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Assessing tree species vulnerability to climate change in French Guiana using joint species distribution models

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Joint Species Distribution Models (JSDMs)

Species Distribution Model (SDM), for one single species.

- $y_i \sim Bernoulli(\theta_i)$, $y_i \in \{0, 1\}$
- i : site
- $p(\theta_i) = X_i\beta$
- X : environmental variables
- β : species effects

JSDM = SDM for community of species.

- $p(\theta_{ij}) = \alpha_i + X_i\beta_j + \Sigma_{ij}$
- i : site, j : species
- Site effect α_i : mean site suitability
- Variance-covariance matrix Σ_{ij} : species co-occurrences

Joint Species Distribution Models

JSDMs provide a convenient statistical framework to test **trait-environment** interactions.

β_j can be expressed as a function of functional traits

- $p(\theta_{ij}) = \alpha_i + X_i\beta_j + \Sigma_{ij}$
- $p(\beta_j) = N(T_j\gamma, V_\beta)$

JSDMs can help narrow the gap between **correlative** and **mechanistic** species distribution models.

`jSDM` R package (first chapter of Jeanne's PhD thesis), https://ecology.ghislainv.fr/jSDM/

Objectives of METRADICA (Task 3)

Using JSDMs :

- Test **trait-environmment** interactions for determining tree species distribution in French Guiana.
- Assess species vulnerability to climate change (through contraction of species range).
- Interpret species vulnerability to climate change in terms of functional traits.
- Derive maps of α and β diversity for French Guiana.
- Identify refuge area for biodiversity under climate change (stable tree communities).

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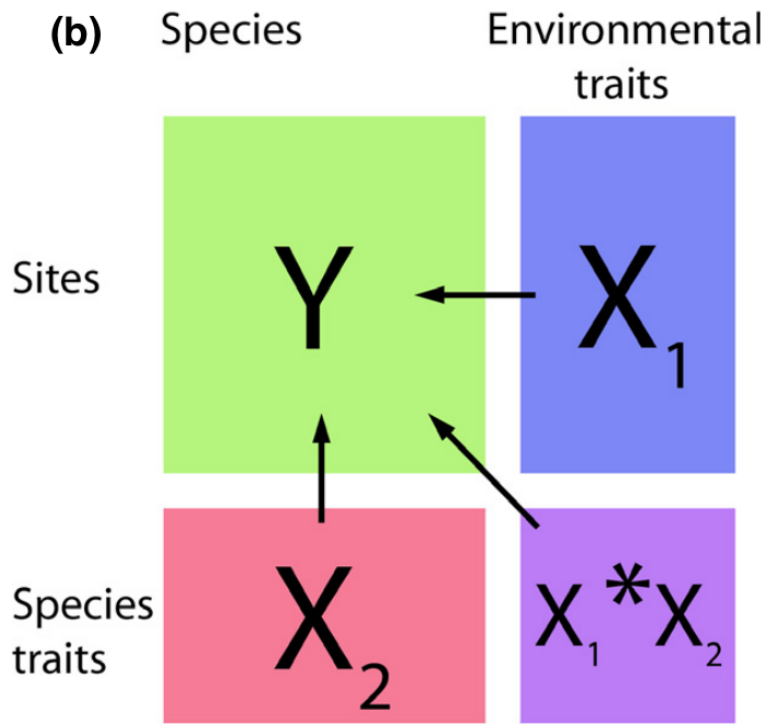
Datasets

