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BioSceneMada

Forest carbon maps and climate-change

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FRB FONDATION POUR LA RECHERCHE SUR LA BIODIVERSITÉ

FFEM Fonds Français pour l'Environnement Mondial

Biodiversity modelling and scenarios
FRB FLAGSHIP PROGRAMME

1. Introduction
   - Tropical forests and climate change
2. Materials and methods
   - Forest inventory data
   - Modelling forest carbon stocks
   - Forecasting forest carbon storage
3. Results
   - Model performance and variable importance
   - Comparison with global carbon maps
   - Impact of climate change on carbon emissions
4. Discussion
   - Shifts in tree size and species composition
   - Conservative approach

Tropical forests and climate change

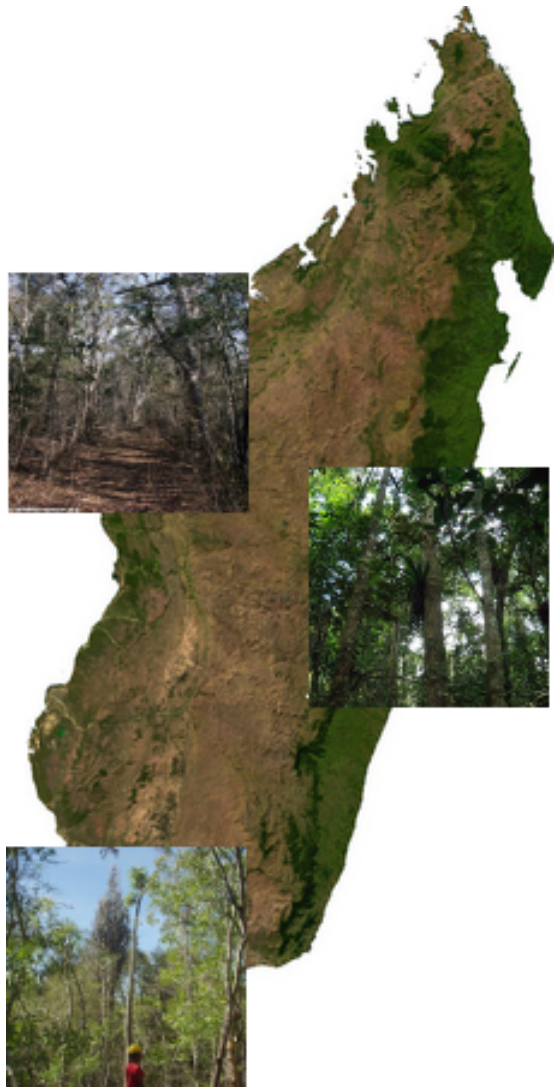
Impact of deforestation on climate

- Forest carbon stock : 861±66 Pg C (1 Pg=10^{15}g)
- 55% in tropical forests
- Tropical deforestation : 6–17% of carbon dioxide emissions

- **Impact of climate change on forest carbon stock ?**
- Carbon-cycle feedbacks ?

Objectives of the study

- Climate and tropical forest carbon stock relationship
- Correlative bioclimatic envelope models
- Madagascar : large climatic gradient



