RELIQUES project – Monday, 30th of September 2019 – Noumea, NC

Modelling and projecting deforestation and forest fragmentation in New-Caledonia

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   - Historical deforestation
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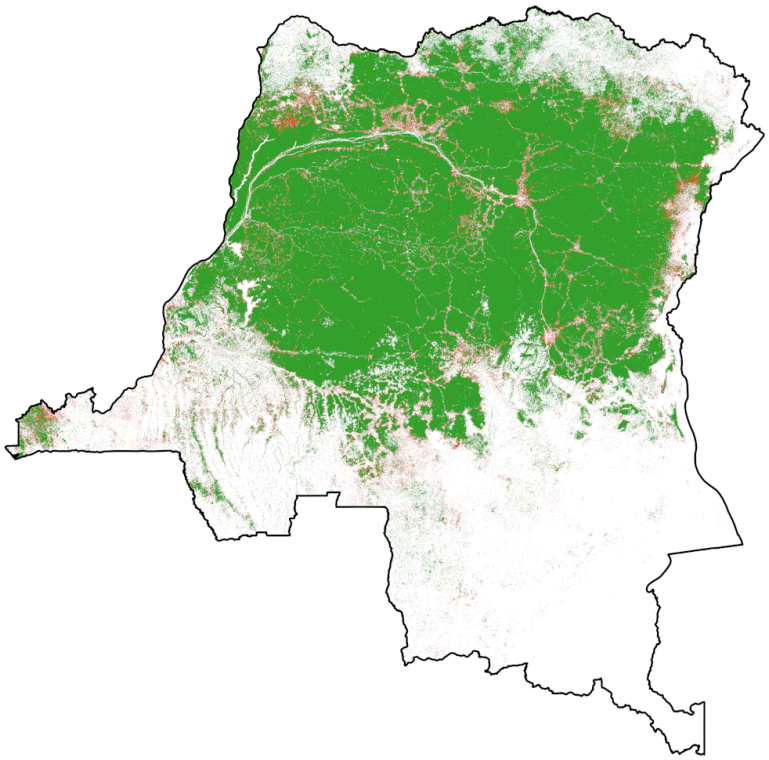
Long term projections

- Tropical forests shelter most of the terrestrial biodiversity and carbon stocks
- They are currently being deforested at rates close to **1%/yr**

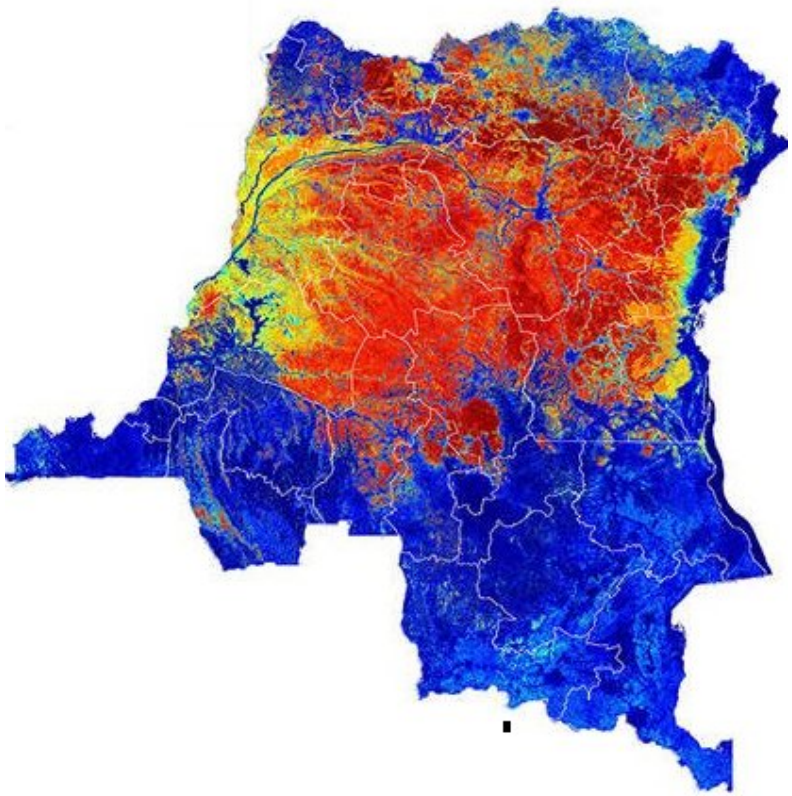


2005-2015 deforestation in Democratic Republic of the Congo

What happens when you project annual deforestation on the medium or long term (2050-2100) ?

Spatial projections

- Not all forests are equally threathened
- And biodiversity and forest carbon stocks vary spatially

