Deforestation process in the dry forests of the Menabe region, western Madagascar – Mission report

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1. Context

Objectives

In the framework of the BioSceneMada project, one of the objectives is to model the deforestation process in order to be able to build scenarios of deforestation in the future and help decision for biodiversity conservation. To model and forecast deforestation, we must (i) identify the main factors responsible of the deforestation, (ii) estimates the effects of each of this factor on the deforestation, (iii) model the deforestation process with a statistical model, and (iv) forecast the deforestation projecting the effects of the explicative factors in the future. For this work to be done, it is necessary to rely on accurate historical deforestation maps. The objective of the field mission was first to validate the historical deforestation map for Madagascar on the period 1990-2000-2010 using field observation points. Second, the objective was to identify the main factors responsible of the deforestation, explaining both the intensity of deforestation and the location of the deforestation through household and stakeholder surveys. Third, the objective was to assess the accuracy of our predictive model of deforestation, based on a comparison between predicted and observed deforestation on the period 2010-2014 and discussing the realism of our scenarios and projections with local experts. We focused on two main study areas, one including the Kirindy-Mitea national park (KMNP, E: 43.67555, W: 44.35067, S: -21.36469, N: -20.50137) and the other one including the Menabe-Antimena new protected area (MANAP, E: 44.20934, W: 44.8185, S: -20.3644, N: -19.55838) in the Menabe region (west of Madagascar).

Basic informations

- Project: BioSceneMada (Cirad)
- Sites: Kirindy-Mitea national park (KMNP) and Menabe-Antimena new protected area (MANAP)
- Dates: from 4th to 12th of June 2016
- Participants: Clovis Grinand (1), Miguel Pedrono (2), Tsiky Rabetrano (3), Bruno Rakotoarivelo (4), Fety A. Rakotomalala (1), Dimby Razafimpahanana (3) and Ghislain Vieilledent (2,5)
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Program

- Saturday 04th: Antananarivo – Morondava
- Sunday 05th: Morondava – Belo-sur-Mer. Contact with Stefan, keeper at Madagascar National Park (MNP) office
- Monday 06th: deforestation from cyclone and uncontrolled fires in KMNP and savannas
- Thuesday 07th: visit to the dunes and lake in KMNP and illegal logging. Discussion with KMNP conservation director
- Wednesday 08th: avorted trial to see the "Sentier des baobabs". Discussion at the Ecolodge du Menabe with Roland Eve from WWF
- Thursday 09th: Belo-sur-Mer – Morondava – Marofandilia. Meeting with Direction Régionale des Eaux et Forêt (DREF) in Morondava
- Friday 10th: deforestation from *"hatsake"* around Kirindy-Village and Lambokely. Contact with EPFL PhD student. Visit of the de Haulme concession
- Saturday 11th: Naturalist observations around Bedo lake
- Sunday 12th: Marofandilia – Antananarivo

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- Roland Eve, reve@wwf.mg, Landscape Planning and Management advisor and Chief Technical advisor WWF MDCO
- Mme Cynthia, Directrice par intérim, Direction Régionale des Eaux et Forêts, région Menabe
- Rebecca Lewis, rjlewis@austin.utexas.edu, Associate Professor, Antrhopology, University of Texas, Director of the Ankoasikafa research station in KMNP. Study of Verreaux's sifaka (*Propithecus verreauxi*)
- Tahina Riniavo, tahinariniavo@gmail.com, NGO Fanamby, Responsable conservation Menabe-Antimena

2. Summary

1. Madagascar is recognized for both its unparralleled biodiversity, concentrated mainly in tropical forests (Fig. 1), and its high level of threat which is associated in particular to deforestation. Madagascar population, which is rapidly increasing, is one of the poorest in the world and people rely strongly on forests for their livelihood. Since the end of the colonization (in 1960), much effort has been done to fight poverty and curb deforestation through implementing large development and conservation programs. Despite this, Madagascar remains in the top countries with the highest deforestation rates and the forest cover, particularly in the western dry ecoregion, is rapidly decreasing.