Objectives of the study

Spiny forest

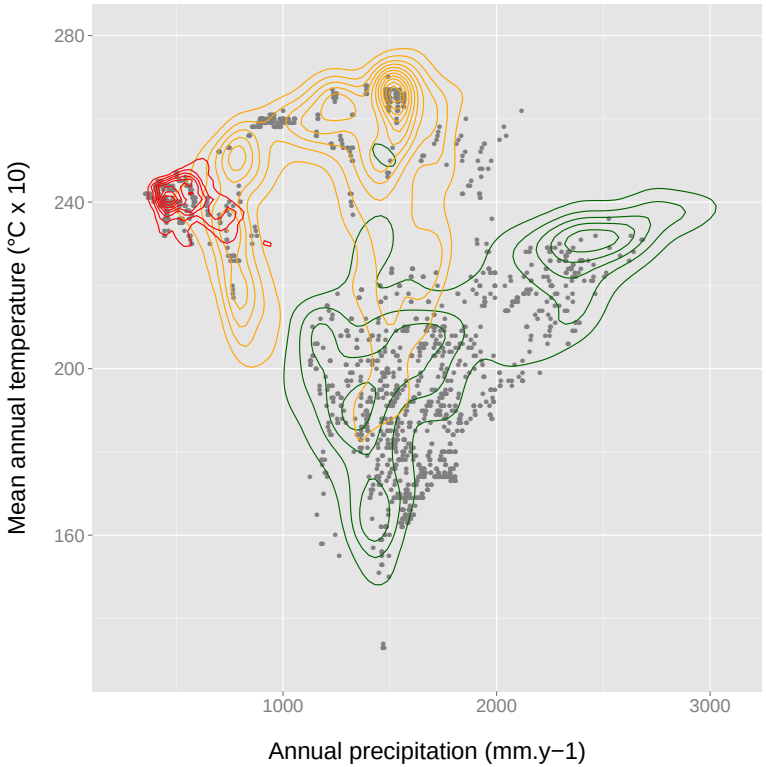
Spiny forest

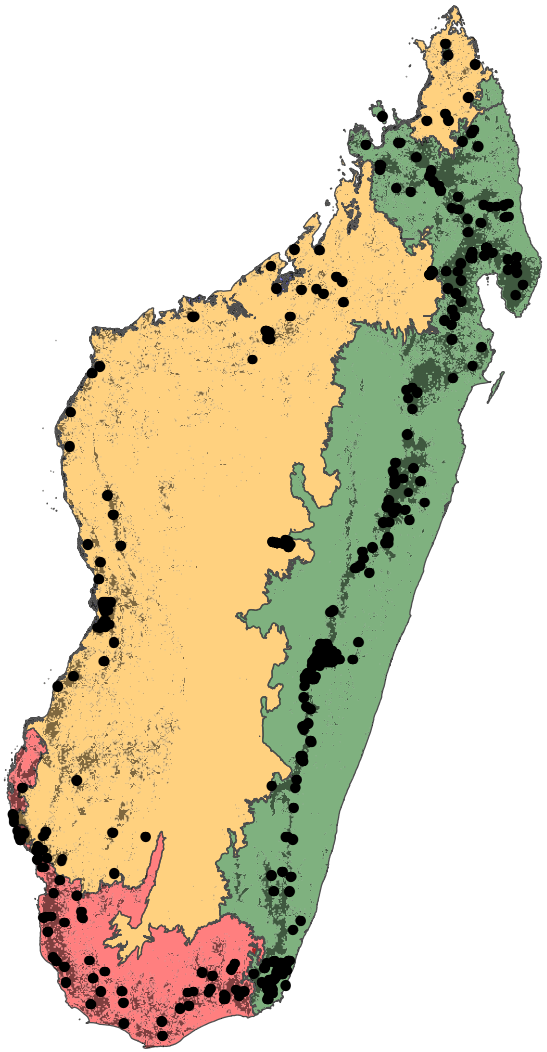
Dry forest

Moist forest

Forest inventory data

- 1771 forest plots (0.13 to 0.28 ha)
- Inventories : 1996-2013
- Eight institutions (Ministry, NGOs, research institutes)





Modelling ACD using the Random Forests algorithm

ACD = f(Topography + Vegetation indices + climate)

- topography : altitude (SRTM)
- vegetation indices : EVI, VCF (MODIS)
- climate : temp. seas, mean annual temp., annual precip.

- algorithm : Random Forests
- regression trees
- mean of multiple decision trees