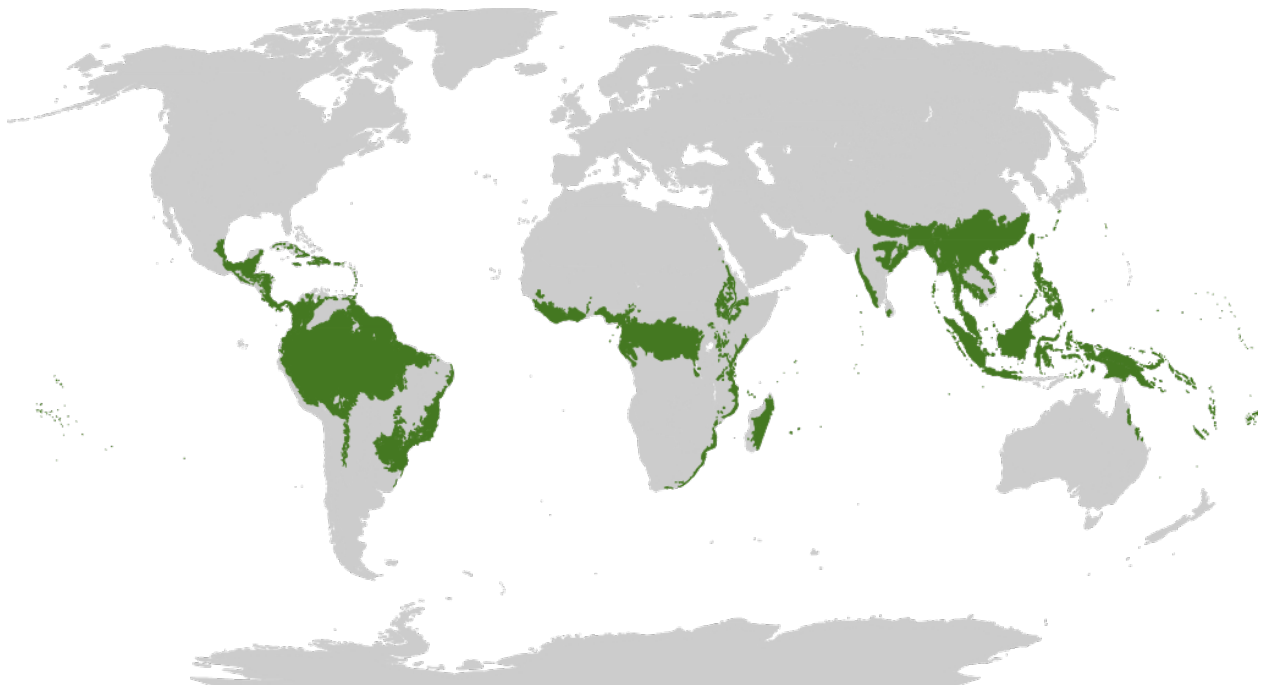


Aboveground biomass in Democratic Republic of the Congo

What are the consequences of long term deforestation for biodiversity and CO2 emissions ?

Objectives

- Modelling the deforestation process spatially
- Deriving high-resolution maps of the spatial probability of deforestation
- Projecting forest cover change until 2050 under a business-as-usual scenario
- At the pantropical scale



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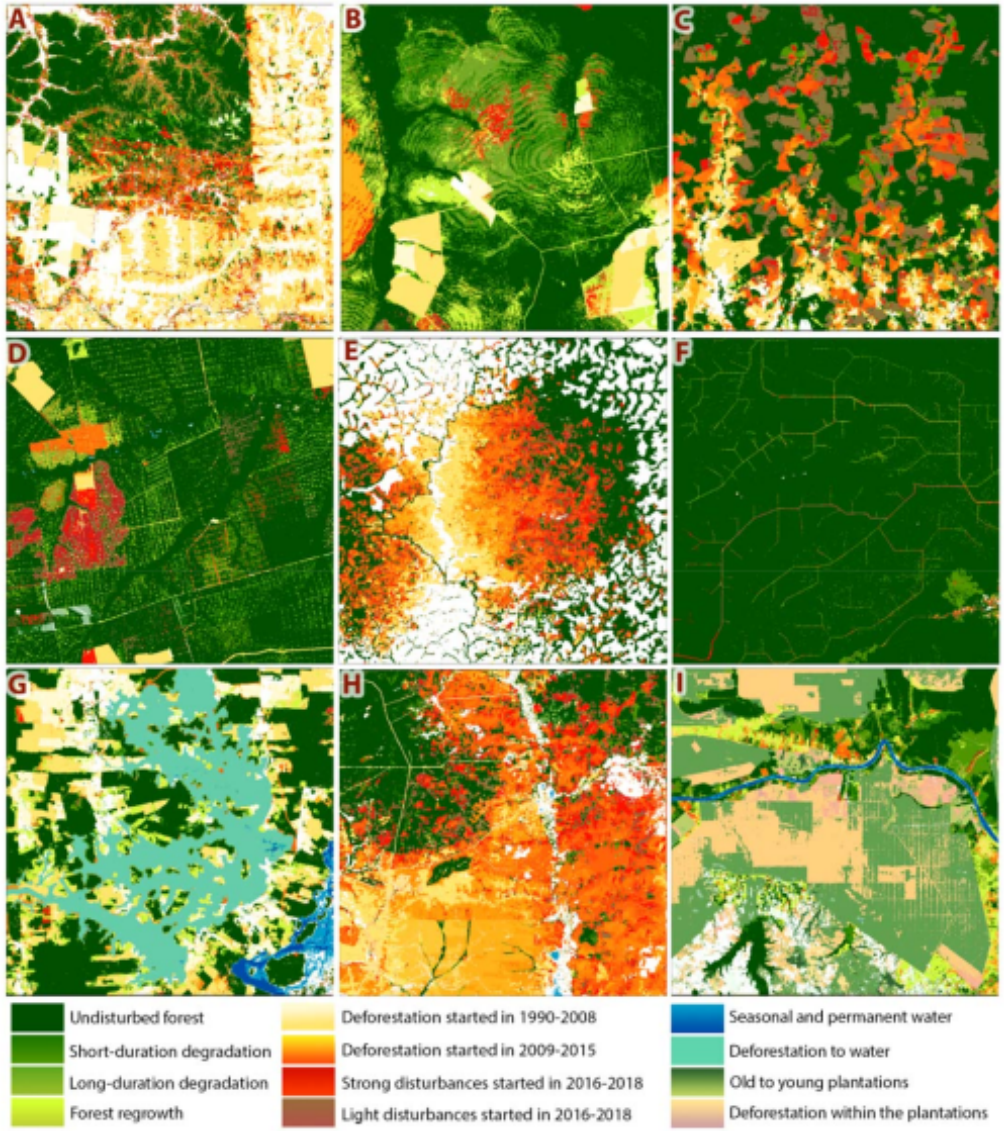
Historical deforestation

- Wall-to-wall map of **tropical moist forest cover change** at 30 m resolution from 1990 to 2018
- Using the 37-years full Landsat satellite archive and Google Earth Engine
- Time-series analysis at the pixel scale using a complex decision tree based on expert knowledge

Historical deforestation



Historical deforestation

- **Vancutsem Ch., F. Achard , J.-F. Pekel , G. Vieilledent, S. Carboni , D. Simonetti , J. Gallego.** Long-term monitoring of the tropical moist forests dynamics reveals unprecedented deforestation rates. Submitted to *Nature Communications*.
- Hansen et al. 2013 : underestimated deforestation rates in Africa (small scale mosaic deforestation)
- Response variable : deforestation on 2005-2015

Explicative variables

- Variable types : **landscape**, **accessibility**, **protection status**

Product	Source	Variable derived	Unit	Resolution (m)
Deforestation maps (2005-2015)	Vancutsem et al. (1)	forest/non-forest	–	30
		distance to forest edge	m	30
		distance to previous deforestation	m	30
Digital Elevation Model	SRTM v4.1 CSI-CGIAR (2)	altitude	m	90
		slope	°	90
Highways	OSM - Geofabrik (3)	distance to roads	m	150
Places		distance to towns	m	150
Waterways		distance to river	m	150
Protected areas	WDPA (4)	presence of protected area	–	30

