

BIODIVERSITY SCENARIOS IN MADAGASCAR

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OBJECTIVES: BIODIVERSITY UNDER CLIMATE CHANGE AND DEFORESTATION

The **BioSceneMada** project aims at obtaining biodiversity scenarios under the effects of both climate change and anthropogenic deforestation in Madagascar with the objective of identifying priority areas for conservation.

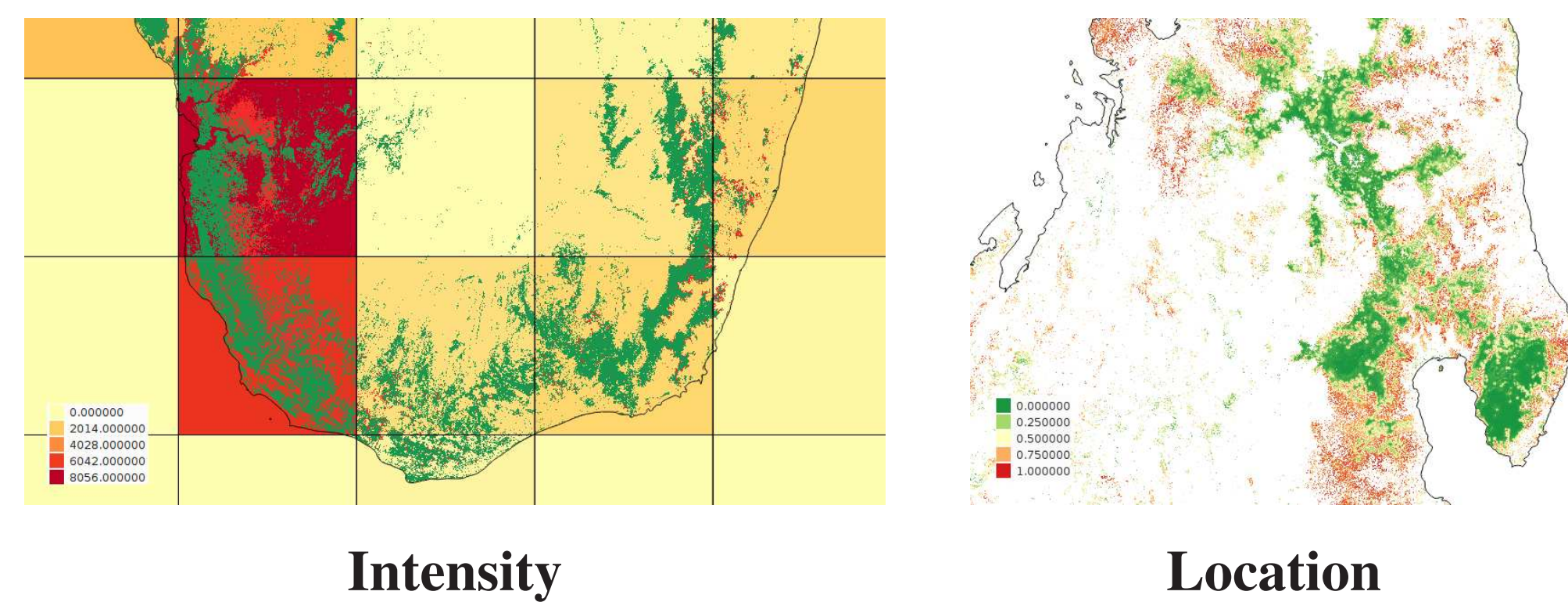
DEFORESTATION MODELLING

Data: Cloud free 1990-2010 30 m resolution deforestation map obtained from Harper *et al.* (2007) and Hansen *et al.* (2013).