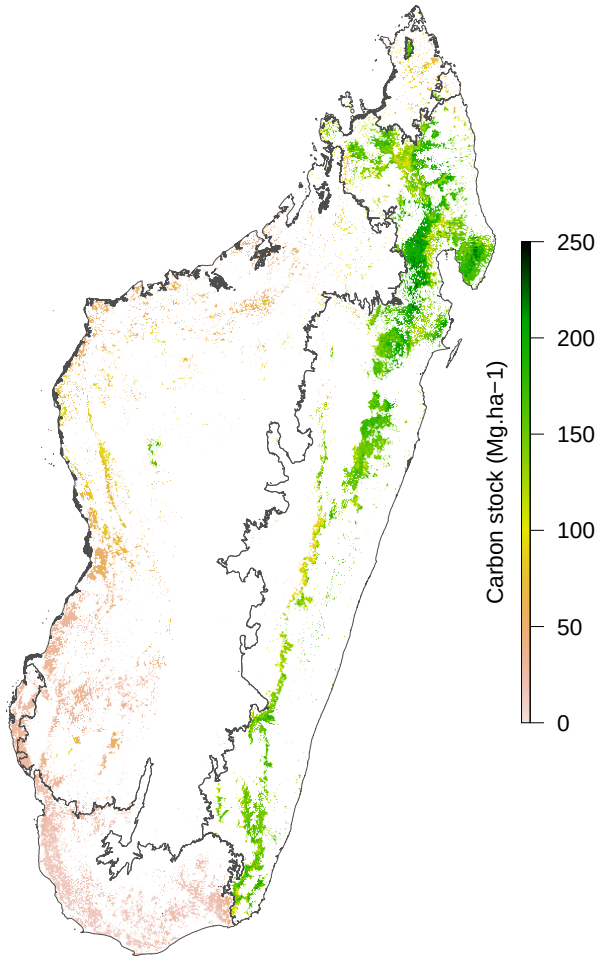
Deriving a 2010 forest carbon map

$$\mathbf{ACD}_{2010} = \text{f}(\text{Topography} + \text{Vegetation indices}_{2010} + \text{Climate}_{2010})$$

- Topography : SRTM (90 m)
- Vegetation indices : MODIS (250 m)
- Climate : WorldClim (1 km)

- Map of forest carbon stock
- For the year 2010
- At 250 m

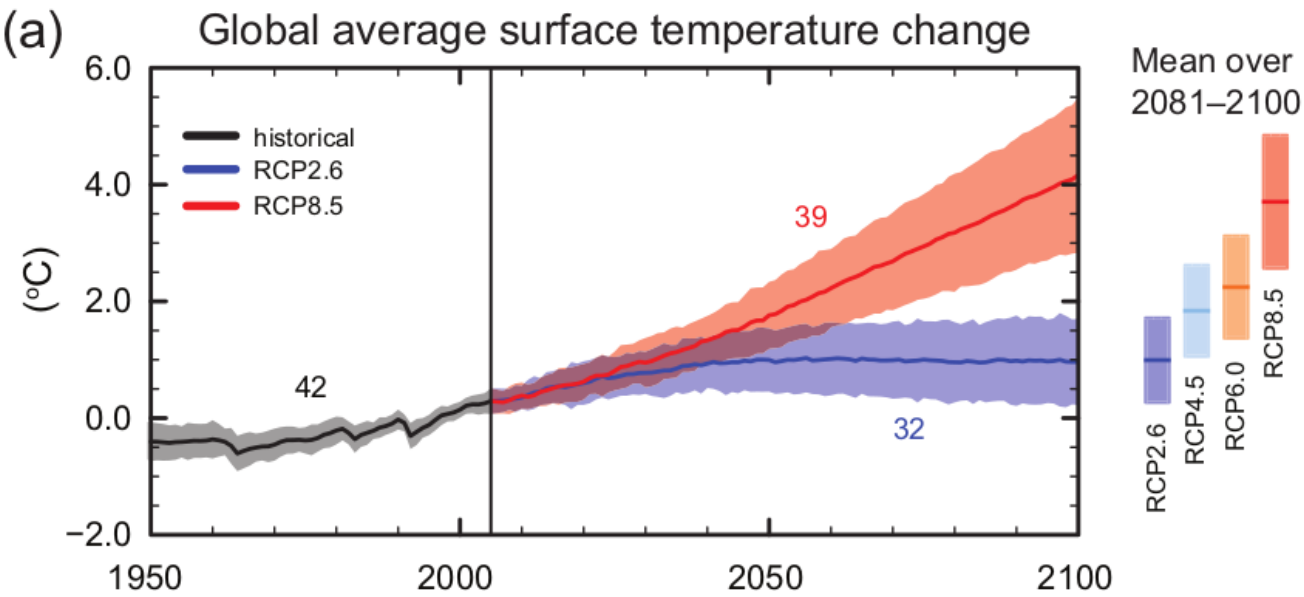
- bioscenemada.net/carbonmaps
- doi:10.5061/dryad.9ph68



