Update to: Combining global tree cover loss data with historical national forest cover maps to look at six decades of deforestation and forest fragmentation in Madagascar[§]

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Abstract

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1 Introduction

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2 Data accessibility

Data and code used for this study have been made permanently and publicly available on the CIRAD Dataverse repository so that the results are entirely reproducible:

- Input data: http://dx.doi.org/10.18167/DVN1/2FP7LR

- Code: http://dx.doi.org/10.18167/DVN1/275TDF

- Output data: http://dx.doi.org/10.18167/DVN1/AUBRRC

3 References

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Harper, G.J., Steininger, M.K., Tucker, C.J., Juhn, D. & Hawkins, F. (2007) Fifty years of deforestation and forest fragmentation in Madagascar. *Environmental Conservation* **34**, 325–333.

MEFT, USAID & CI (2009) *Evolution de la couverture de forêts naturelles à Madagascar, 1990-2000-2005.*

Ministère de l'Environnement (1996) IEFN: Inventaire Ecologique Forestier National. Tech. rep., Ministère de l'Environnement de Madagascar, Direction des Eaux et Forêts, DFS Deutsch Forest Service GmbH, Entreprise d'études de développement rural "Mamokatra", FTM.

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Pekel, J.F., Cottam, A., Gorelick, N. & Belward, A.S. (2016) High-resolution mapping of global surface water and its long-term changes. *Nature* **540**, 418–422.

4 Tables

Table 1: **Change in natural forest cover and deforestation rates from 1953 to 2017 in Madagascar.** Areas are provided in thousands of hectares (Kha). Forest map for the year 1973 has 3.3 Mha of unclassified areas due to the presence of clouds on satellite images. As a consequence, partial deforestation rates for the periods 1953-1973 and 1973-1990 are computed based on the available forest extent. The last two columns indicate the annual deforested areas and annual deforestation rates on the previous time-period (e.g. 1953-1973 for year 1973, 1973-1990 for year 1990, etc.).

Year	Forest (Kha)	Unmap (Kha)	Annual defor. (Kha/yr)	Rate (%/yr)
1953	15,968	0	-	-
1973	14,241	3,317	86	0.6
1990	10,762	0	205	1.6
2000	9,879	0	88	0.8
2005	9,673	0	41	0.4
2010	9,320	0	71	0.7
2015	8,770	0	110	1.2
2017	8,446	0	162	1.9

Table 2: **Comparing Madagascar forest cover estimates with previous studies on the period 1953-2017**. We compared our estimates of forest cover with the estimates from three previous studies (Harper *et al.*, 2007; MEFT *et al.*, 2009; ONE *et al.*, 2015). Areas are provided in thousands of hectares (Kha). We obtained a Pearson's correlation coefficient of 0.99 between our forest cover estimates and forest cover estimates from previous studies. The increase in mangrove and spiny forest covers from 1953 to 1973 in Harper *et al.* (2007) and our study is most probably due to differences in forest definition and mapping methods between the 1953 aerial-photography derived map and the 1973 Landsat image derived map.

Forest type	Source	1953	1973	1990	2000	2005	2010	2013	2017
Total	Harper2007	15,996	14,173	10,606	8,982	-	-	-	-
	MEFT2009	-	-	10,650	9,678	9,413	-	-	-
	ONE2015	-	-	-	-	9,451	8,977	8,486	-
	this study	15,968	14,242	10,762	9,879	9,673	9,320	9,066	8,446
Moist	Harper2007	8,766	6,876	5,234	4,167	-	-	-	-
	MEFT2009	-	-	5,271	4,788	4,700	-	-	-
	ONE2015	-	-	-	-	4,556	4,457	4,345	-
	this study	8,578	6,989	5,270	4,872	4,771	4,633	4,478	4,145
Dry	Harper2007	4,252	4,028	2,712	2,457	-	-	-	-
	MEFT2009	-	-	3,321	3,085	3,028	-	-	-
	ONE2015	-	-	-	-	3,223	2,970	2,679	-
	this study	4,762	4,435	3,225	2,941	2,882	2,735	2,647	2,416
Spiny	Harper2007	2,978	3,030	2,420	2,132	-	-	-	-
	MEFT2009	-	-	2,124	1,872	1,757	-	-	-
	ONE2015	-	-	-	-	1,682	1,559	1,467	-
	this study	2,462	2,582	2,054	1,857	1,811	1,744	1,733	1,678
Mangroves	Harper2007	-	-	240	226	-	-	-	-
	MEFT2009	-	-	-	-	-	-	-	-
	ONE2015	-	-	-	-	174	171	170	-
	this study	143	200	181	178	178	177	177	176

