Species Distribution Modeling for characterizing biodiversity hotspots and threats in Mozambique

May 2019

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Context

- **Importance of Mozambique's Biodiversity** due to mainly its large extent of remaining Miombo ecosystem (40% of the country extent)
- **Mozambique Biodiversity is under major threats**, due to land use changes (~220 000 ha of deforestation per year) and climate changes processes
- **Lack of available data and knowledge** regarding species occurrence and distribution at national scale
- **New spatial modeling tools** that combine biodiversity's observations with environmental variables enable to provide rapid, large-scale, current and future biodiversity distribution patterns

Objectives

- **Test the *speciesaltas* R packages** to develop species distributions maps over Mozambique

- **Produce scenarios of biodiversity** evolution under climate change

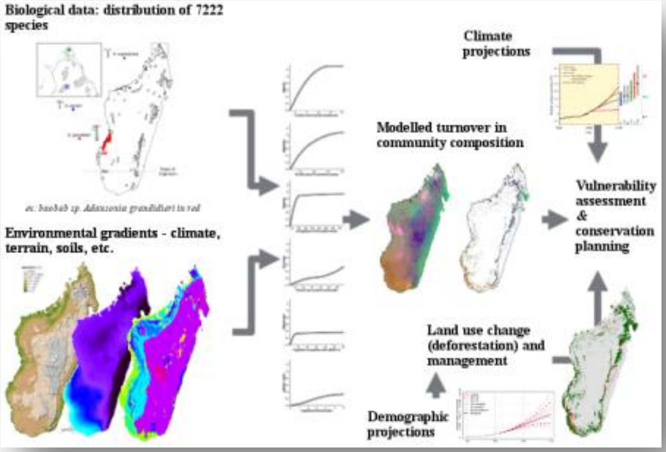
The final goal of this study is to support the identification of high priority areas for biodiversity conservation

Methodology

Methodology

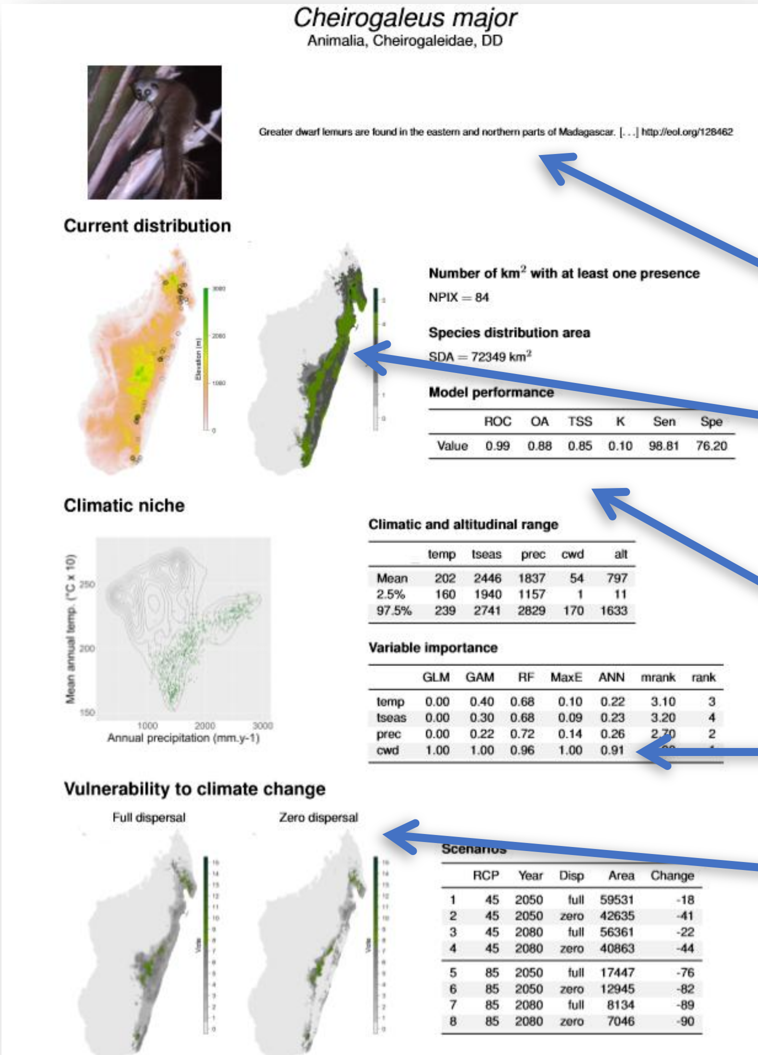
- **Based on a current project in Madagascar** (*BioSceneMada**), the idea is to apply this open-source methodology in Mozambique.