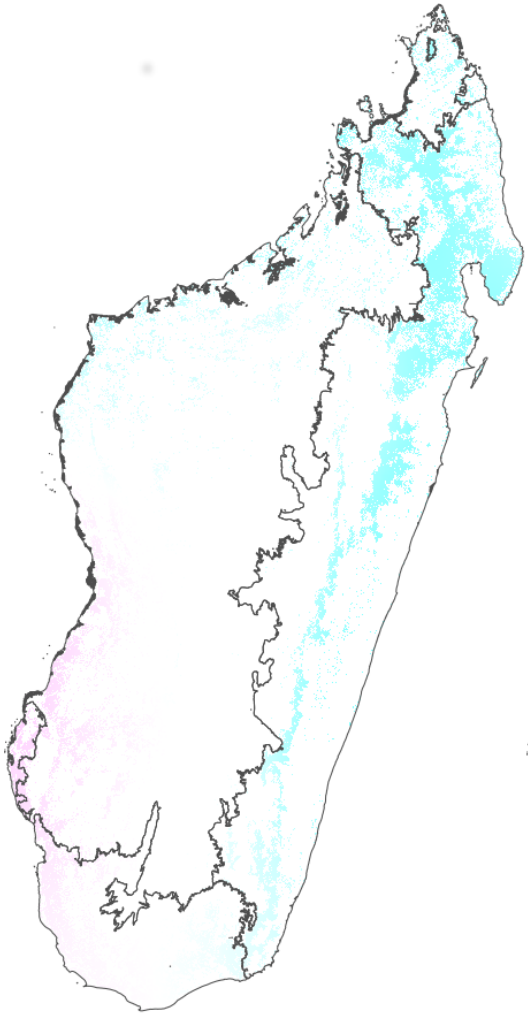
Effects of climate change on forest carbon storage

$$\mathbf{ACD_{future}} = f(\text{Topography} + \text{Vegetation indices}_{2010} + \text{Climate}_{future})$$

- Climate projections from seven IPCC CMIP5 global climate models
- Climatic scenarios : RCP 4.5 and 8.5
- ACD projections in 2050 and 2080