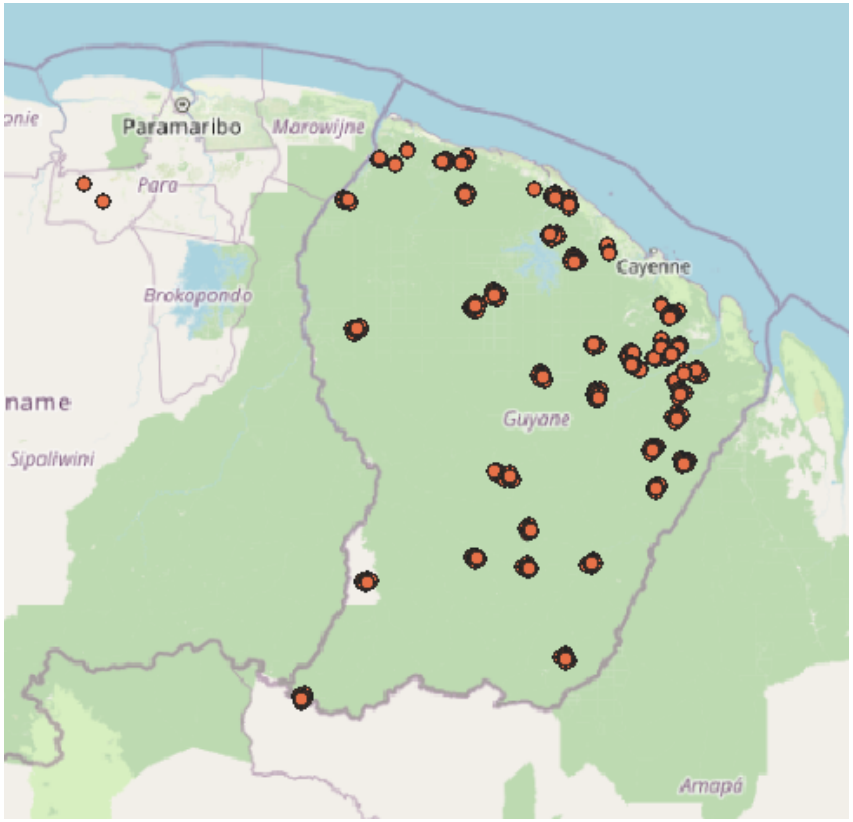
Three types of data-sets :

- Species occurrences on sites
- Species trait database
- Environmental database



Occurrences

- Forest plot inventories coming from several networks combined together
- Networks : Guyafor, Gentry, Habitat, Guyadiv
- Presence-absence data and abundances
- 285 forest plots
- About 1700 tree species, most of which are rare



Traits

- Large “soft” trait (WD, LSA, tree max height, etc.) databases from previous CEBA projects.
- Five additional mechanistic traits from Metradica project :
  - leaf water potential at which cells lose turgor (Ptlp), minimum leaf conductance (gmin), leaf saturated water content (LSWC), vein density (VLA), stomatal density (SD).
  - 24 species, 672 trees, three sites with both hills and valleys spread on a precipitation gradient.

Environment

- Topographic data (SRTM and LiDAR)
- Soil data
- Distance to human infrastructures (roads, villages)
- Climatic data (Chelsa) in the present and the future
- https://guyaclim.cirad.fr

Scales : biogeography and micro-environment

Local scale : microtopography × traits

- Scale = ~10km, resolution = ~5m
- Explicative model : E × T
- Using MNT at 5m : hills (*"terra firme"*) and valleys

Country scale (French Guiana)

- Scale = FG, resolution = ~1km
- Explicative and predictive model
- Two models
  - Without traits
    - Predictive model
    - Present : distribution and co-occurrences of species
    - Future : range contraction in the future : (i) species vulnerability to climate change, (ii) change in species composition
  - With traits
    - Explicative model : E × T
    - Explaining species location (biogeography)

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Model comparison with forest dynamics models

TROLL model

- Tropical forest dynamics model
- Growth, mortality, recruitment through carbon allocation
- Species parameters are derived from traits
- Calibrated on some forests of French Guiana

Model comparison

- Species excluded from the community with TROLL under climate change.
- Do the same species experience a severe range contraction with JSDMs ?

Applications

- Anticipating climate change effects on tropical forest in French Guiana
  - Massive tree mortality events and forest conversion to savannas ?
  - Change in species composition ?
- Identification of refuge areas for conservation $\Rightarrow$ systematic conservation planning.

. . . Thank you for attention . . .

https://ecology.ghislainv.fr/presentations

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