2. To try to explain why it is so difficult to stop deforestation in Madagascar, we analyzed further the deforestation process in two dry forest areas in the central Menabe (western Madagascar) around two protected areas with high biodiversity, the Kirindy-Mitea national park and the Menabe-Antimena new protected area. We derived historical deforestation maps for these two areas from Landsat satellite images on the periods 1990-2000-2010-2014. We validated these maps and identified the main causes of deforestation with field verification points and through household and stakeholder surveys. We then established a map of the future deforestation on the period 2010-2050 assuming a business-as-usual scenario.

3. We showed that deforestation had recently increased in the two study areas, with a deforestation rate of about 2.35%.yr-1 on the period 2010-2014 compared to 0.85%.yr-1 on the period 2000-2010. We identified two major causes of deforestation, the first one being illegal slash-and-burn agriculture for the cultivation of peanut and maize as cash crops, the second one being uncontrolled forest fires after

cyclonic events. These fires are set by farmers in nearby grasslands to obtain flush of green pasture for livestock. Agents from institutions in charge of the management of the protected areas do not have the means to inforce law against deforestation. Slash-and-burn agriculture intensified recently due to the settlement or migrants following climate-induced famines in southern Madagascar. Money earned by farmers from peanut and maize productions is used to invest into zebu cows. Peanut production is exported outside Madagascar and a large part of the maize production is used to brew the national beers. These activities benefit to several intermediaries, some of who having political responsibilities, which underlies a conflict of interest in the application of the law against deforestation.

4. *Conclusions:* In the absence of an efficient strategy to stop deforestation, we expect that half of the forest present in 2000 will have disappeared before 2050. Forest loss, apart from biodiversity loss and climate-change global issues, will be at the expense of local population. Contrary to what is commonly accepted, deforestation in western Madagascar is not associated to agriculture for autoconsumption. International pressure should be put on the Malagasy government to apply in the first place the law of the environmental code and make use of repressive measures to stop deforestation. Of course, these measures must be accompagnied by incentive measures, through for example agricultural development programs, to offer alternatives to deforestation when necessary.

Keywords: biodiversity conservation, protected areas, Madagascar, deforestation causes, illegal logging, slash-and-burn agriculture, cyclones, fires, demographic growth.

3. Results

3.1 Historical deforestation

The deforestation rate has continuously increased since 1990 for the two study areas (Table 1). We estimated that 3960 ha and 3295 ha of forest have disappeared annually on the period 2010-2014 in the study areas around the Kirindy-Mitea national park and the Menabe-Antimena new protected area, respectively. This represent annual deforestation rates of about 2.35%.yr-1. The annual deforestation has more than doubled on the period 2010-2014 compared to the period 2000-2010, with an annual deforestation rate on this period of about 0.85%.yr-1. In the study area around the Kirindy-Mitea national park, mosaic deforestation associated to slash-and-burn agriculture occured outside the protected area, showing a relative effectiveness of the protected area to prevent deforestation (Fig. 2a, label A). Much larger patches of deforestation have been observed on the period 2010-2014 on the east part of the protected area associated to uncontrolled fires after cyclone events (Fig. 2a, label B). Dispersed and small-scale deforestation has also been observed in the northern and western part of the park associated to illegal logging activities (Fig. 2a, label B). In the Menabe-Antimena new protected area, large patches of deforestation were surprisingly not associated to uncontrolled fires but to slash-and-burn agriculture. Most of the deforestation occured around the Kirindy and Lambokely villages and at the south of Belo-sur-Tsiribihina (Fig. 2a).

Site	D90-00	D00-10	D10-14	D10-50,S1	D10-50,S2
KMNP	833 (0.43%)	1565 (0.85%)	3960 (2.34%)	1205 (0.80%)	2239 (1.78%)
MANAP	1042 (0.64%)	1301 (0.87%)	3295 (2.38%)	1162 (0.98%)	1841 (1.79%)

Table 1: **Evolution of the annual deforestation with time in the Kirindy-Mitea national park (KMNP) and the Menabe-Antimena new protected area (MANAP).** *D00-10*, *D10-14* and *D10-50*: annual deforestation (in ha.yr-1) for the periods 2000-2010, 2010-2014 and 2010-2050, respectively followed by the annual deforestation rate in %.yr-1. The annual deforestation has more than doubled on the period 2010-2014 compared to the period 2000-2010. The last column of the table indicates the mean annual deforestation on the period 2010-2050 resulting from the projection of the forest cover in 2050.