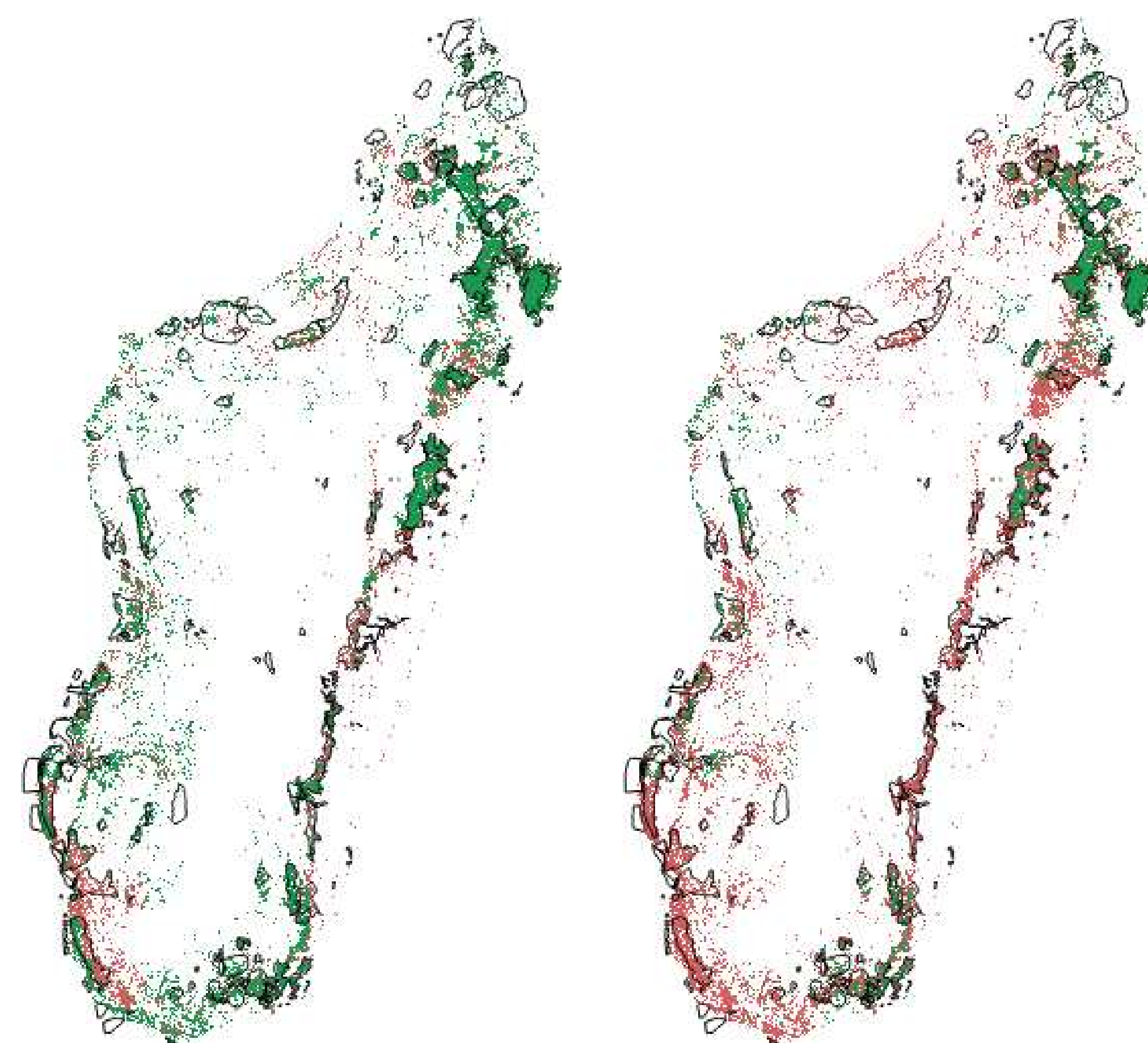
Intensity model: Mean annual deforestation area (in ha.yr⁻¹) for each 120 × 120 km grid cell on the period 1990-2010. National average: ~73,000 ha.yr⁻¹

Location model:

- At the pixel level (30 m resolution).
- δ : spatial probability of deforestation on 2000-2010.
- $\delta = f(\text{spatial environmental factors})$
- Environmental factors: landscape (dist. to forest edge, dist. to 1990-2000 past deforestation), accessibility (altitude, dist. to road, town, river), land-policy (protected area network).
- Algorithm used to fit the model: **randomForest**.

