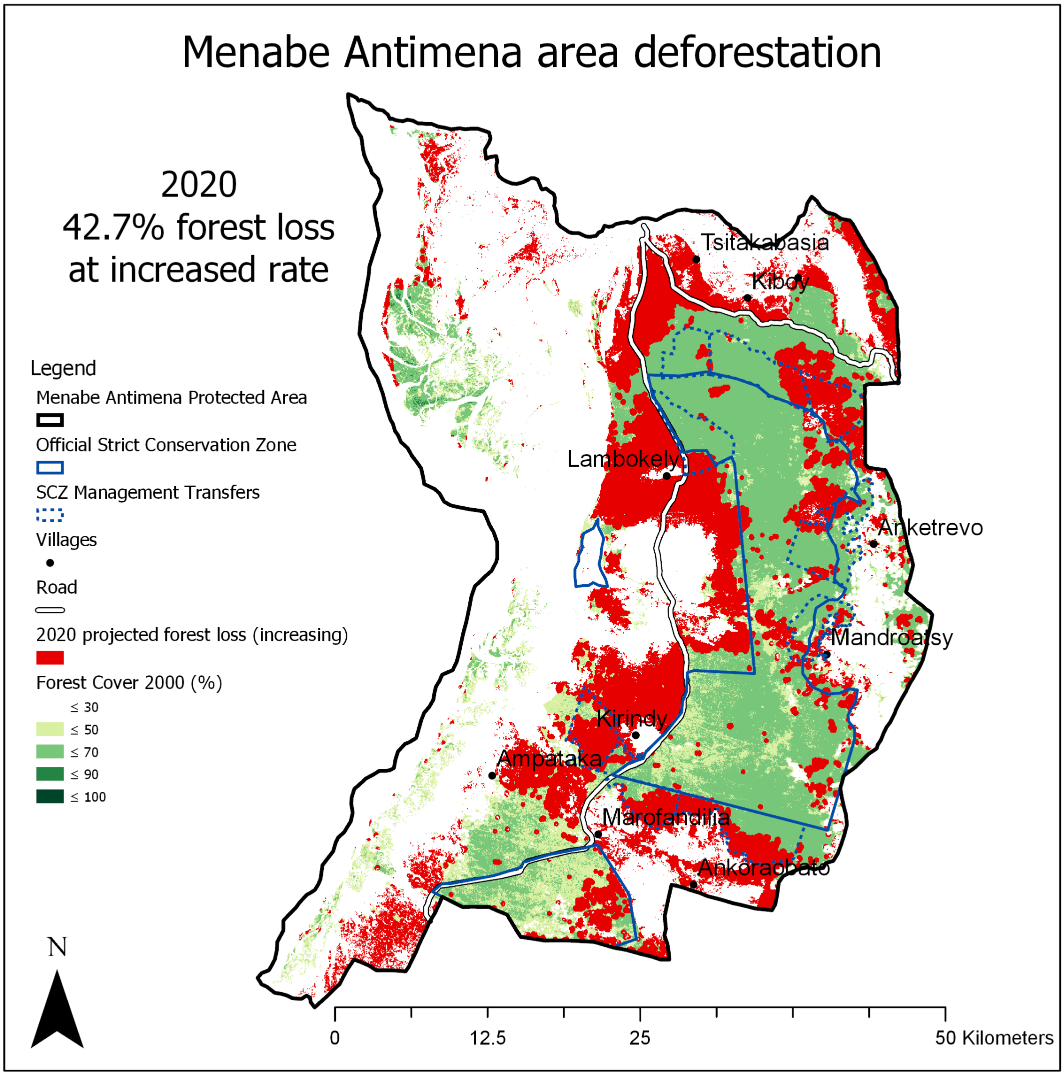

Figure 10. Map of projected forest loss by 2020 assuming forest loss increases as modelled using the extended best fit line generated for the 2000 – 2015 forest loss data in Figure 5.