Figure 1: **Emblematic species representative of the biodiversity of the central Menabe.** The dry forest of the central Menabe is home to a very large number of species, many of which being endemic to the region. We present here some examples of this biodiversity for different taxonomic groups: Plants, Birds, Mammals (including Lemurs), Amphibians, Reptiles. From top-left to bottom-right: 1. *Adansonia grandidieri* (Baillon, 1888), 2. *Adansonia suarezensis* (Perrier de la Bâthie,1952), 3. *Aglyptodactylus laticeps* (Glaw, Vences & Böhme, 1998) 4. *Cryptoprocta ferox* (Bennett, 1833), 5. *Falco newtoni* (Gurney, 1863), 6. *Furcifer labordi* (Grandidier, 1872), 7. *Hypogeomis antimena* (Grandidier, 1869), 8. *Leptosomus discolor* (Hermann, 1783), 9. *Mesitornis variegata* (Geoffroy Saint-Hilaire, 1838), 10. *Microcebus berthae* (Rasoloarison, Goodman & Ganzhorn, 2000), 11. *Mimophis mahafaliensis*, 12. *Mirza coquereli* (Grandidier 1867), 13. *Mungotictis decemlineata* (Grandidier 1867), 14. *Propithecus verreauxi* (Grandidier, 1867), 15. *Pyxis planicauda* (Grandidier 1867), 16. *Uroplatus guentheri* (Mocquard, 1908). Sources: 1,2,5,8,10,11: authors; 3: Miguel Vences; 4,6,7,9,13,14,15,16: Wikipedia; 12: Louise Jasper.