(1) Vancutsem et al., (2) http://srtm.csi.cgiar.org,
(3) http://www.geofabrik.de, (4) http://protectedplanet.net

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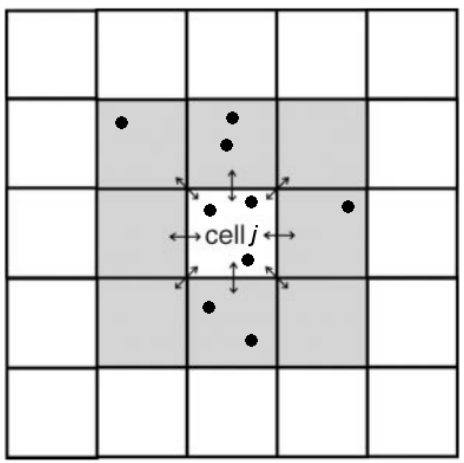
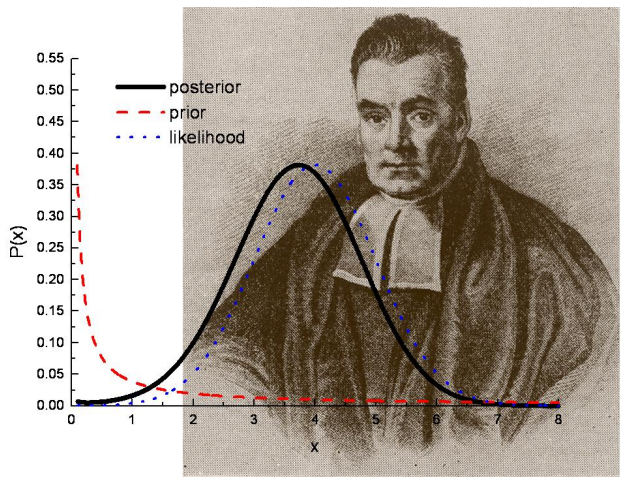
Statistical model

- $Y_{ij} \in \{0, 1\} \sim \mathcal{B}ernoulli(\theta_{ij})$
- $\text{logit}(\theta_{ij}) = X_i\beta + \rho_j$
- Autocorrelated spatial random effects ρ_j (10 km) to account for **unmeasured** or **unmeasurable** factors : population density, soil type, geographical barriers, law enforcement locally
- Structure spatially the **residual variability** that is not explained by the model's variables
- Hierarchical Bayesian framework

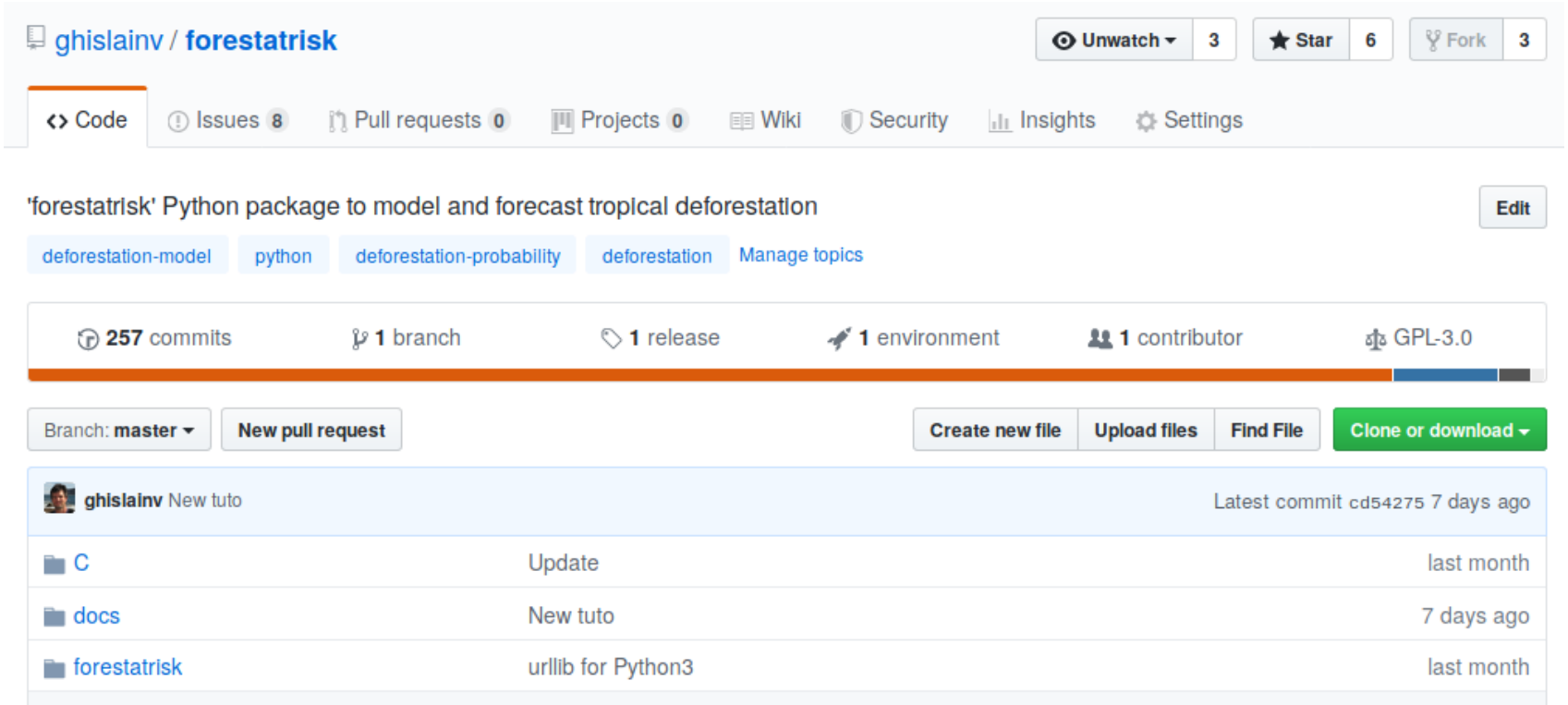




Statistical model

- One model per country
- 40,000 sample points (balanced sampling deforested/non-deforested areas)
- Variable selection (statistical significance + process coherence)