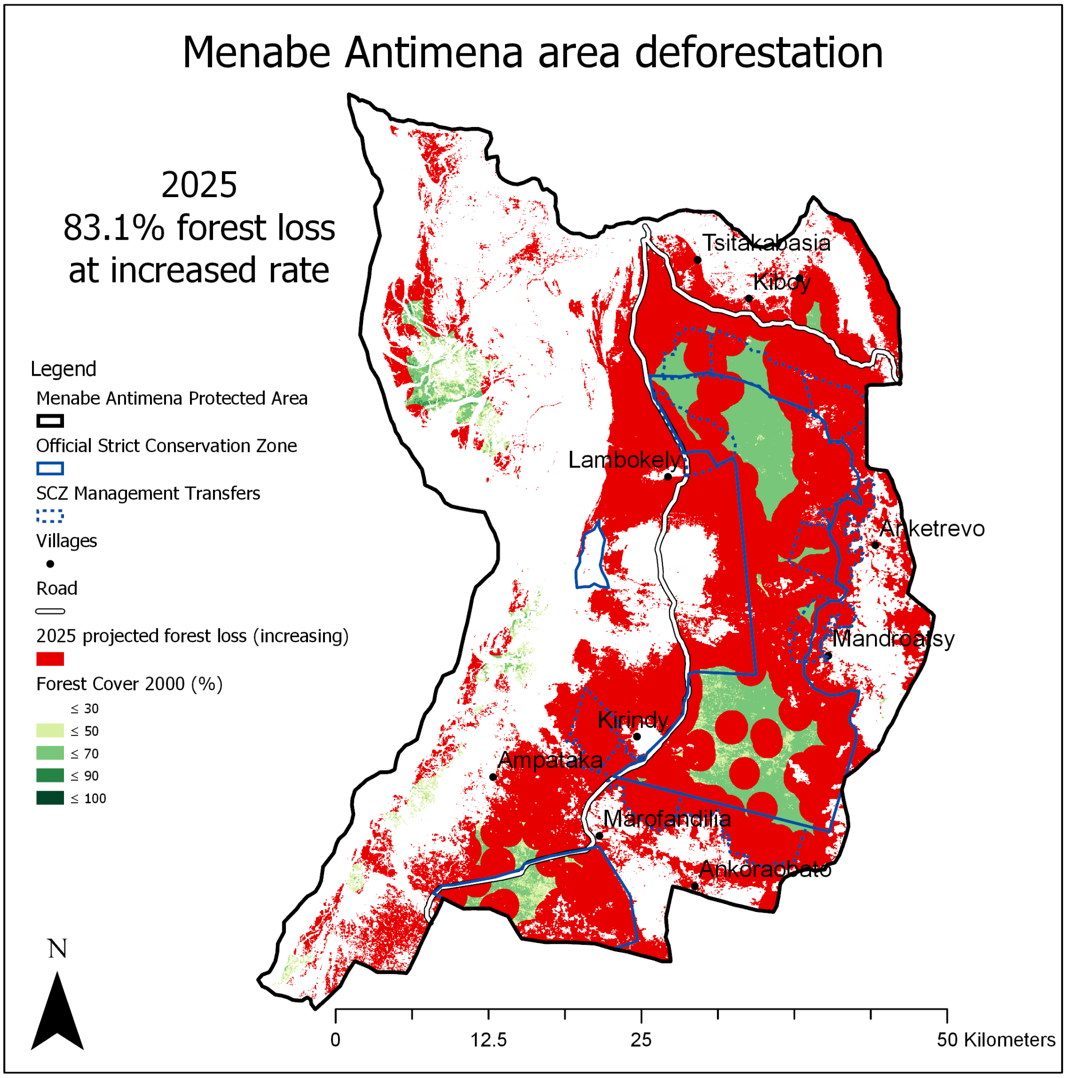

Figure 11. Map of projected forest loss by 2025 assuming forest loss increases as modelled using the extended best fit line generated for the 2000 – 2015 forest loss data in Figure 5. At this point, the forest has been all but lost leading to the extinction of the site endemic species, *Microcebus berthae* (Madame Berthe's mouse lemur) and *Hypogeomys antimena* (Giant jumping rat).