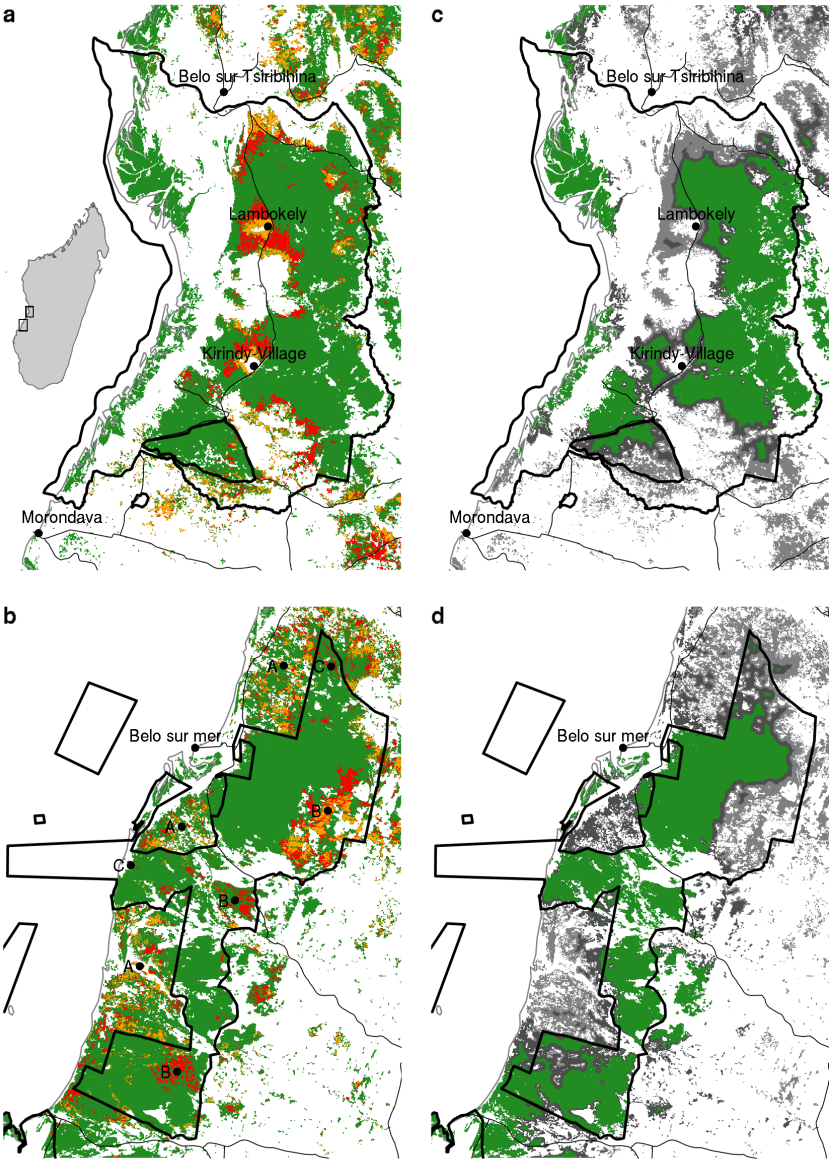

Figure 2: **Historical and forecasted deforestation in the study areas around the Kirindy-Mitea national park (KMNP) and Menabe-Antimena new protected area (MANAP).** Madagascar map is represented on the top left panel (a), with the Menabe-Antimena study area at the north and the Kinrindy-Mitea study area at the south (black rectangles). On each of the sub-panels, the boundaries of the protected areas are represented with black polygones (source: Rebioma project at http://rebioma.net). Main roads are represented with thin black lines (source: FTM BD500). Coast line is represented with a thin grey line. Morondava and Belo-sur-Tsiribihina are the main cities located near MANAP. Belo-sur-Mer is the main village located near KMNP. **a-b**: *Historical deforestation on the period 2000-2010-2014 for the Menabe-Antimena and Kirindy-Mitea study areas, respectively.* Green: forest cover in 2014, orange: 2000-2010 deforestation, red: 2010-2014 deforestation (source: BioSceneMada project at http://bioscenemada.net). In the Menabe-Antimena study area, the main cause of the deforestation is the slash-and-burn agriculture (*"hatsake"*) for maize and peanut crops. Most of the 2000-2014 deforestation occured around the villages of Kirindy and Lambokely. In the Kirindy-Mitea study area, the main causes of deforestation are (A) slash-and-burn agriculture, (B) cyclones followed by uncontrolled fires and (C) illegal logging. **c-d**: *Projected deforestation on the period 2010-2050.* Green: projected forest cover in 2050, light grey: 2010-2050 deforestation following conservative scenario S1 (projecting 1990-2010 mean annual deforestation), dark grey: 2010-2050 additional deforestation following scenario S2 (projecting 2000-2014 mean annual deforestation). Most of the 2010-2014 deforestation observed on panels (a-b) is included in the 2010-2050 projections. We predicted a loss of 36-55% of the forest cover in 2050 compared to 2000 depending on the scenario. Most of the remaining forest will be inside the protected areas.

3.2 Causes of deforestation

3.2.1 Slash-and-burn agriculture, uncontrolled fires and illegal logging

In the study area around the Menabe-Antimena new protected area, the main cause of deforestation was the slash-and-burn agriculture (also know as *"hatsake"*) for maize (*Zea mays* (Linné)) and peanut (*Arachis hypogaea* (Linné)) crop (Fig. 2a). The burning of forest provides nutrient rich ash and light for crops. Peanut is cultivated as cash crop and is transformed into peanut oil. A part of the production is at the destination of the national market but most of it is exported outside Madagascar, mainly for the Chinese market (Fig. 3). Maize is cultivated for auto-consumption and as cash crop. The production of maize is at the destination of the national market and is used in particular to brew national beers, such as the Three Horse Beer (THB) by the Malagasy company Star (bought in 2011 by the French company Castel) which is made from both barley and maize (Fig. 3). Peanut and maize are sold by farmers to resellers at the price of 7000 Malagasy francs (MGF) (equivalent to 1400 Malagasy ariary, MGA) and 2000 MGF (400 MGA) per kilo, respectively. For 2016, the production for a household was of 1.6 tonnes (T) of peanut and 2.5 T of maize, thus providing an annual income of about 3.24 millions MGA. With the money earned from the sale of the maize and peanut harvest, farmers invest in buying zebu cows (*"omby"*).

We identified three causes of deforestation in the study area around the Kirindy-Mitea national park (Fig. 2b). Slash-and-burn agriculture for maize crops was identified as the main cause of deforestation in several areas at the periphery of the protected area (Fig. 2b, label A). Inside the protected area, uncontrolled fires were identified as the main cause of deforestation (Fig. 2b, label B). People repeatedly set fire on former grasslands (*"bozake"*) outside the protected area to obtain flush of green pasture for their livestock. When uncontrolled, fires can spread on large areas of the forest and cross the boundaries of the protected area. In 2009, the cyclone named *"Fanele"* impacted a large area of the forest in the Kirindy-Mitea national park leaving a lot of wood fuel on the ground. This has allow uncontrolled fires to spread on large areas of the park in the years following the cyclone (Fig. 2b, label B). These fires were difficultly stopped with buckets of water and sand by the agents of the park with the help of the local people from surrounding villages. Illegal logging was also identify as a cause of deforestation in Kirindy-Mitea (Fig. 2b, label C). Timbers are mainly used for house and boat construction and sold in local markets in Belo-sur-Mer and Morondava.