- The tool allow to produce an **Atlas on Biodiversity in Mozambique** using Species Distribution Models **SDMs** (collaboration with CIRAD)



[*https://bioscenemada.cirad.fr](https://bioscenemada.cirad.fr)

Methodology



Cheirogaleus major

Animalia, Cheirogaleidae, DD

Greater dwarf lemurs are found in the eastern and northern parts of Madagascar. [. . .] http://eol.org/128462

Current distribution

Number of km^2 with at least one presence

NPIX = 84

Species distribution area

SDA = 72349 km^2

Model performance

	ROC	OA	TSS	K	Sen	Spe
Value	0.99	0.88	0.85	0.10	98.81	76.20

Climatic niche

Climatic and altitudinal range

	temp	tseas	prec	cwd	alt
Mean	202	2446	1837	54	797
2.5%	160	1940	1157	1	11
97.5%	239	2741	2829	170	1633

Variable importance

	GLM	GAM	RF	MaxE	ANN	mrank	rank
temp	0.00	0.40	0.68	0.10	0.22	3.10	3
tseas	0.00	0.30	0.68	0.09	0.23	3.20	4
prec	0.00	0.22	0.72	0.14	0.26	2.70	2
cwd	1.00	1.00	0.96	1.00	0.91	[illegible]	[illegible]

Vulnerability to climate change

Scenarios

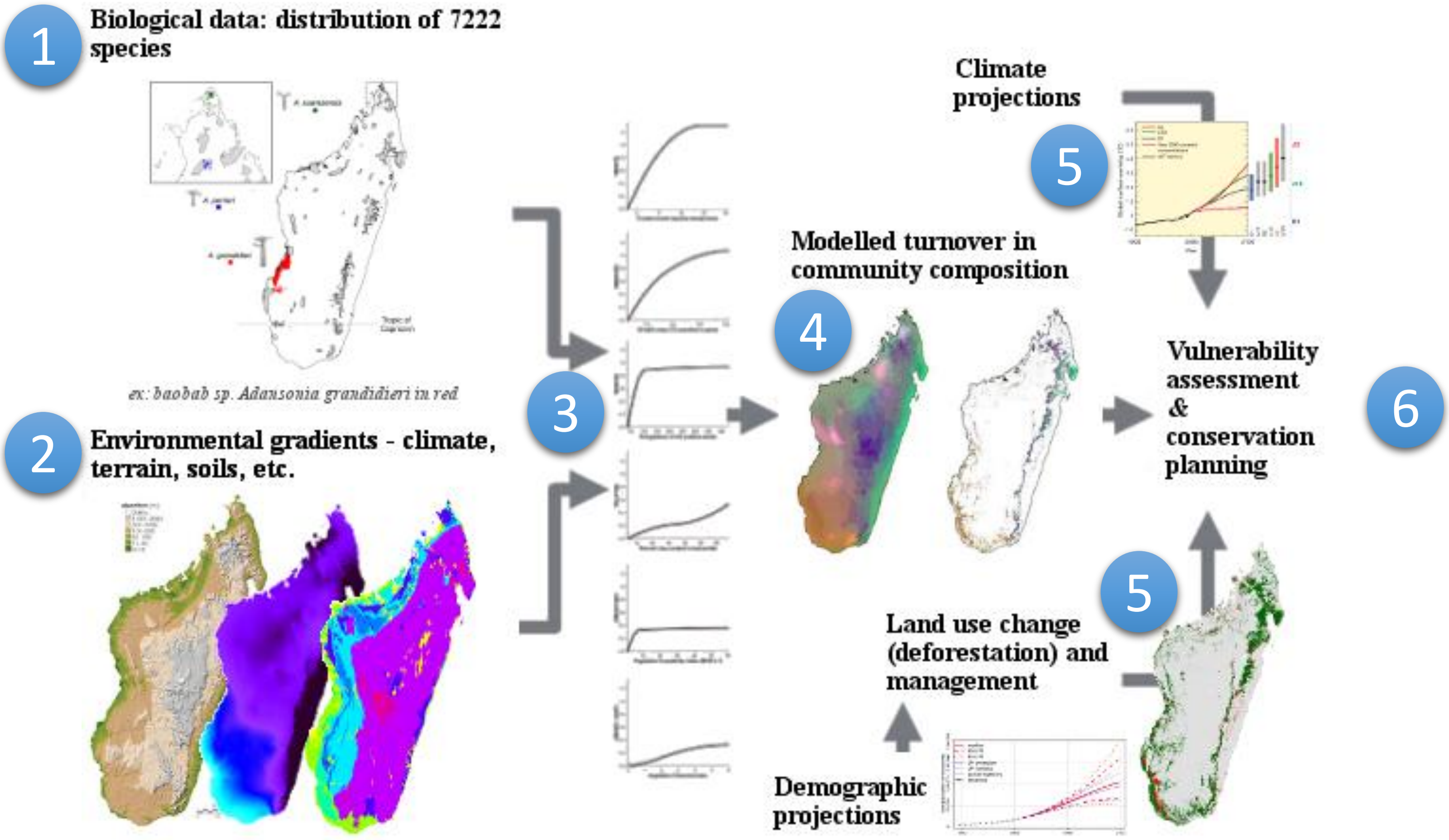
	RCP	Year	Disp	Area	Change
1	45	2050	full	59531	-18
2	45	2050	zero	42635	-41
3	45	2080	full	56361	-22
4	45	2080	zero	40863	-44
5	85	2050	full	17447	-76
6	85	2050	zero	12945	-82
7	85	2080	full	8134	-89
8	85	2080	zero	7046	-90