Impact On Site Endemic Species

In this section, the impact of forest loss on the range of site endemic species is examined and the impact of future loss is predicted. Menabe Antimena is home to two globally threatened, site endemic species, Madame Berthe's mouse lemur (*Microcebus berthae* - the world's smallest primate) and the giant jumping rat (*Hypogeomys antimena*), details about which can be found in Table 1. The area within each of these species ranges which is predicted to be lost under the two scenarios outlined in section 2.5 is calculated using the deforestation displayed on maps in section 2.6. To examine the impact of the current drivers of deforestation rather than historical drivers, predictions are made from a starting point of 2010, the year in which forest loss begins the upward inflection in Figure 1. Predictions of future impact were made over the period of approximately three generations for each species (Pacifici et al. 2013) as recommended by the IUCN Red List measures of extinction risk (i.e. 2010 – 2030). The projected range area lost and Red List category by the end of this period were calculated and are recorded in Tables 2 and 3.

Table 1. Estimated reduction in the range of site endemic species between 2010 and 2015 based on forest loss estimates to date. Maps of the original ranges are shown in Figure 12.

Species	Common name	Red List category	IUCN est. range size 2010 (km^2)	Deforested area (km^2) 2010 - 2015	% decline forested range	New forested range 2015 (km^2)
Hypogeomys antimena	Giant jumping rat	EN	333	45	10.8	297
Microcebus berthae	Madame Berthe's mouse lemur	EN	546	89	13.9	470