Software



- `forestatrisk` Python package : https://github.com/ghislainv/forestatrisk
- Rasters processed by chuncks : high resolution (30 m, large spatial scale)
- Fast, without memory issues
- Parallel computation : one node per country

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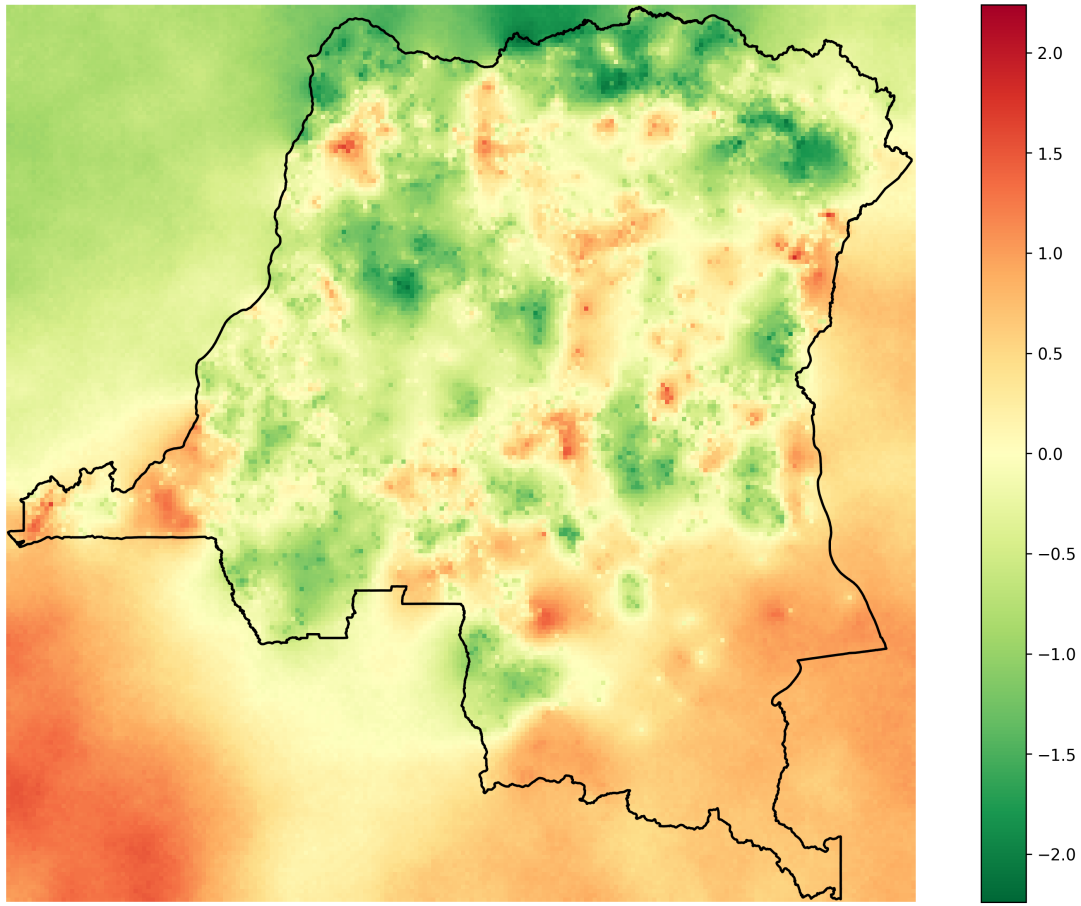
Parameters

Parameter values : β and variance V_ρ of the spatial random effects.

```
Binomial logistic regression with iCAR process
  Model: I(1 - fcc23) + trial ~ 1 + C(pa) + scale(slope) + scale(dist_defor) +
scale(dist_edge) + scale(dist_road) + scale(dist_town) + scale(dist_river) + cell
  Posteriors:
                        Mean        Std     CI_low    CI_high
       Intercept      -4.64      0.155      -4.92      -4.37
     C(pa)[T.1.0]     -0.206      0.101     -0.402   -0.00777
     scale(slope)    -0.0505      0.028     -0.113    0.00411
scale(dist_defor)      -5.64      0.304      -6.21      -5.08
 scale(dist_edge)      -7.19      0.315      -7.76      -6.54
 scale(dist_road)      -0.22     0.0416     -0.303      -0.14
 scale(dist_town)     -0.171      0.042     -0.258    -0.0922
scale(dist_river)    -0.0664     0.0311     -0.124    0.00367
             Vrho        2.7      0.304       2.32       3.39
         Deviance   1.25e+04       89.6   1.23e+04   1.27e+04
```

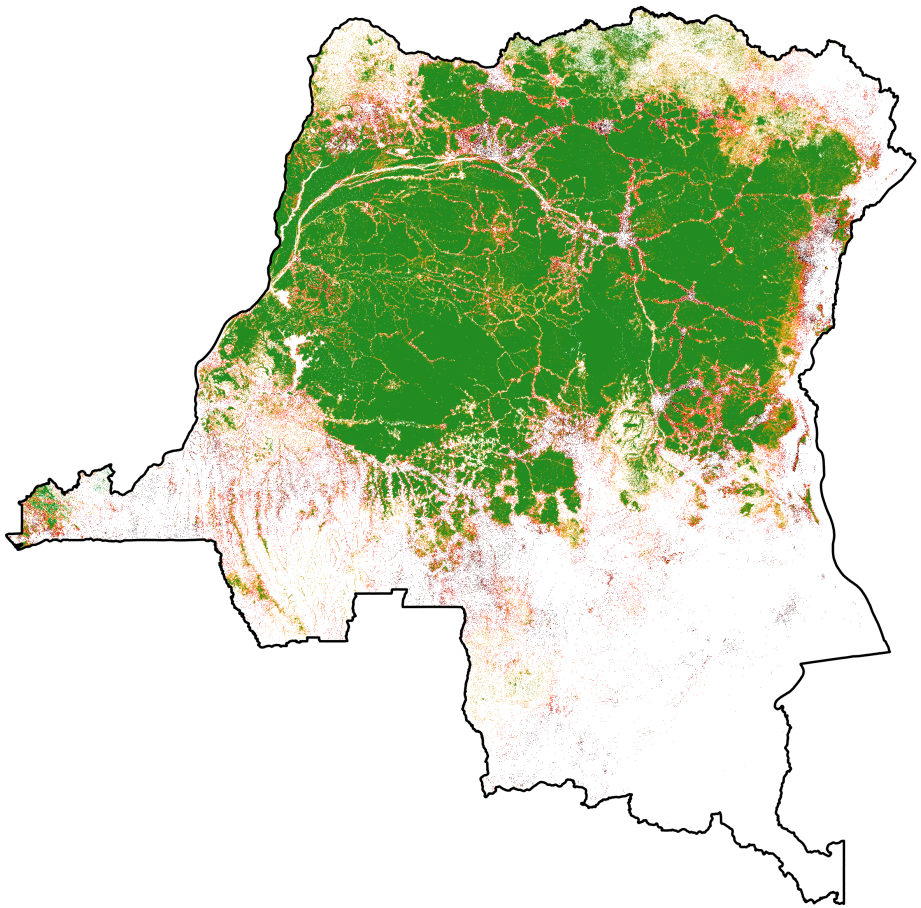
- Set of parameters for each country.
- Each effect can be easily interpreted.
- Effects can be compared between countries (efficiency of the protected areas, effect of road infrastructures).