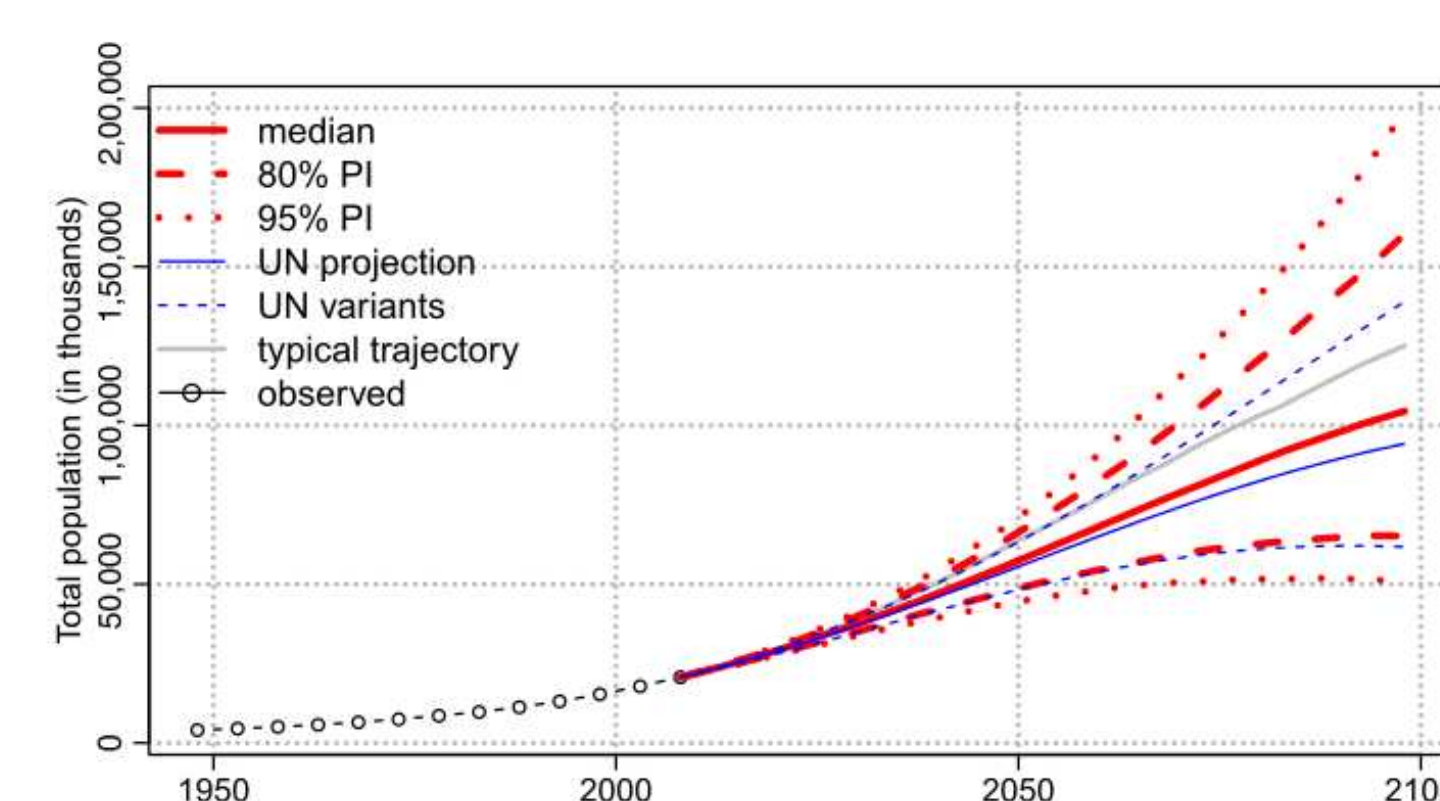


FOREST MAPS IN 2050 AND 2100



■ deforestation 2010-2050/2100 ■ forest in 2050/2100

DEMOGRAPHIC GROWTH



Actual population growth rate is ~3%.yr⁻¹ (Vieilledent *et al.*, 2013b). No demographic transition before 2050. More than 50 M people in 2050 compared to 20 M in 2010 (Raftery *et al.*, 2012).