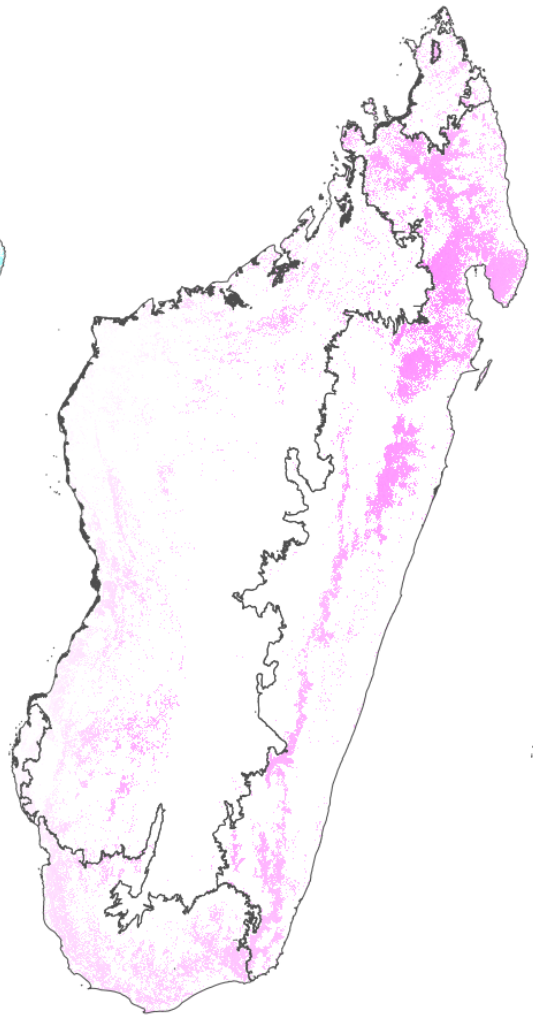


Effects of climate change on forest carbon storage



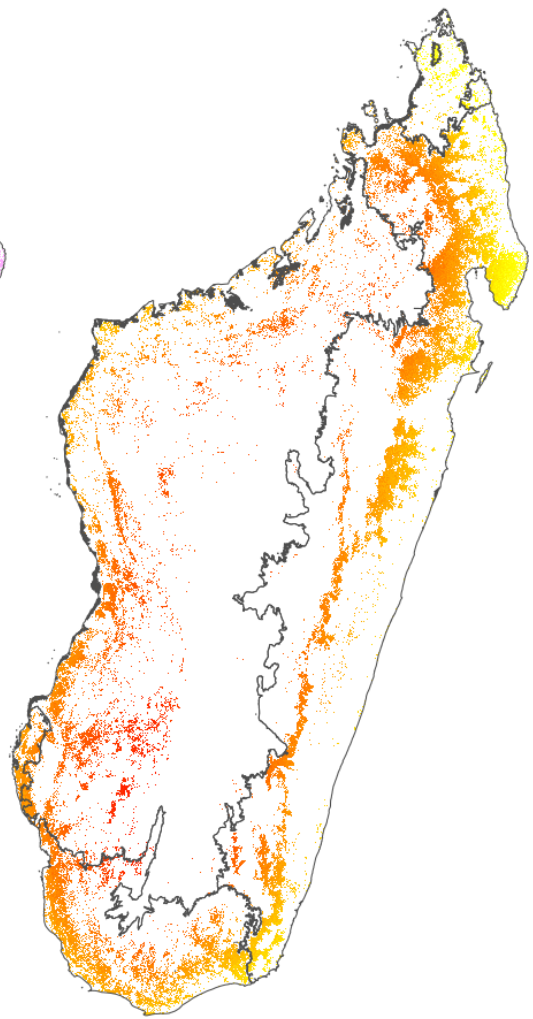
Precip. anomalies (mm.y-1)

-250 -125 0 +125 +250



Temp. seas. anomalies (sd x 100)

-250 -125 0 +125 +250



Temp. mean anomalies (°C x 10)

+30 +35 +40 +45

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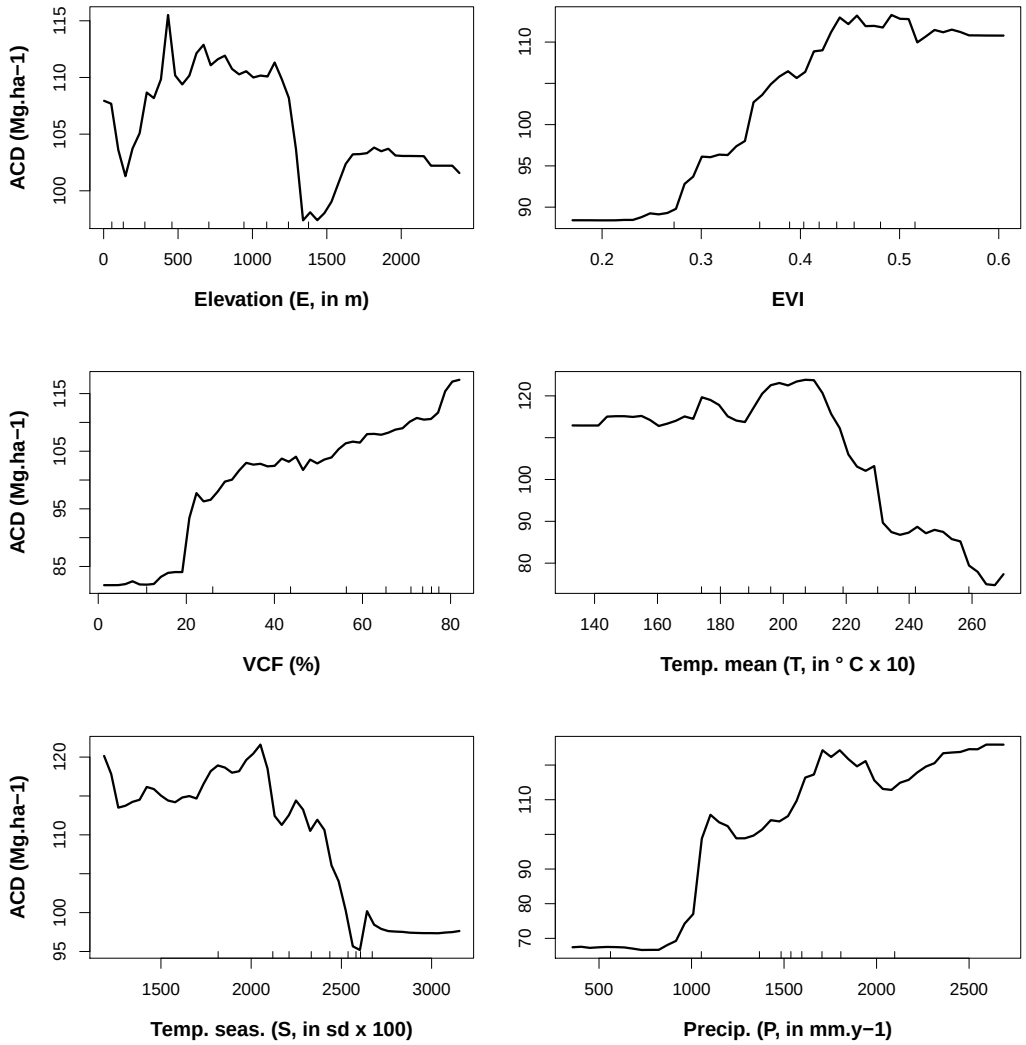
Model performance and variable importance