Spatial random effects

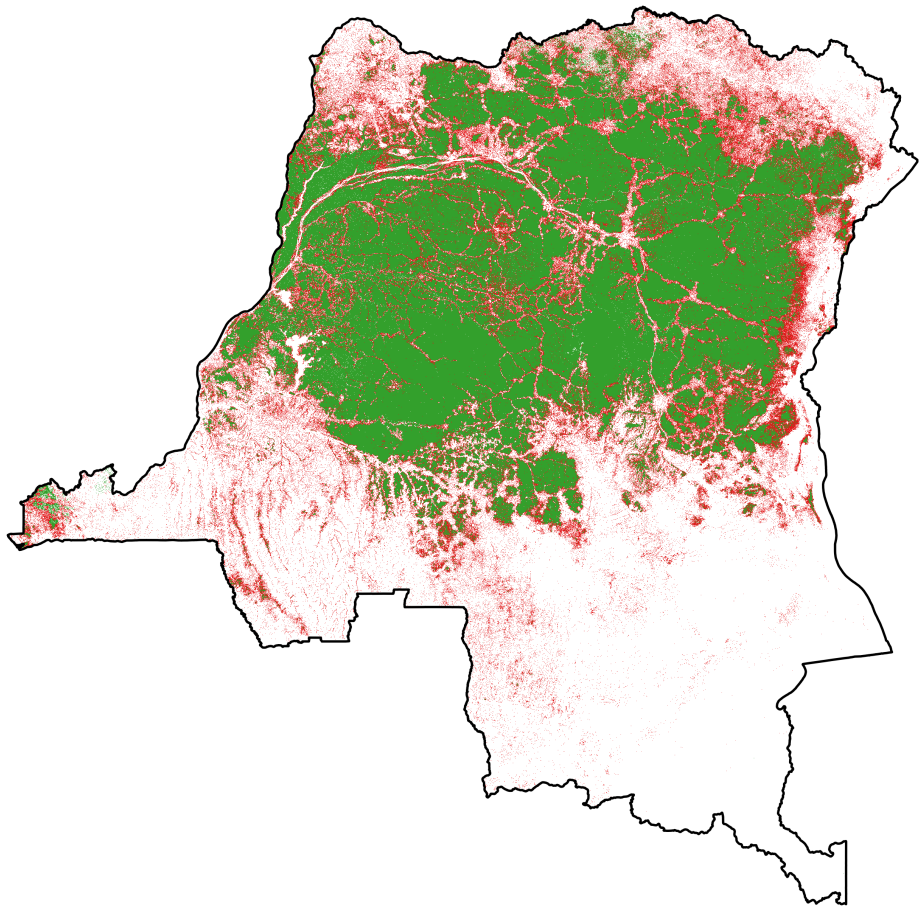


Then interpolated at 1km.