3.2.2 Socio-economic causes of deforestation

Population growth

Population increase in central Menabe, associated to demographic growth and migration have accentuated the pressure on forest. The population of the Kirindy-Village and Lambokely villages (Fig. 2a) have been roughly multiplied by 5 between 2010 and 2015 (from about 600 to 3000 inhabitants for Kirindy-Village and from 1000 to 5000 for Lambokely). This was both due to demographic growth and migration. The demographic rate in Madagascar is close to 3%.yr-1 (Vieilledent et al., 2013) which means that the population doubles each 25 years on average. In Lambokely and Kirindy villages, the family we surveyed had all more than six children. Also the possibility of cropping cash crops have attracted many people from the south of Madagascar during the last years, in particular from the *"Androy"* region. First migrants arrived in the central Menabe to work in large agricultural concessions authorized by the French colonial government. Notably, many *"Antandroy"* migrants have arrived in the 1960s and established near the Beroboka village (located between Kirindy village and Lambokely) to work in the sisal (*Agave sisalana* (Perrine, 1838)) plantations of the de Haulme family which are now abandoned.

No application of conservation measures

Forest clearance is illegal in Madagascar since 1987 (Décret n°87-143, 20 April 1987), even outside the protected areas. However, the law is not respected nor applied. Almost nobody is prosecuted for forest clearance. During our stay in the field, seven people were arrested for doing slash-and-burn agriculture but were relaxed a few days later. The political crisis of 2009, followed by several years of political instability, have