The tool *speciesatlas* provide synthetic informations by species:

- Species information and description
- **Current specie's distribution** using model averaging/bagging
- Quality assessment of the SDMs
- Variable's importance in the SDMs
- **Future specie's distribution** (IPCC GCM 2050 and 2080)

Framework

1) Collect biodiversity observations (point locations)
2) Derive and select the relevant environmenental variables
3) Model species distribution using SDMs
4) Combine all the results (# models, # species)
5) Apply land use change and climate change scenarios
6) Assess hot spots of biodiversity and priorities of conservation



Biodiversity dataset used

- **So far, collection of GBIF dataset** (presence) for different taxonomic groups : **amphibians, reptiles and mammals**

- We carried out **pre-processing and cleaning tasks**
  - Selection of species with at least 10 “individuals”

  → 1 “individual” is one - or several – observation(s) in a 1 km cell
  - Correction of taxonomy names using R package « taxize »

- Summary of this step

Taxonomic Group	Nb of Species reported	Nb of ground observations	Nb of species that can be modeled
Amphibians	52	353	4
Mammals	96	783	0
Reptiles	63	324	3

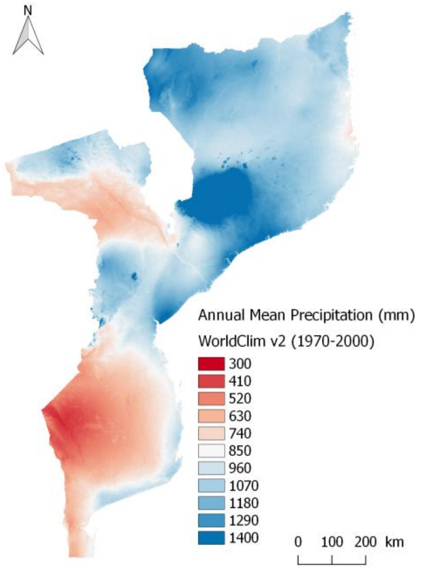
Environmental datasets used

We derived, used and tested 7 climatic and environmental variables derived from:

- **WorldClim data** for current climate methodology at 1 km^2
- **Laurel LULCC 2016** to calculate forest cover (%) at 1 km^2

These variables are

- Mean annual rainfall (mm)
- Mean annual temperature (°C)
- Rainfall seasonality (mm)
- Temperature seasonality (°C)
- Climatic water deficit (mm)
- Number of dry month (#)
- Forest cover (%)



For future climatic change scenarios we used another source of data:

- **CGIAR CCAFS data** at 1 km^2

Species Distribution Models

5 SDMs were applied and their outputs combined to calculate the species distribution map

- Random Forest (RF)
- Maxent (MaxE)
- Artificial Neural Network (ANN)
- Generalized Additive Model (GAM)
- Generalized Linear Model (GLM)

Theses models run using the package *BioMod2* (model parameterization and ensemble forecasting)

Results

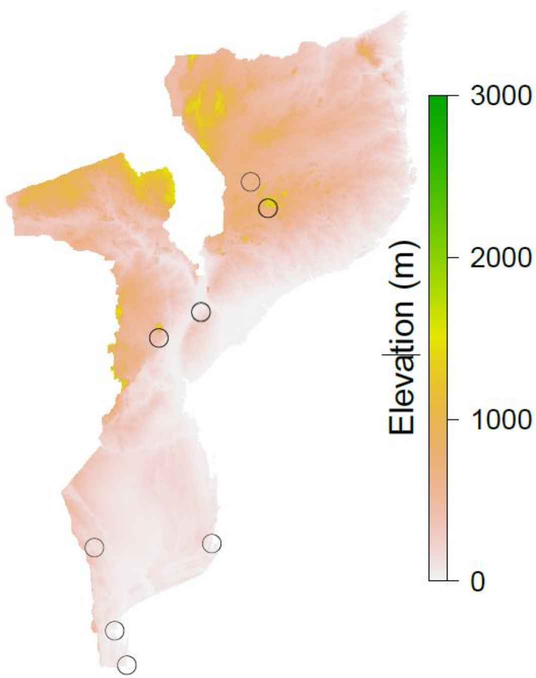
Results

From occurrence points to current ecological niche

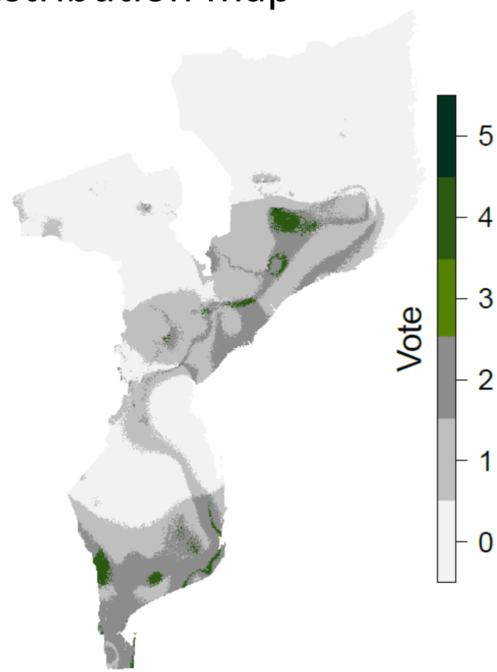
Lygodactylus capensis

Current Area* : 14 385 km²

Field Observations



Specie Distribution map



Number of vote
=> number of model that predict a presence of the specie

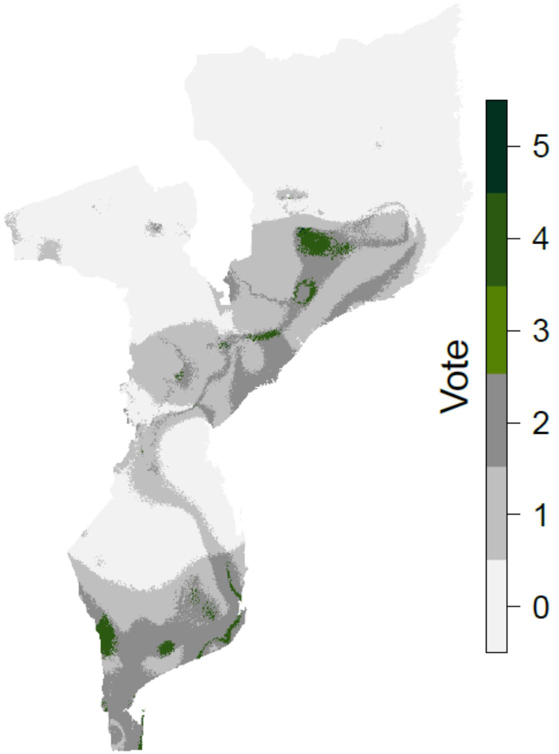
*Area with agreement of at least three models (=3 votes, green areas)