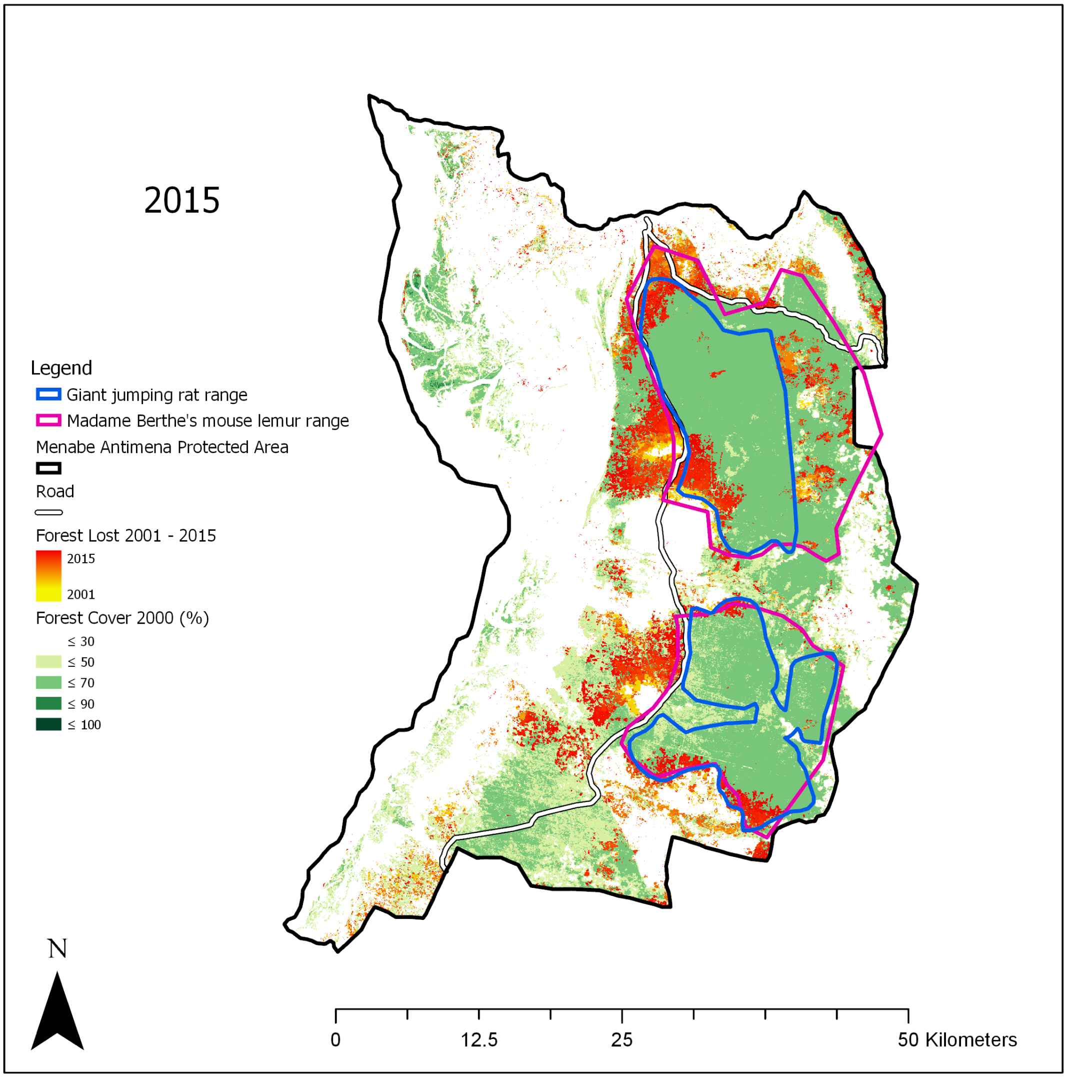

Figure 12. A map of the year 2010 ranges of the two site endemic species in Menabe Antimena; the giant jumping rat and Madame Berthe's mouse lemur, shown over the deforestation estimates between 2000 – 2015. The impact on the species' ranges is already noticeable.

Table 2. Projected range loss of site endemic species between 2010 and 2030 based on the 'current scenario'.i.e. continued loss of forest post 2015 across the protected area at the same rate as that observed in 2015.

Species	Common name	Red List category	IUCN est. range size 2010 (km^2)	% range loss by 2030	Projected range size 2030 (km^2)
Hypogeomys antimena	Giant jumping rat	EN	333	43.5	188
Microcebus berthae	Madame Berthe's mouse lemur	EN	546	58.2	228

Deforestation would result in the direct loss of habitat for both site endemic species. But both species are sensitive to forest disturbance, and the giant jumping rat survives only in good quality habitat (Young et al. 2007). The estimates of habitat area lost are, therefore, likely to be underestimates, with far greater areas being lost as suitable habitat for these species as small scale selective logging activities and human disturbance are not being detected within this analysis.

Table 3. Projected range loss of site endemic species between 2010 - 2025 based on loss of forest post 2015 at an increased rate, extracted from the best fitting models for the entire protected area in Figure 5. Whilst the period 2010 - 2030 represented three generations of the focal endemic species, this table shows the projected species ranges in 2025, as both species would be extinct by 2030 time under this scenario.

Species	Common name	Red list category	IUCN est. Range size 2010 (km^2)	Predicted % range loss by 2025	Predicted range size in 2025 (km^2)	Predicted Red List category 2025
Hypogeomys antimena	Giant jumping rat	EN	333	86.8	43.9	CR
Microcebus berthae	Madame Berthe's mouse lemur	EN	546	91.5	46.4	CR

In addition to the loss of these site endemic species, globally important and charismatic species such as the fossa (*Cryptoprocta ferox*) will be lost by 2025 under this scenario.