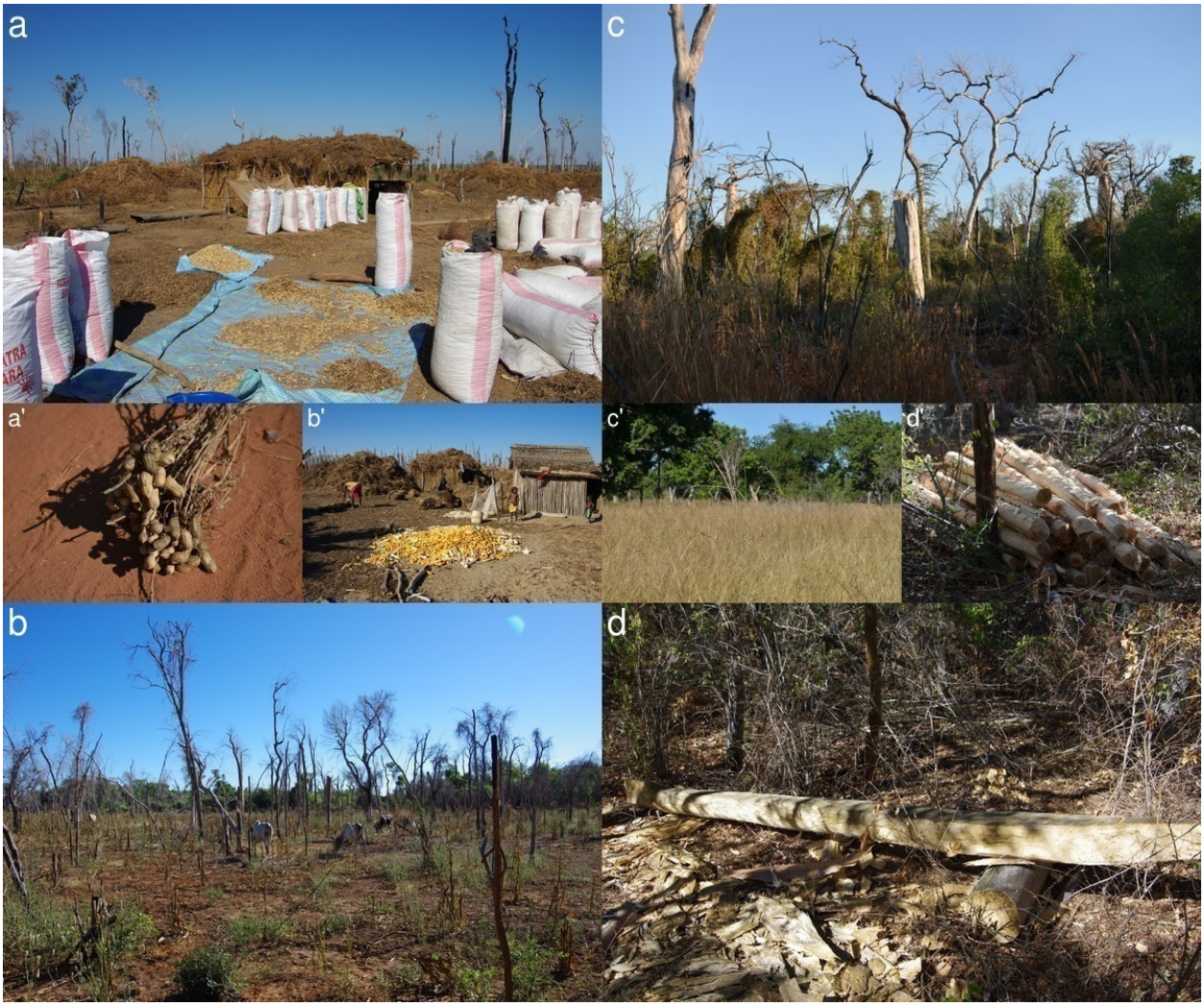

Figure 3: **Main causes of deforestation in central Menabe. a-a'**: *Slash-and-burn agriculture (*"hatsake"*) for peanut crop.* Peanut (a') is cultivated as a cash crop. Part of the production is at the destination of the national market but most of it is exported outside Madagascar, mainly for the Chinese market. **b-b'**: *Slash-and-burn agriculture for maize crop.* maize (b') is cultivated for auto-consumption and as a cash crop. The production of maize is at the destination of the national market and is used in particular to brew the national beers. **c-c'**: *Cyclone followed by uncontrolled fires.* Cyclone *"Fanele"* (2009) caused tree mortality and accumulation of wood fuel on the ground. As a consequence, uncontrolled fires set on nearby pastures (c') spread over large areas of forest after 2009. **d-d'**: *Illegal logging.* Timbers are used for house and boat construction.

reinforced this state of lawlessness. Indeed, many politics in Madagascar are also business leaders. Moreover, authorities have often economic interests in not stopping deforestation as they are often involved in the trade associated with cash crops. Regarding the institutes in charge of the management of the protected areas, such as the NGO Fanamby for the Menabe-Antimena new protected area or Madagascar National Park for the Kirindy-Mitea national parks, they have no means to enforce the laws. Their unique role concerning forest conservation in the field is to make populationx aware of the forest conservation issues, to inventory and monitore the biodiversity in the parks and to organize patrols to prevently avoid forest clearance or report offenses. But in any case they have the right to arrest people or to draw up a report and decide on a fine. Other NGOs can pay people from local communities (named *"polis ny ala"*) to patrol the forest but they have practically no power and will difficultly report illegal acts from known neighbours or relatives.

3.3 Projected deforestation

Following the conservative scenario S1 (projecting 1990-2010 mean annual deforestation) and the worst-case scenario S2 (projecting 2000-2014 mean annual deforestation), we predicted that 36-55% of the forest present in 2000 will have disappeared in 2050 (Table 2). On the period 2000-2014, around 17% of the forest have already disappeared. Forest in 2050 should remain preferentially in the protected areas but deforestation should not stop at the boundaries of the parks (Fig. 2c and 2d). The model predicted that deforestation in the future should occur close to places were deforestation occurred in the past, thus correctly simulating the contagious process of deforestation (Fig. 2). Deforestation is also more likely to occur at short distances to villages and roads and in the forest edge (Fig. 2c and 2d). Forest fragmentation is also predicted to increase in association to deforestation (see the higher number of disconnected forest patches in Fig. 2c and 2d). We estimated that most of the deforestation observed on the period 2010-2014 was included in the deforested area predicted by the model on the period 2010-2050, (60-82% for MANAP and 51-72% for KMNP for scenarios S1 and S2, respectively) thus validating partly the predictions of the location of the future deforestation (Fig. 2c and 2d).