Spatial probability of deforestation

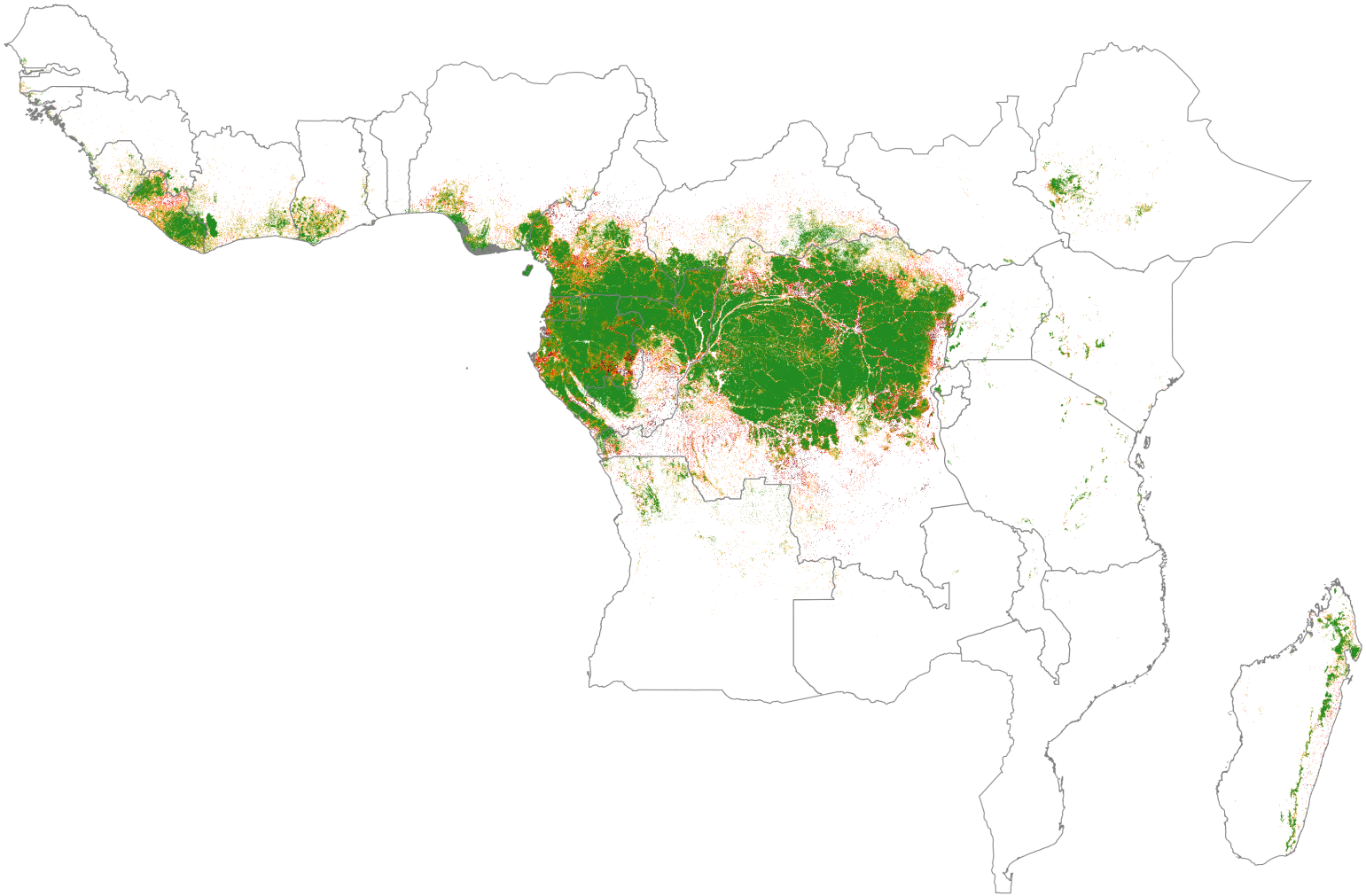


Future forest cover



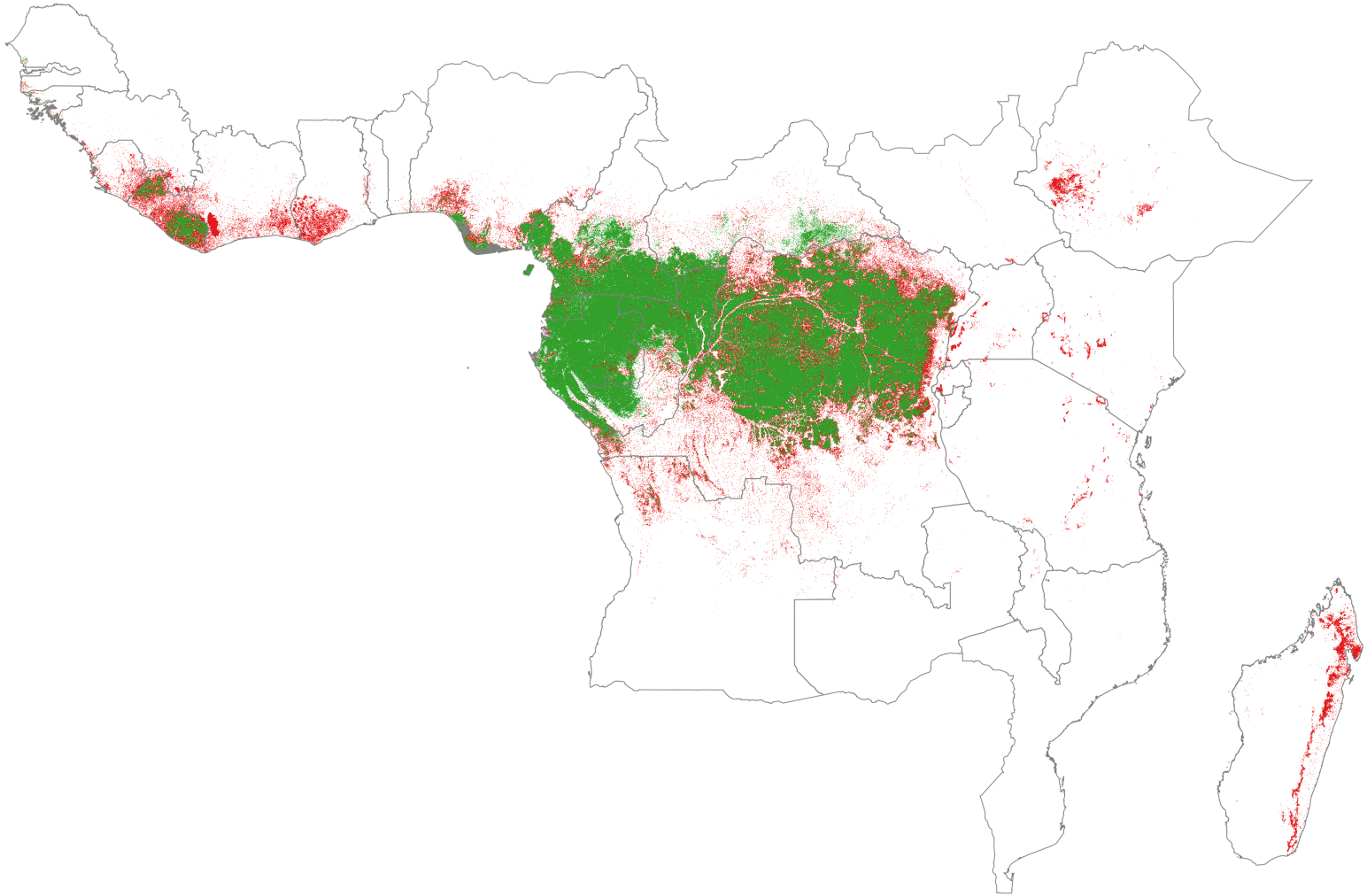
Projected forest cover change in **2015-2050** under a business-as-usual scenario.
BAU : historical deforestation (ha/yr) observed on **2005-2015**.