Deforestation within Menabe Antimena 2015 - 2017

As forest loss data were not available after 2015 from Global Forest Watch, the Copernicus Sentinel-2 and USGS Landsat-8 tiles from 2017 were downloaded and inspected visually for areas of deforestation. Figures 13 - 15 show that deforestation outside the strict conservation zone appears to have continued or increased during 2017, particularly in the south of the area. Deforestation inside the special conservation zone appears to have been limited, but is occurring particularly in areas shown in Figures 13 - 15.

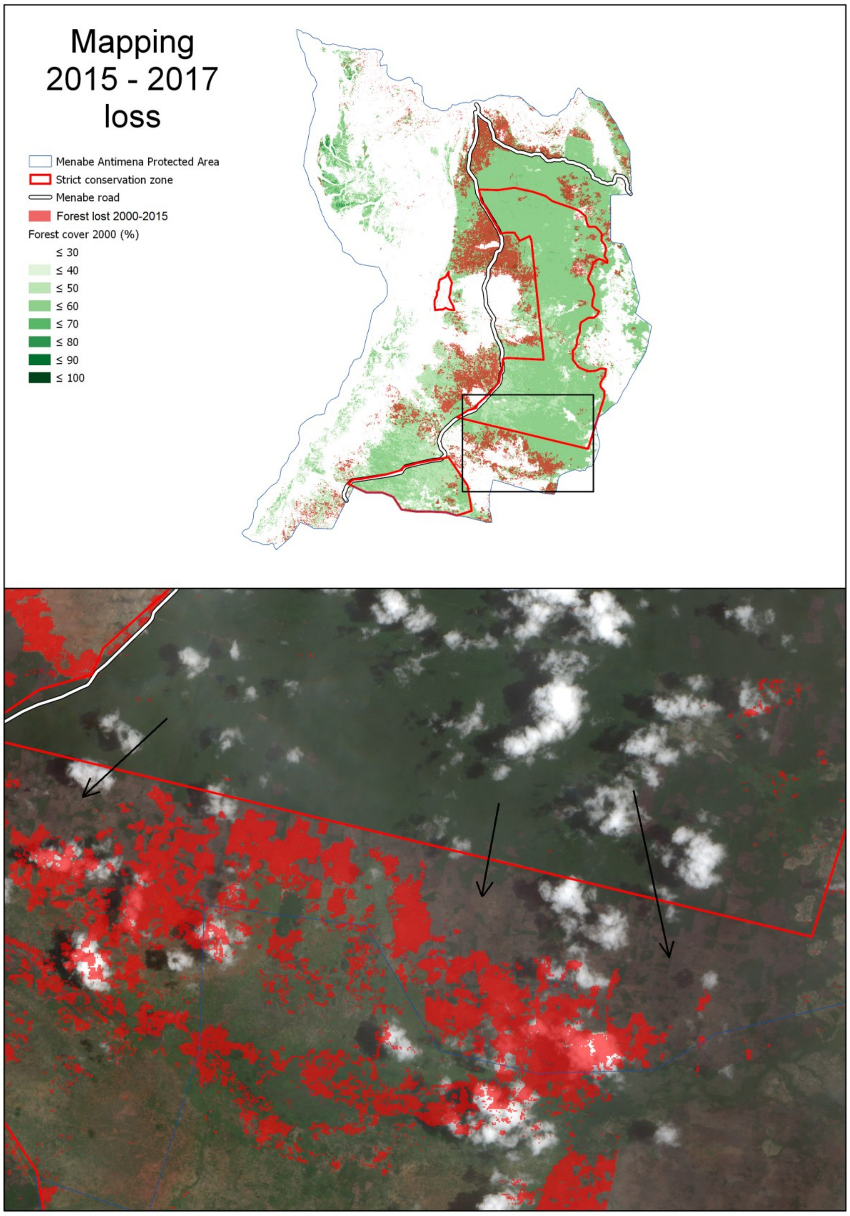

Figure 13. High resolution satellite image identifying areas of likely deforestation between 2015 and 2017. Here there is widespread deforestation apparent in the management transfer strict conservation zones in the south of the protected area. Major areas of concern are highlighted with arrows. It appears deforestation in this area between 2015 - 2017 near matches deforestation in the previous 15 years.