Table 3: **Comparing Madagascar annual deforestation rates with previous studies on the period 1953-2013**. Annual deforested areas (in thousands of hectares per year, Kha/yr) and annual deforestation rates (second number in parenthesis, in %/yr) are provided. For deforestation rates in %/yr, exact same numbers as in scientific articles and reports from previous studies (Harper *et al.*, 2007; MEFT *et al.*, 2009; ONE *et al.*, 2015) have been reported. The way annual deforestation rates in %/yr have been computed in these previous studies can slightly differ from one study to another, but estimates always correct for the potential presences of clouds on satellite images and unclassified areas on forest maps. Annual deforested areas in Kha/yr have been recomputed from forest cover estimates in Tab. 2 (except for Harper *et al.* (2007) for the periods 1973-1990 and 1990-2000 for which annual deforested areas in Kha/yr were derived from numbers reported in the original publication, see methods) and do not correct for the potential presence of clouds.

Forest type	Source	1953-1973	1973-1990	1990-2000	2000-2005	2005-2010	2010-2013
Total	Harper2007	91 (0.3)	200 (1.7)	81 (0.9)	-	-	-
	MEFT2009	-	-	97 (0.8)	53 (0.5)	-	-
	ONE2015	-	-	-	-	95 (1.2)	164 (1.5)
	this study	86 (0.6)	205 (1.6)	88 (0.9)	41 (0.4)	71 (0.7)	85 (0.9)
Moist	Harper2007	94 (0.6)	87 (1.7)	32 (0.8)	-	-	-
	MEFT2009	-	-	48 (0.8)	17 (0.4)	-	-
	ONE2015	-	-	-	-	20 (0.5)	37 (0.9)
	this study	79 (1.0)	101 (1.6)	40 (0.8)	20 (0.4)	28 (0.6)	52 (1.1)
Dry	Harper2007	11 (0.2)	77 (1.9)	20 (0.7)	-	-	-
	MEFT2009	-	-	24 (0.7)	11 (0.4)	-	-
	ONE2015	-	-	-	-	51 (1.8)	97 (2.3)
	this study	16 (0.4)	71 (1.9)	28 (0.9)	12 (0.4)	30 (1.0)	29 (1.1)
Spiny	Harper2007	-3 (-0.1)	36 (1.2)	28 (1.2)	-	-	-
	MEFT2009	-	-	25 (1.2)	23 (1.2)	-	-
	ONE2015	-	-	-	-	25 (1.7)	31 (1.7)
	this study	-6 (-0.2)	31 (1.3)	20 (1.0)	9 (0.5)	13 (0.8)	4 (0.2)
Mangroves	Harper2007	-	-	1 (0.2)	-	-	-
	MEFT2009	-	-	-	-	-	-
	ONE2015	-	-	-	-	0 (0.3)	0 (0.2)
	this study	-3 (-1.7)	1 (0.6)	0 (0.2)	0 (0.0)	0 (0.0)	0 (0.0)

Table 4: **Change in forest fragmentation from 1953 to 2017 in Madagascar**. Five forest fragmentation classes, based on the percentage of forest in the neighborhood, are defined: 0-20% (highly fragmented), 21-40%, 41-60%, 61-80% and 81-100% (lowly fragmented). The percentage of forest falling in each forest fragmentation class is reported for each year. Forest areas are provided in thousands of hectares (Kha).