REFERENCES DEFORESTATION

- Harper *et al.* (2007) Fifty years of deforestation and forest fragmentation in Madagascar. *Environmental Conservation*, **34**, 325–333.
Hansen *et al.* (2013) High-resolution global maps of 21st-century forest cover change. *Science*, **342**, 850–853.
Raftery *et al.* (2012) Bayesian probabilistic population projections for all countries. *PNAS*, **109**, 13915–13921.
Vieilledent *et al.* (2013b) Forecasting deforestation and carbon emissions in tropical developing countries facing demographic expansion: a case study in Madagascar. *Ecol. and Evol.*, **3**, 1702–1716.

IMPACT OF CLIMATE CHANGE

Through the project, we also aim at estimating the impact of climate on biodiversity at both the species and community level (distinguishing α and β diversity).

BIODIVERSITY DATA-SET

	Group	Species	Genus	Obs.
Plants	Trees	531	283	40178
	Palms	178	16	5105
	Ferns	317	82	1664
	Legumes	724	149	30305
	Grasses	283	113	3469
	Other	1229	359	34265
Vertebrates	Mammals	189	69	28316
	Lemurs	64	15	3136
	Birds	285	172	60895
	Reptiles	153	41	4938
	Amphibians	78	21	208
Invertebrates	Snails	537	113	1635
	Ants	379	46	70012
	Butterflies	262	82	16396
	Other	355	203	6202
	TOTAL=		4969	1749

Various sources: web (ReBioMa.net), research institutes, articles. Taxonomy checked with **taxize**.

SPECIES DISTRIBUTION MODELS

- Model averaging (glm, gam, RF, maxent) and ensemble forecasting for **4969** species (Vieilledent *et al.*, 2013a) with **R** package **biomod2** (Thuiller *et al.*, 2009).
- Present and future (IPCC AR5) climate data for Madagascar : <http://MadaClim.org>.
- Atlas of the biodiversity for Madagascar: species distribution and niche + vulnerability to climate change.
- Stacked SDMs for α and β diversity: present and future hotspots of biodiversity.

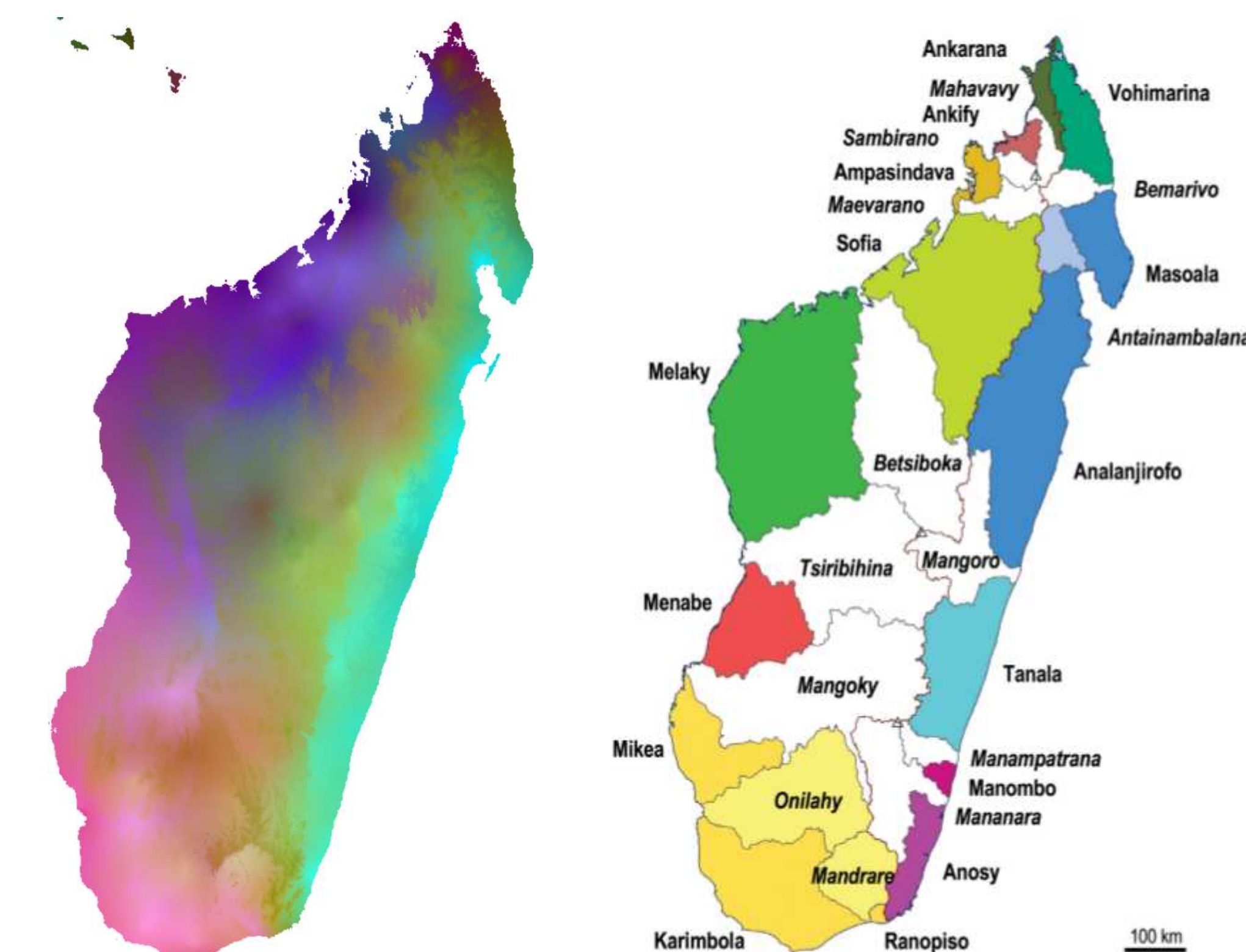
GENERALIZED DISSIMILARITY MOD.