Results

Understanding current distribution of the species

→ **Analyse the variable's range and importance in the model**

Lygodactylus capensis



Climatic and Environmental range of values

	temp	tseas	prec	pseas	alt
Mean	245	1253	1094	78	278
2.5%	228	944	552	48	11
97.5%	263	1469	1783	94	728

Variables importance (rank) according to the SDMs

	GLM	GAM	RF	MaxE	ANN	mrank	rank
temp	0.00	0.08	0.22	0.00	0.44	3.90	4
tseas	0.65	0.67	0.57	0.25	0.95	1.40	1
prec	0.00	0.15	0.36	0.02	0.85	2.90	3
pseas	1.00	0.47	0.54	0.61	0.46	1.80	2

Results

Exploring future and potential distribution of the specie

→ **Identify future niche areas** and change compared to current distribution using differents parameters;

→ 2 differents **RCP scenarios**

- **8.5** Worst case scenario
- **4.5** Paris Agreement scenario

→ Years : **2050** and **2080**

→**Dispersion capacities** of the specie : **Full** or **Zero** dispersal capacity

Lygodactylus capensis

Scenarios

	RCP	Year	Disp	Area	Change
1	45	2050	full	46 314	222
2	45	2050	zero	969	-93
3	45	2080	full	49 221	242
4	45	2080	zero	977	-93