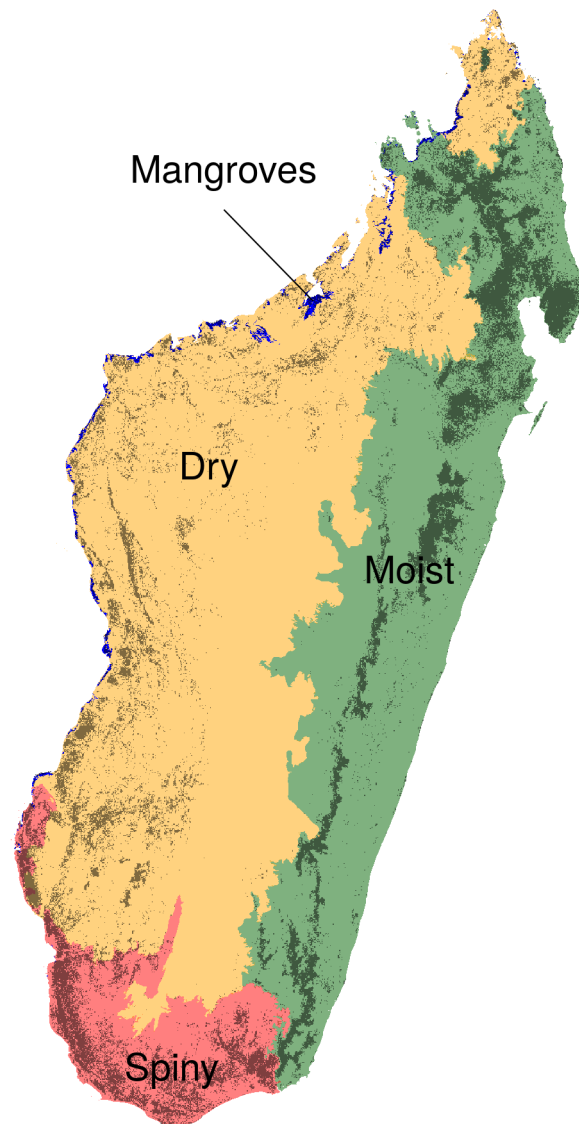| Year	Forest (Kha)	0-20	21-40	41-60	61-80	81-100
1953	15,968	0	1	8	12	78
1973	14,242	6	9	12	16	57
1990	10,762	7	10	13	17	53
2000	9,879	7	11	14	17	51
2005	9,673	8	11	14	18	49
2010	9,320	8	12	15	18	47
2015	8,770	9	14	16	19	43
2017	8,446	10	14	16	18	41