Model performance

- $R^2 = 63\%$
- RMSE $= 46$ Mg.ha^{-1} and Bias $= +31\%$

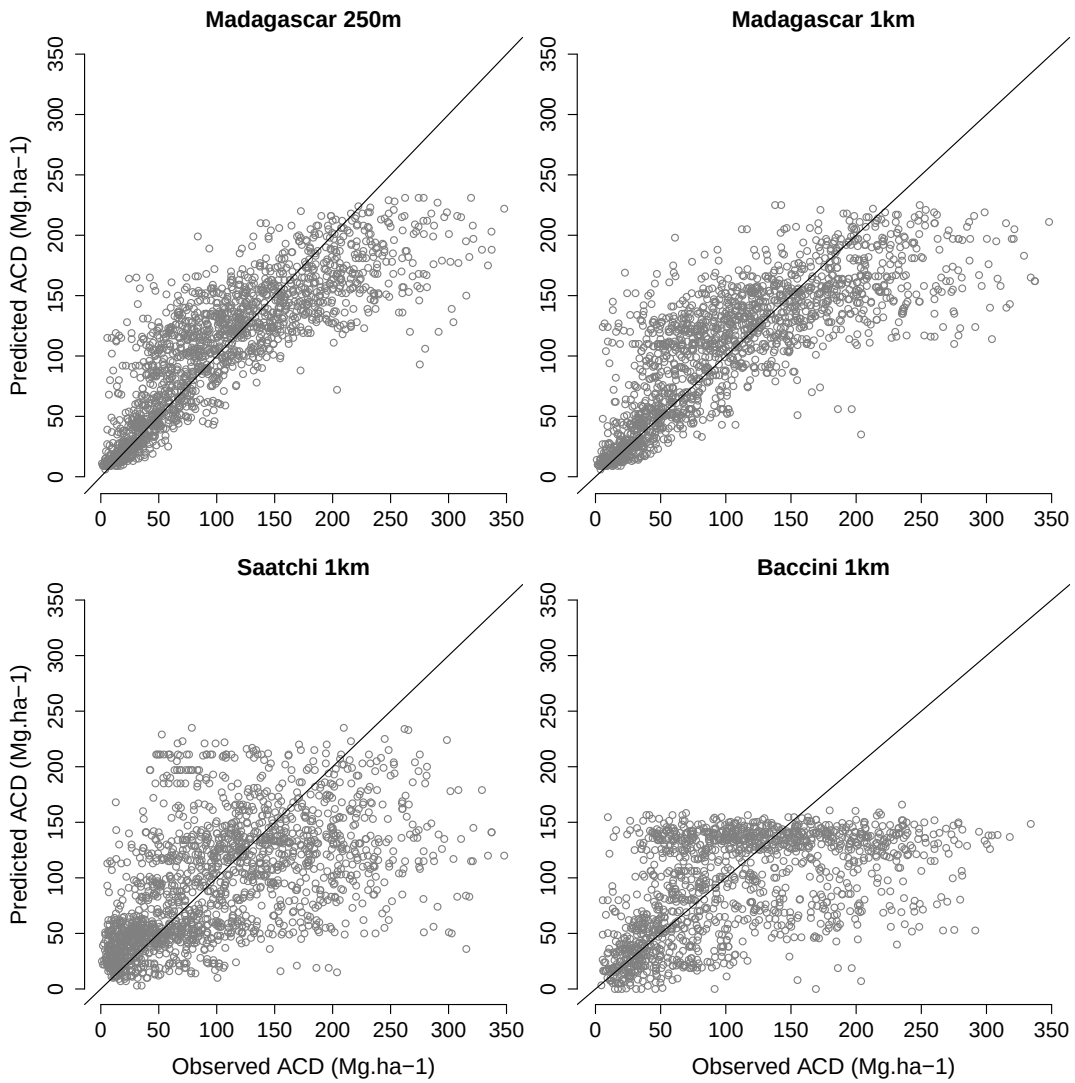
Variable importance

- T seas (63 % IncMSE), Precip (49), Temp (48), Elev (46), EVI (39), VCF (39)