African continent



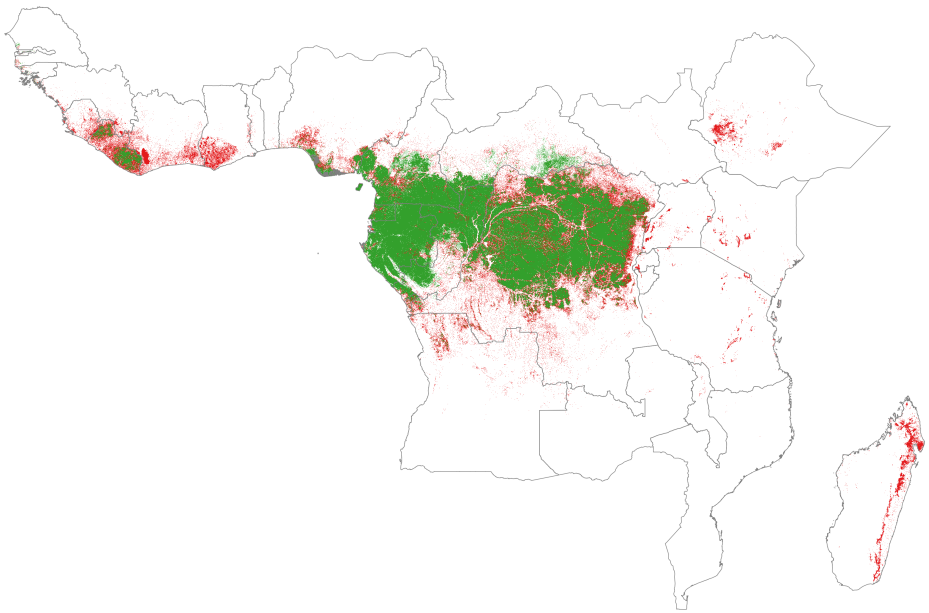
Spatial probability of deforestation.

African continent



Forest cover change in **2015-2050**, BAU scenario **2005-2015**.

African continent



- **No more moist forests in 2050** : West-African countries except Liberia, East-African countries including Madagascar
- **Remaining forest block** : Congo, Gabon, Equatorial-Guinea, Cameroon
- **Highly fragmented forest** : Democratic Republic of the Congo
- **Two blocks of forest on both sides of the Congo River**

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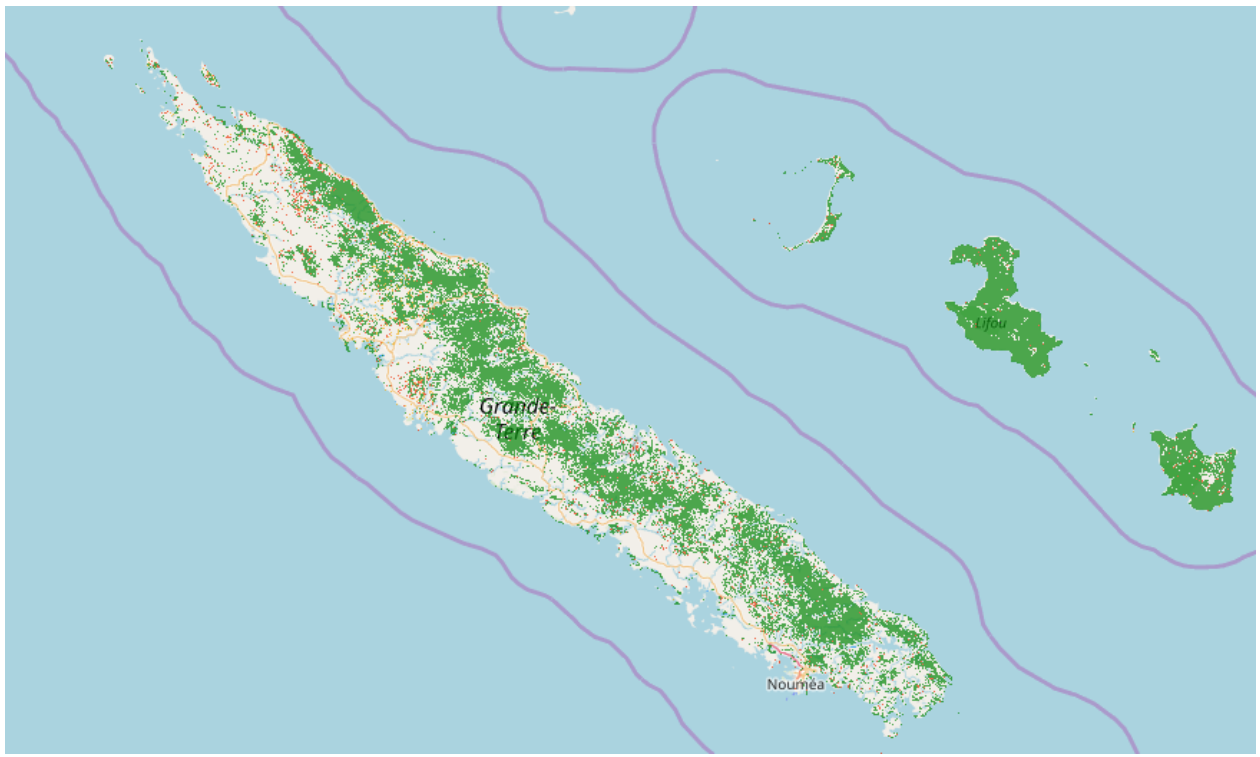
Historical forest cover change

- Past deforestation 2000-2010-2019
- Map : https://forestatrisk.cirad.fr/newcal
- Forest cover AND deforestation



Comparison for New-Caledonia

Forest cover :

- FAO statistics (825,000 ha)
- CIRAD-IAC : Digitized map at 1/3000 from 2008 aerial photos

Deforestation :

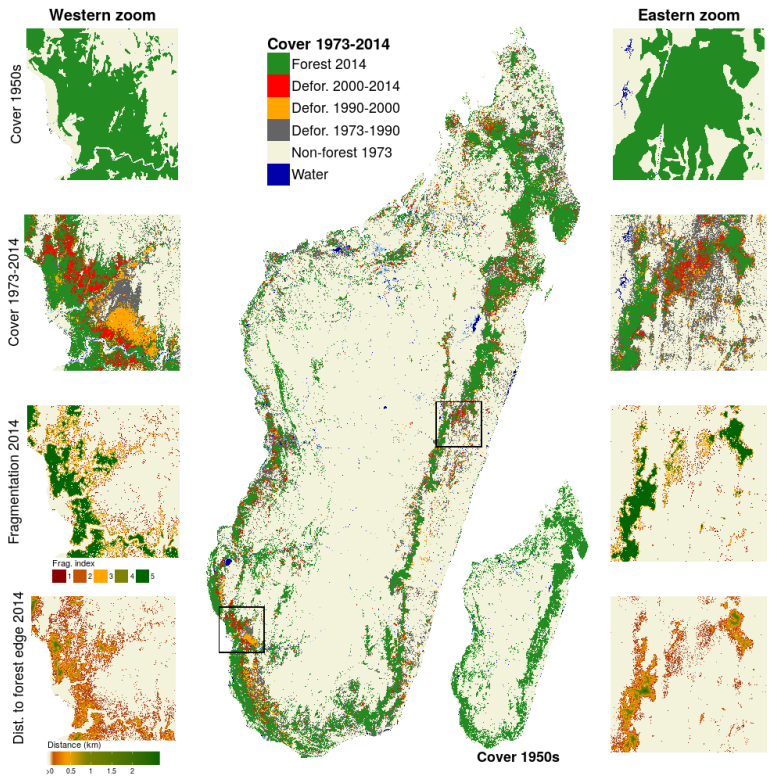
- FAO statistics (0 ha/yr)
- OEIL : fires, in 2017 24,145 ha, 1/3 in forest