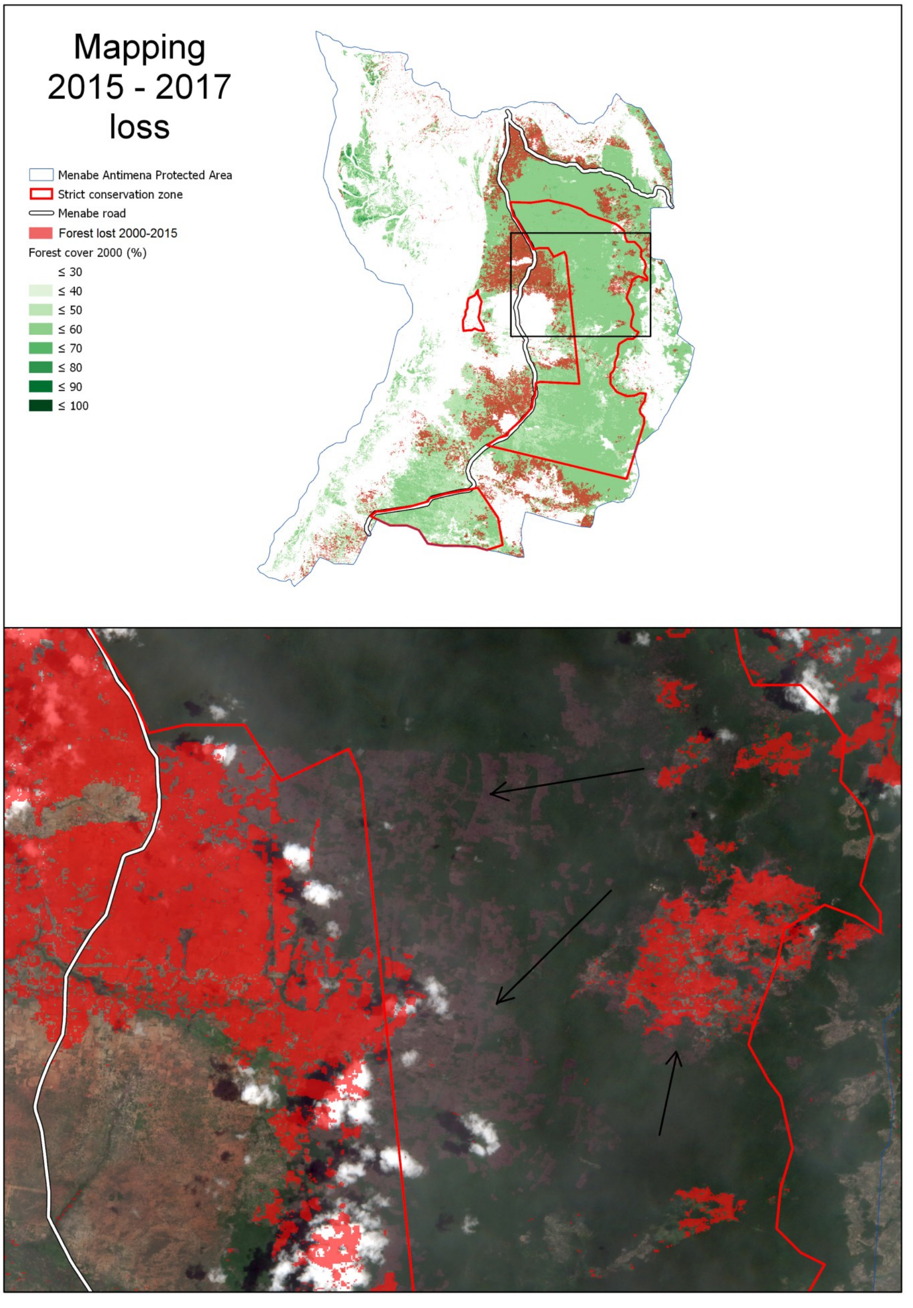

Figure 14. High resolution satellite image identifying areas of likely deforestation between 2015 and 2017. Here there are areas of deforestation apparent on the edge of, and within the strict conservation zone in the centre of the protected area. Major areas of concern are highlighted with arrows.