- Modelling species turnover (Ferrier *et al.*, 2007).
- Bray-Curtis dissimilarity d_{ij} between pairs of locations i and j as a function of n environ. variables, x_1 to x_n :
 $-\ln(1 - d_{ij}) = a_0 + \sum_{p=1}^n |f_p(x_{pi}) - f_p(x_{pj})|$
- **R** package **gdm**.

PERSPECTIVES CLIMATE-CHANGE

- Habitat (β diversity) maps for Madagascar.
- Identifying biodiversity refuges under climate-change.
- Proposals to optimize the protected area network: priority areas, corridors, restoration.

CLIMATE/WATERSHED HYPOTHESIS



Climatic gradient

Watersheds

GDM RESULTS

Percentage of deviance explained.

Group	Clim	WS	C+WS	Full
Plants				
Trees	30	28	43	44
All	24	16	31	32
Animals				
Lemurs	56	84	87	88
Birds	8	3	9	11
Reptiles and Amphibians	34	33	40	40
Invertebrates	9	3	9	11
All	6	2	6	9

- Effect (relative and absolute) of climate and watersheds vary with taxonomic group.
- Importance of species dispersion abilities.
- Animal-vegetation relationship.

REFERENCES CLIMATE-CHANGE

- Ferrier *et al.* (2007) Using generalized dissimilarity modelling to analyse and predict patterns of beta diversity in regional biodiversity assessment. *Divers. and Distrib.*, **13**, 252–264.
Thuiller *et al.* 2009. BIOMOD – a platform for ensemble forecasting of species distributions. *Ecography*, **32**, 369–373.
Vieilledent *et al.* (2013a) Vulnerability of baobab species to climate change and effectiveness of the protected area network in Madagascar: Towards new conservation priorities. *Biol. Conserv.*, **166**, 11–22.

DEFORESTATION FORECASTS

Date	Forest area (Mha, 9.3 in 2010)
2050	6.4
2100	2.8

In 2050, forests are concentrated in protected areas. In 2100, forests remain only in remote areas at high altitude (Tsaratanana, Masoala-Makira peninsula).

PERSPECTIVES DEFORESTATION

- Different scenarios for deforestation intensity: with demographic growth or not, with lower deforestation rates assuming agricultural development.
- Effects of deforestation on biodiversity: including the forest cover (% in 1 km pixels) in SDMs and GDMs.
- Future biodiversity hotspots under high threat from deforestation.