5 Figures

Figure 1: **Ecoregions and forest types in Madagascar.** Madagascar can be divided into four climatic ecoregions with four forest types: the moist forest in the East (green), the dry forest in the West (orange), the spiny forest in the South (red), and the mangroves on the West coast (blue). Ecoregions were defined following climatic (Cornet, 1974) and vegetation (Ministère de l'Environnement, 1996) criteria. The dark grey areas represent the remaining natural forest cover for the year 2017. Forest types are defined on the basis of their belonging to one of the four ecoregions.
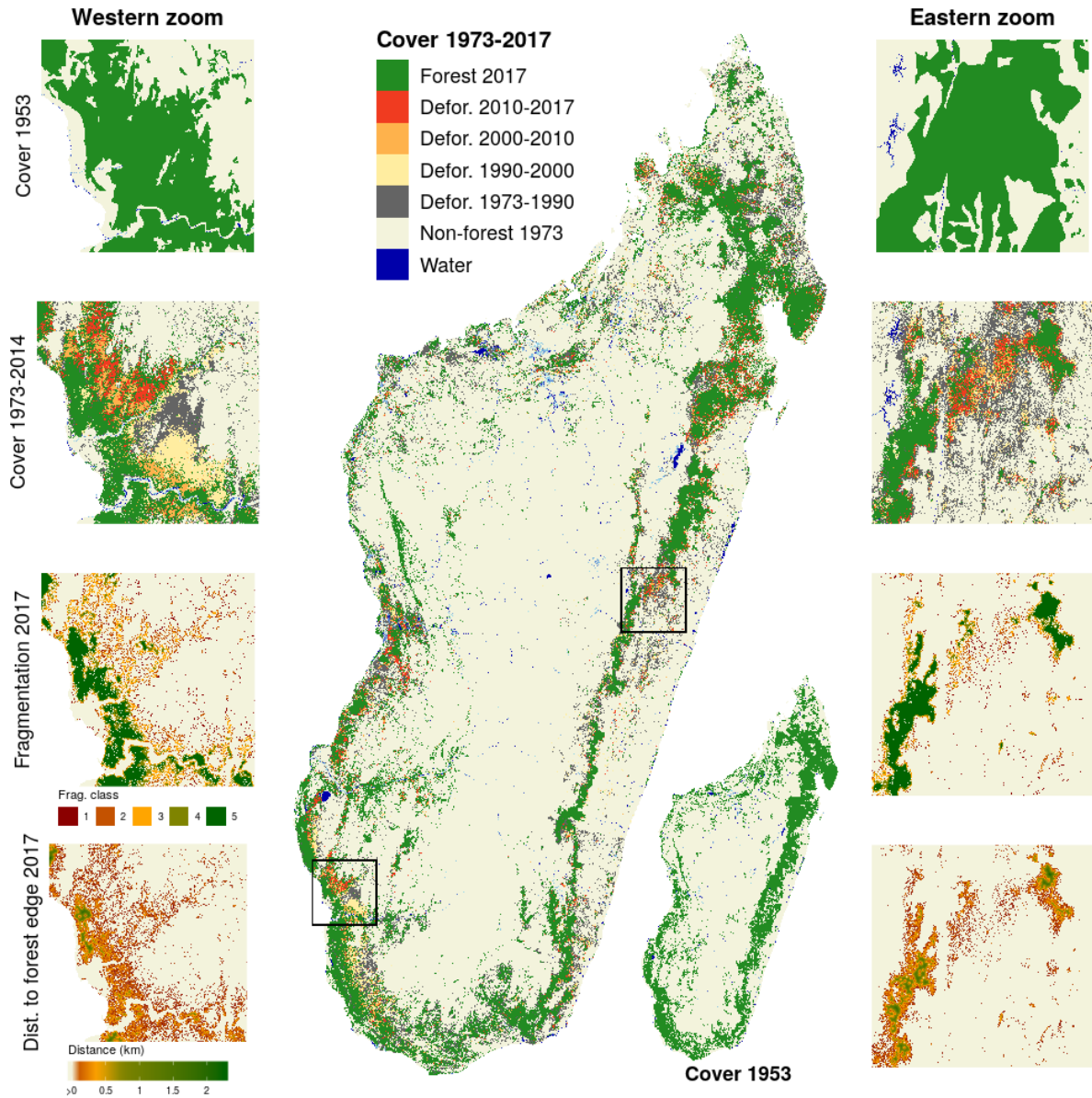
Figure 2: **Forest cover change on six decades from 1953 to 2017 in Madagascar.** forest cover changes from 1973 to 2017 are shown in the main figure, and forest cover in 1953 is shown in the bottom-right inset. Two zooms in the western dry (left part) and eastern moist (right part) ecoregions present more detailed views of (from top to bottom): forest cover in 1953, forest cover change from 1973 to 2017, forest fragmentation in 2017 and distance to forest edge in 2017. Data on water bodies (blue) and water seasonality (light blue for seasonal water to dark blue for permanent water) has been extracted from Pekel *et al.* (2016).
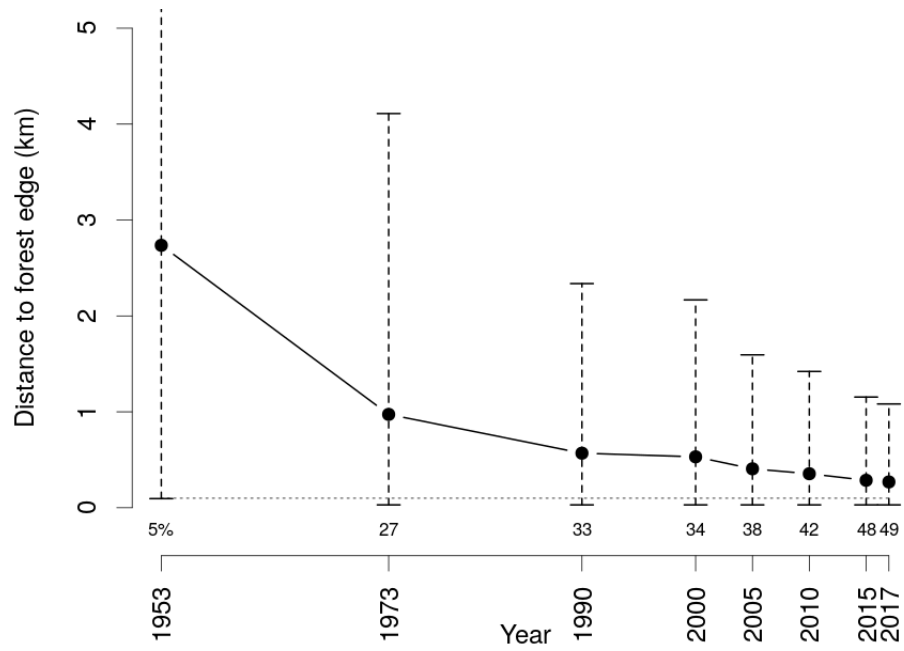
Figure 3: **Change in distance to forest edge from 1953 to 2017 in Madagascar.** Black dots represent the mean distance to forest edge for each year. Vertical dashed segments represent the 90% quantiles (5% and 95%) of the distance to forest edge. Horizontal dashed grey line indicates a distance to forest edge of 100 m. Numbers at the bottom of each vertical segments are the percentage of forest at a distance to forest edge lower than 100 m for each year.