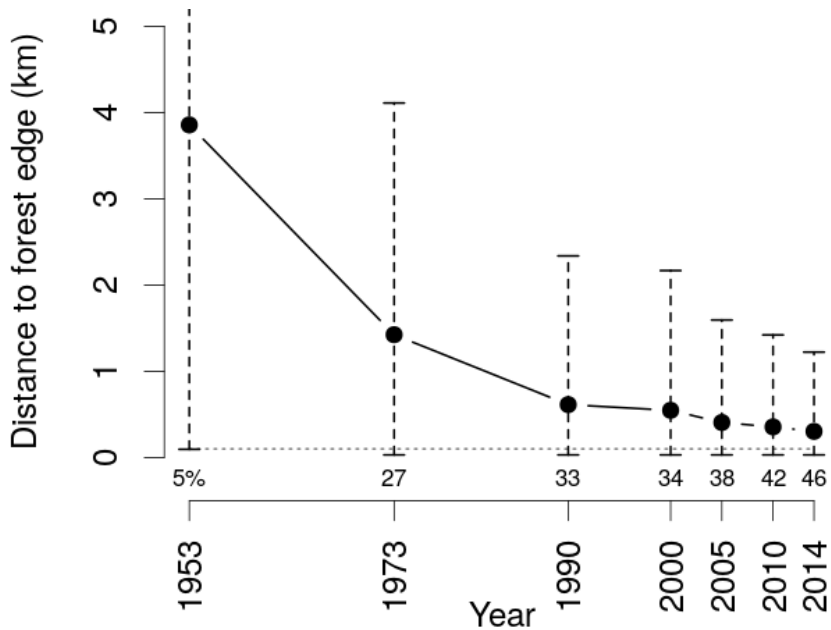
Causes of deforestation

- Effects of mines and ultramafic soils
- Deforestation causes : mines vs. fires

Fragmentation

- Fragmentation : past, future
- Distance to forest edge
- Amount of forest habitat in the neighborhood





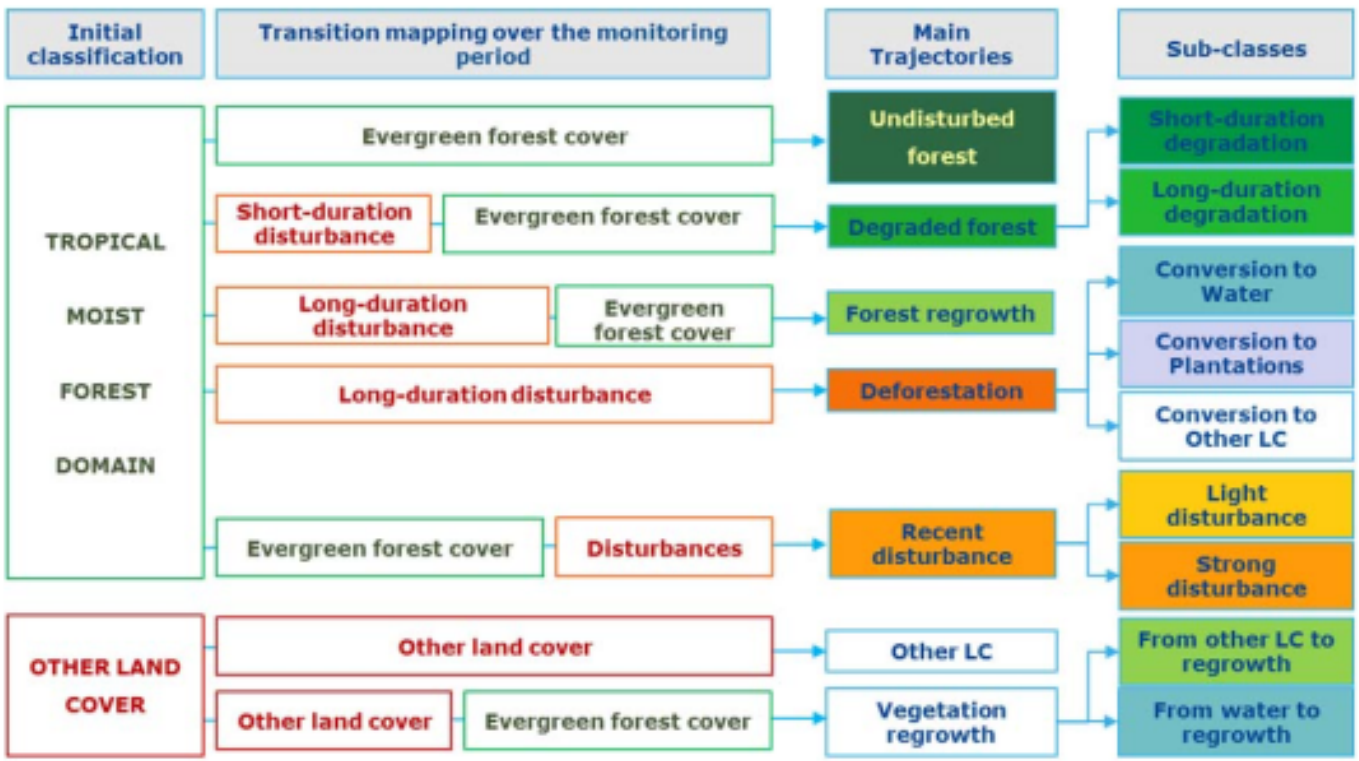
Impact on biodiversity

- Effect of deforestation and fragmentation on biodiversity
- Support for decision makers

β diversity in Madagascar

Forest gain

- Forest regeneration



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