Site	Area	F1990	F2000	F2010	F2014	F2050,S1	F2050,S2
KMNP	388493	198988	190655	175006	159166	126801	85464
MANAP	349229	166647	156223	143208	130028	96711	69588

Table 2: **Evolution of the forest cover with time in the Kirindy-Mitea national park (KMNP) and the Menabe-Antimena new protected area (MANAP).** *Area*: land area (in ha). *F2000*, *F2010* and *F2014*: forest area (in ha) for the years 2000, 2010 and 2014, respectively. *F2050*: projected forest area (in ha) for the year 2050. About 17% of the forest have disappeared on the period 2000-2014 in the two sites and we predict the loss of around 36% and 55% of the forest on the period 2000-2050 for the two sites assuming a conservative (projecting the 1990-2010 annual deforestation) or a worst-case scenario (projecting the 2000-2014 annual deforestation), respectively.

Acknowledgements

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Data availability statement

All the data and codes used for this study are made freely available in the "menabe" repository on the GitHub platform at the follow web address: https://github.com/ghislainv/menabe.git. The results and the

manuscript are fully reproducible running the R script `menabe.R` from the "menabe" repository.

Supplementary materials

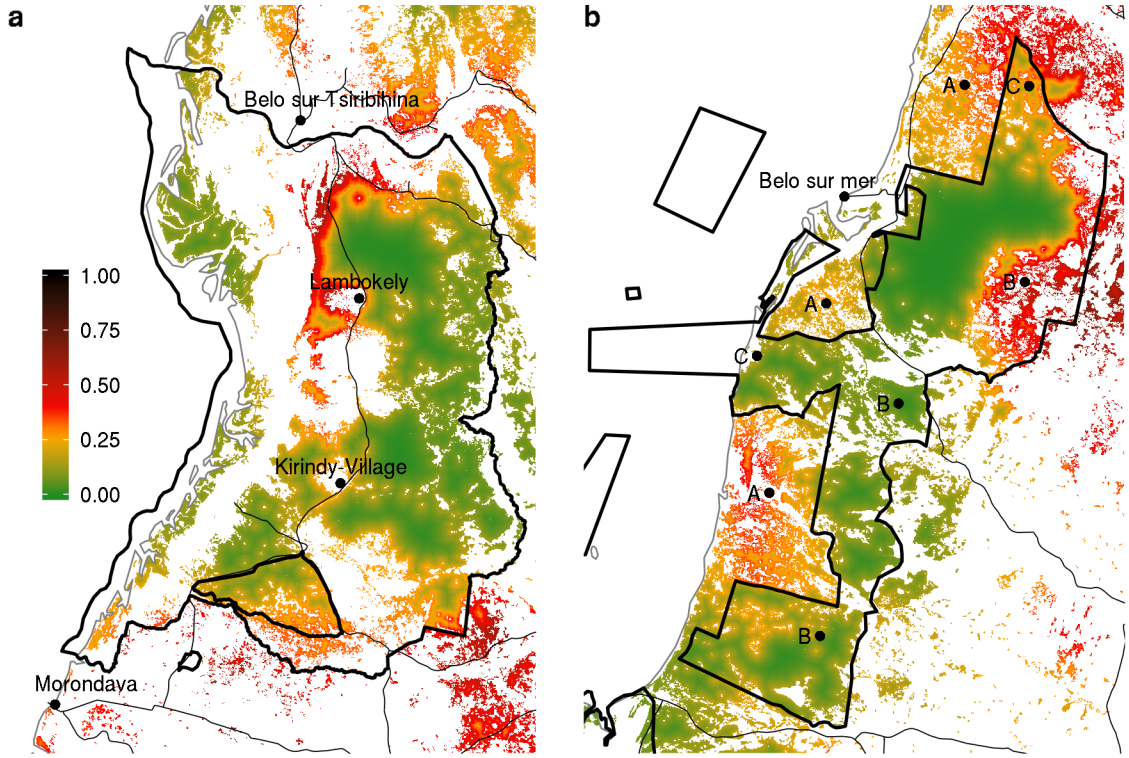

Figure 4: **Spatial probability of deforestation for the year 2010.**

References

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