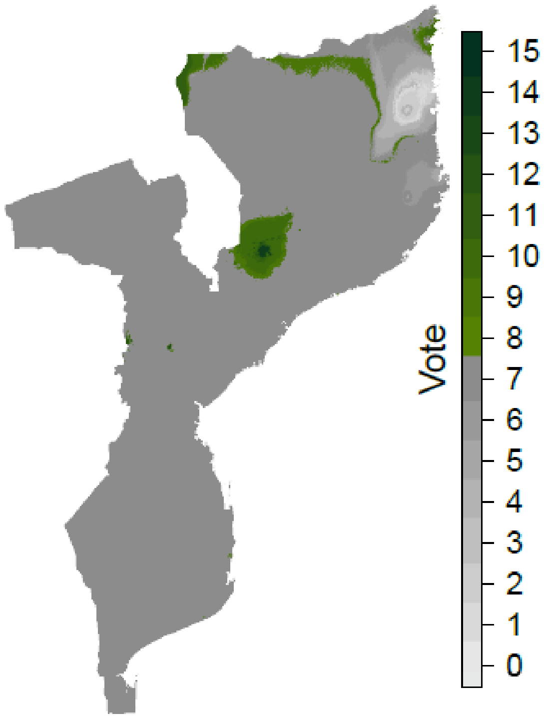
Results

Exploring future and potential distribution of the specie

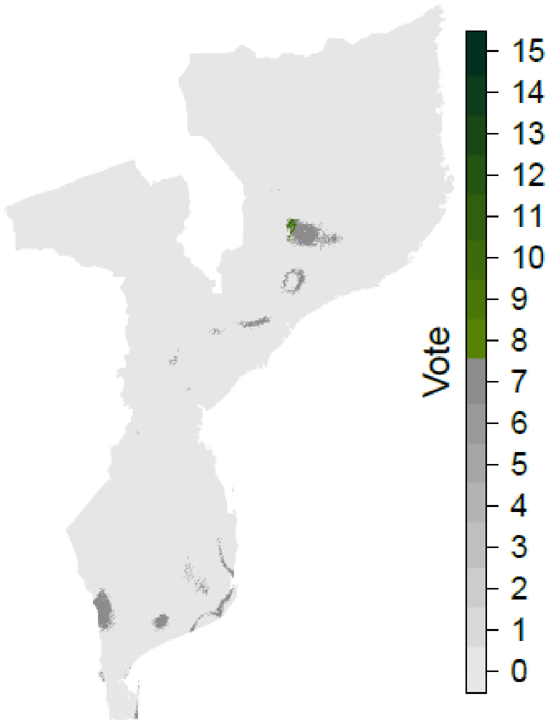
→ Specie Distribution map **in 2050**

Lygodactylus capensis

*with **full dispersal** capacity*



*with **zero dispersal** capacity*



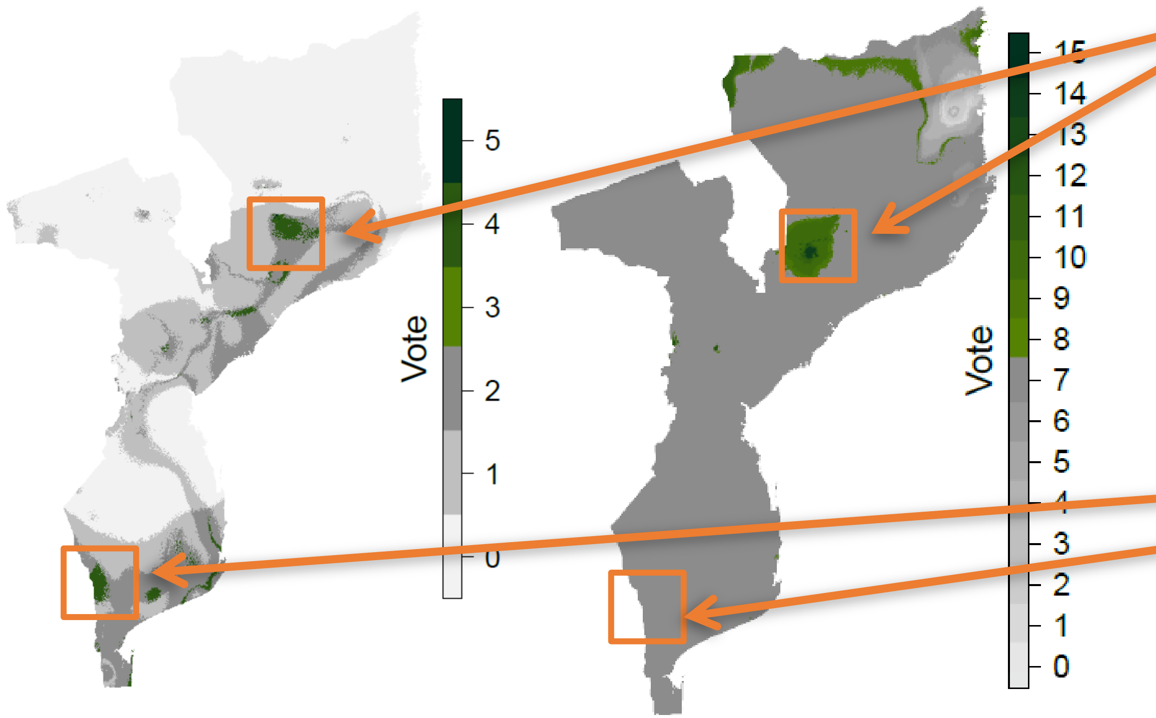
Results

Assessing hot spot of biodiversity

→ Current and future distribution comparison

Lygodactylus capensis

***2017** distribution map* ***2050** distribution map*



Same distribution area (niche) between the current and future forecast

→ Biodiversity refuge with high conservation value

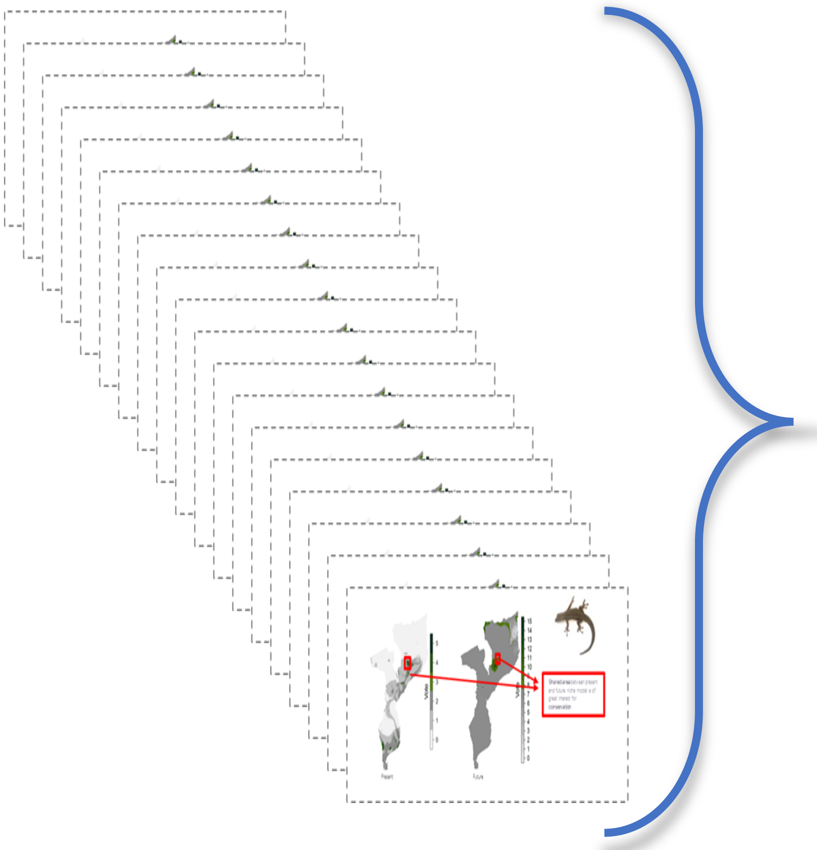
Extinction/Migration of the specie in the future