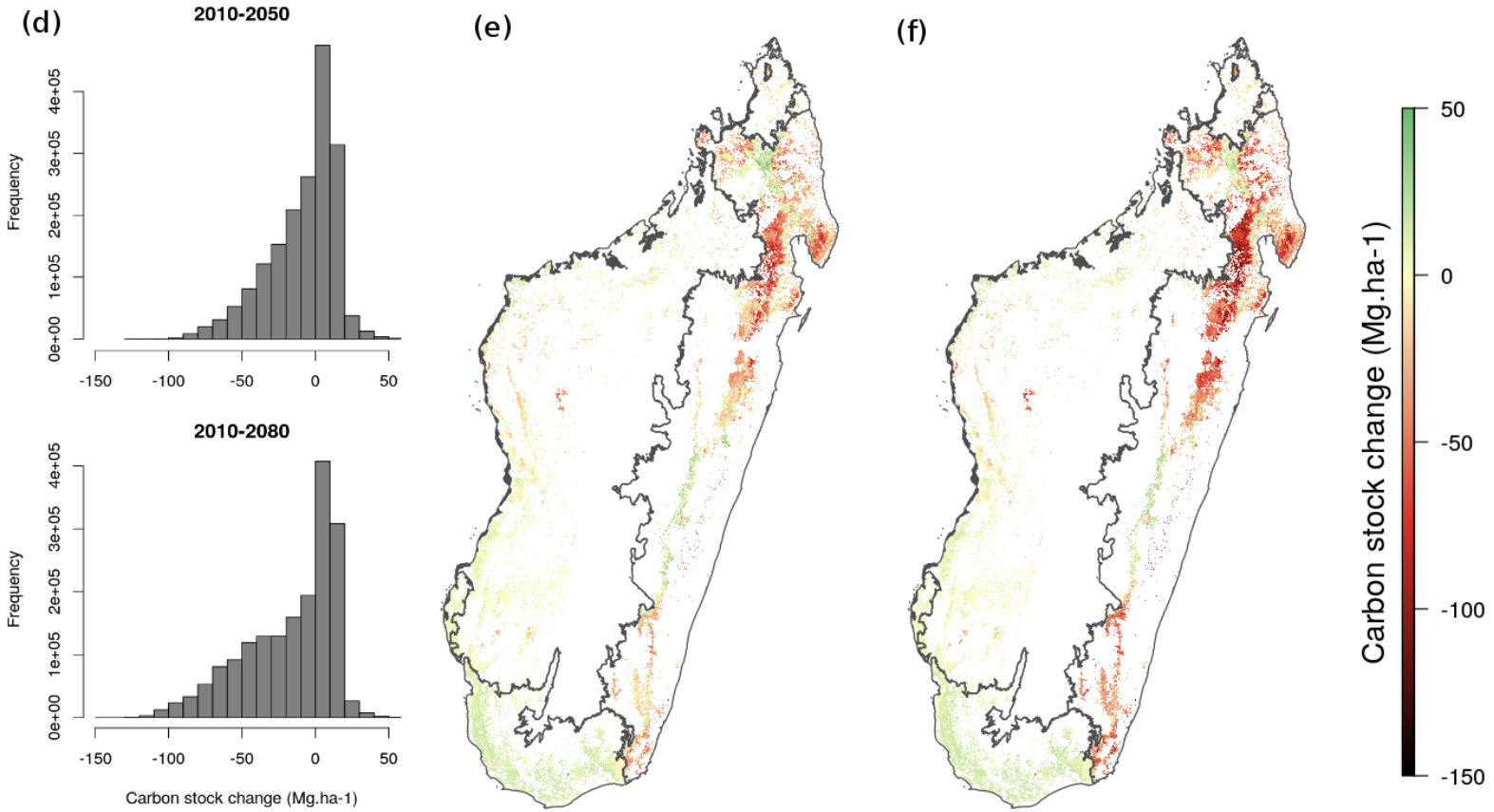


Comparison with global carbon maps

- Our 250 m map :
  $R^2 = 0.71$,
  RMSE =41 Mg.ha^{-1}
- Saatchi :
  $R^2 = 0.26$,
  RMSE =65
- Baccini :
  $R^2 = 0.17$,
  RMSE =65



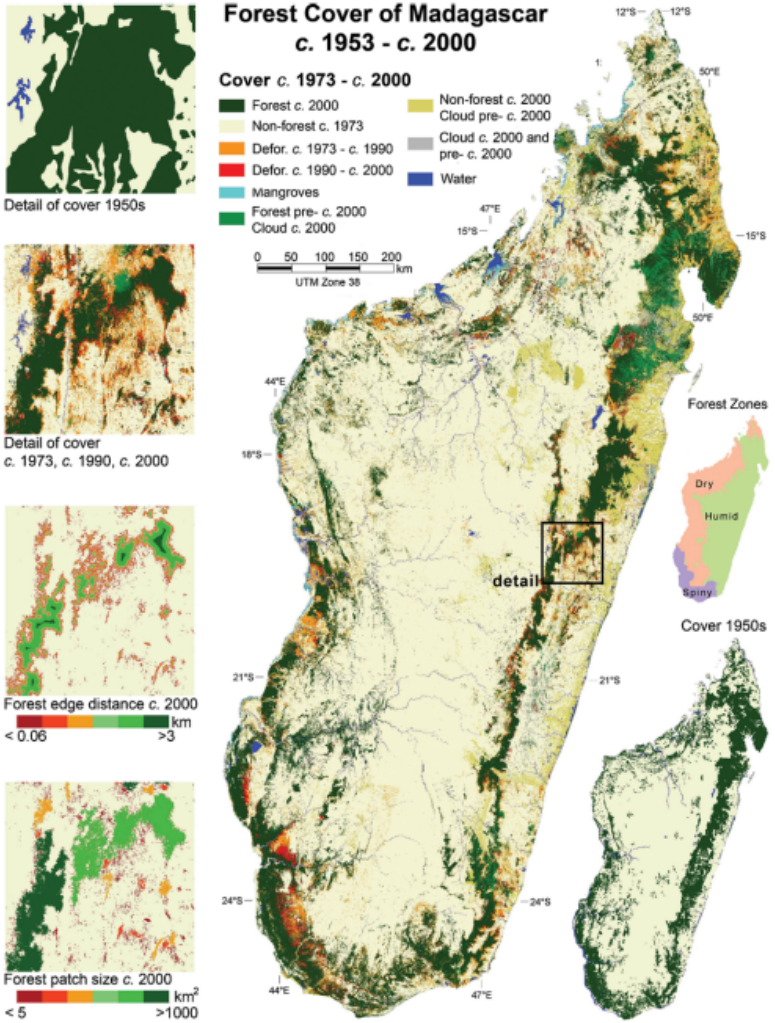
Impact of climate change on carbon emissions



Impact of climate change on carbon emissions

On the period 2010-2080

- Climate : **7-24%**
- Deforestation ($0.5\%.yr^{-1}$) : **29%**



Shifts in tree size and species composition with climate

Effects of climate

- Adaptation to climate : smaller trees
- Impact on tree species growth, recruitment and mortality : selection of **small-statured** tree species
  1. Change in species composition locally
  2. Change in species distribution at large geographical scale

Bunker et al. 2005, Science

- BCI, Panamanian forest, 18 possible species extinction scenarios
- Loss of large-statured tree species : 29% decrease in the total forest carbon stock

Conservative approach

Anderegg et al. 2013, Nature

- Widespread tree-mortality events
- Failure to migrate : lack of tree range expansion
- **Underestimation** of forest carbon loss in our model


. . . Thank you for attention . . .