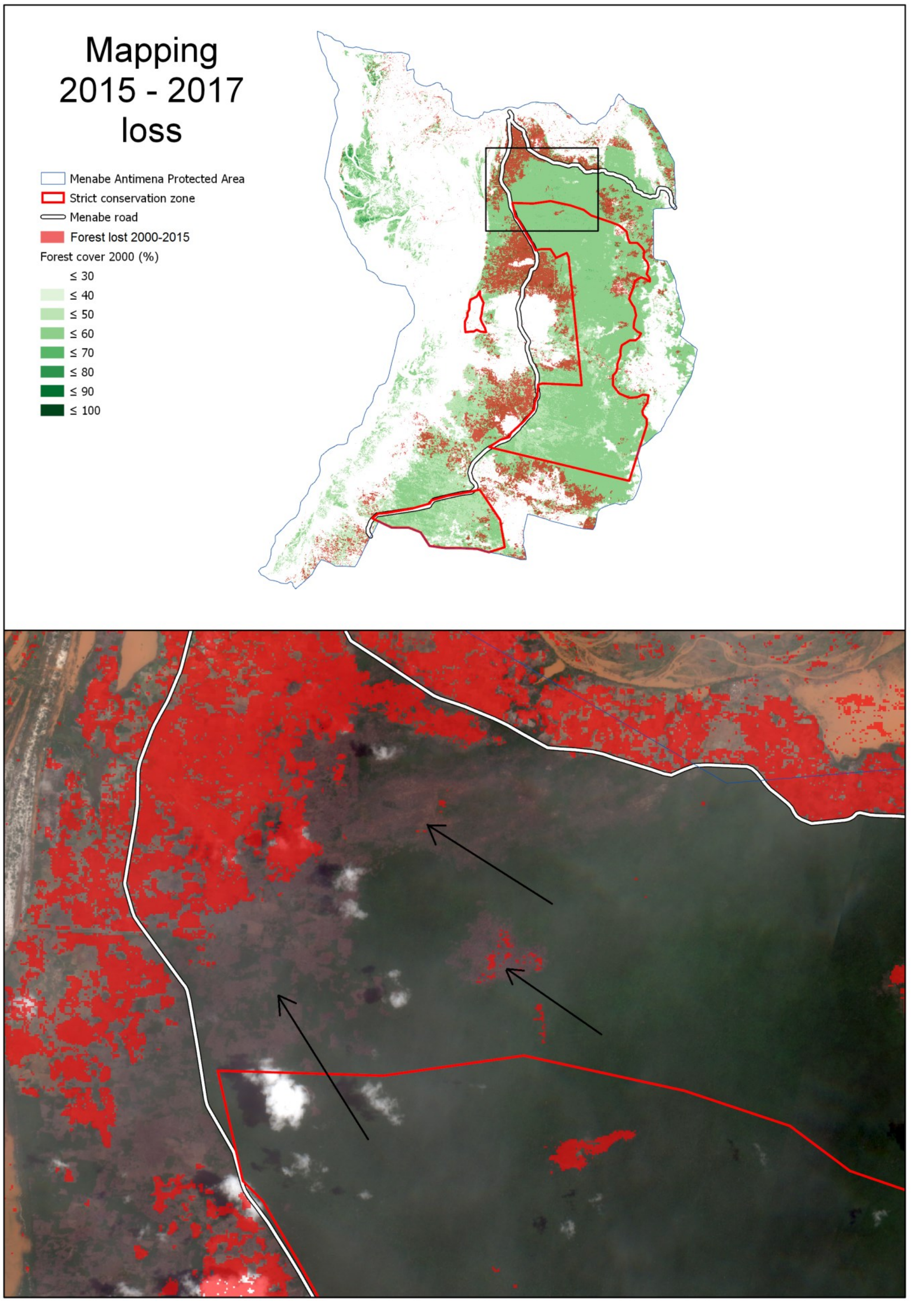

Figure 15. High resolution satellite image identifying areas of likely deforestation between 2015 and 2017. Here there are areas of deforestation apparent on the edge of, and within the strict conservation zone in the north of the protected area. Major areas of concern are highlighted with arrows.

Recommendations

Halting this unprecedented increase in deforestation rate requires stronger governance and higher effectiveness of stakeholders at local and regional level. That will happen only if there is a shared goal and clear collaboration between government officials, civil societies and local authorities.

An MoU between the Ministry of the Environment, Ecology and Forests, the Ministry of Agriculture and the Ministry of Tourism should determine the balance between conservation, agriculture and tourism in the region, benefitting all without impacting the economy of the country.

It is vital to ensure that at least all strict conservation zones within the protected area are strictly protected to guarantee long term provision of ecosystem services, including protection of wildlife. Strict conservation zones should therefore be physically marked with visible posts so that people can recognise them easily. This simple, low-tech action could contribute greatly to improved conservation.

Reinforcing media communication with local journalists and improving law enforcement (especially now that the local convention 'dina' is approved by the tribunal) will lead to 'zero' slash and burn agriculture within strict conservation zones. Mindful of the needs of extremely poor people who rely on slash and burn agriculture, they should be offered space within public lands in each commune to grow crops for income and food. Improving agricultural techniques (e.g. composting) and providing each village with tangible support (e.g. other local business model), will help reduce deforestation.

Conducting negotiations with private companies and collectors on how best to discourage illegal farming within the protected area, though difficult to achieve, would help mitigate the issue.