→ Biodiversity threaten by climate change

Results

Calculating composite biodiversity index based of individuals maps

→ Combinaison of individuals species distributions maps



→ **α-biodiversity**

Species richness

and potential future changes

→ **β-biodiversity**

Species communities/traits

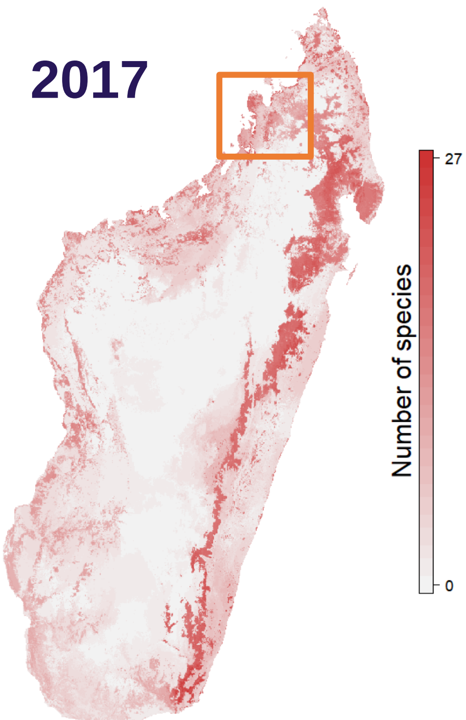
and potential future changes

Results

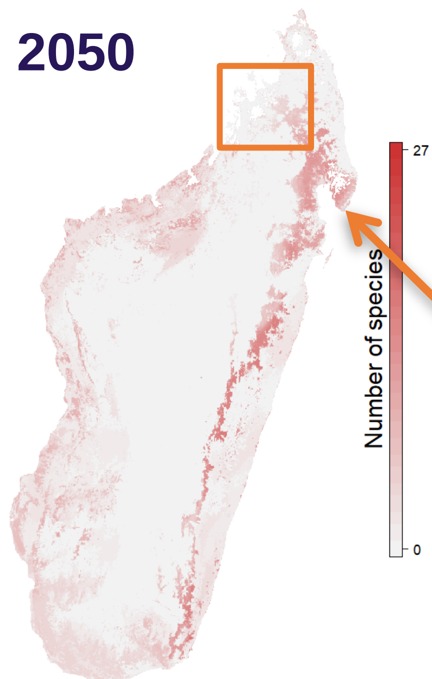
Calculating composite biodiversity index based of individuals maps

→ **Example for α-biodiversity index (richness) in Madagascar with 51 lemurs species**

2017



2050



Observations

- **Global loss of numerous species**
- **Local and full extinctions**

Conclusion &

Discussion

Conclusion and discussion

- **Lack of biodiversity ground observations**, only few records (by species) are available on open/public database and usable
  - **Mammals** : 96 species available, **0** can be modeled
  - **Amphibians** : 52 species available, only **4** can be modeled
  - **Reptiles** : 63 species available, only **3** can be modeled

- **Specifics environmental datasets by taxonomic group** should be selected and derived to better represent the potential relevant explanatory variables

- **Future scenarios could greatly be enhanced** with forest cover forecast (2050 forest cover) to evaluate loss and refuge of biodiversity due to anthropogenic pressure (use of Laurel LULC outputs forecasts)

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