All of this should be preceded by strong public awareness campaigns, under the coordination of the regional direction of environment, ecology and forests, to reinforce the importance of forests to people and wildlife.

Methods

Mapping Forest Loss

Forest loss products were downloaded from Global Forest Watch (www.globalforestwatch.org). The forest loss product (Hansen et al. 2013) is mapped at a 0.00025 degree resolution which is approximately 30m at the equator. The Hansen product runs a learning algorithm on annual USGS Landsat data to determine whether deforestation has occurred at each pixel. A pixel was considered forested if the canopy cover was over 30% by trees of over 5m in height in 2000. Tree cover loss was defined as stand replacement disturbance or the complete removal of tree cover canopy at the Landsat pixel scale. Areas of forest lost in hectares were estimated by dividing the number of grid cells (approx. 900 m^2) deforested by 900.

Projecting Forest Loss

Three models of best fit were created for the forest loss data (in hectares) in R (R core team, 2015). The first was a straight line, the second, a second order polynomial and the third, a third degree polynomial. A chi-squared test was then conducted on nested, successive models to determine the best fit model.

Mapping Projected Forest Loss

Buffers were created in QGIS (QGIS development team, 2017) around each deforested pixel in 2015 of a radius that resulted in the number of pixels being deforested being approximately the same as predicted by the best fitting model (see section 5.2). This resulted in forecasting of uniform future forest loss across the protected area, however in reality there will likely be hotspots of forest loss, but more accurate projections are beyond the remit of this study.

Impact On Site Endemic Species

Species ranges were downloaded from the website of the IUCN Red List of Threatened Species (www.iucn.org). The number of deforested pixels in each future loss map (as per section 5.3) were then counted within each species range polygon and multiplied by 0.09 in order to estimate the area of forest lost in hectares.

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