AMAPhD +

JOURNÉE DES DOCTORANTS, POSTS-DOCTORANTS ET NON PERMANENTS DE L'UMR AMAP

EDITION 2020

AMAP

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ORGANISATION

GIRARD-TERCIEUX Camille

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RÉALISATION

Team AMAPhD

REMERCIEMENTS

L' équipe organisatrice remercie la direction d'AMAP, les organisateurs de l'édition 2019, les tutelles du laboratoire AMAP ainsi que l'ensemble des participant·e·s à cette journée

PROGRAMME

12 NOV. 2020

9h00	*Cérémonie d'ouverture*
9h15	Benjamin DENEU
9h40	Colin THOMAS
10h05	Maximilien COSME
10h30	*Pause café*
11h	Jeanne CLÉMENT
11h25	Laetitia LEMIERE
11h50	Camille GIRARD-TERCIEUX
12h15	*Déjeuner*

13h15	Yali YANG
13h40	Begüm KACAMAK
14h05	Dimitri JUSTEAU-ALLAIRE
14h30	Camille SALMON
14h55	Melilia MESBAH
15h20	*Pause café*
15h45	Nereyda Nathalie CRUZ MALDONADO
16h10	Daniela KREBBER
16h35	Mathieu DE GOËR
17h00	Baptiste OGER
17h25	Gislain II MOFACK
17h50	Claudia Milena HUERTAS GARCIA
18h10	*Fin*

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NOTES

NOTES

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ÉDITION 2020

Malgré les difficultés liées à la crise sanitaire Covid-19, tout le monde reste sur le pont de la Science, en particulier les plus jeunes qui ont organisé et participé à d'AMAPhD+ 2020. La Direction leur en est reconnaissant.

Les questions de recherche abordées dans cette édition s'inscrivent dans les (ou plus souvent aux interfaces des...) 3 axes thématiques du projet 2021-2025 d'AMAP présenté à l'HCERES en début d'année: ***BIODIVERSITE - systématique, biogéographie, écologie ; BIOMASSE - dynamique et production des plantes et des peuplements ; PLANTES NUMERIQUES - modèles, analyses et données de l'organe aux écosystèmes.***
Les synthèses de ce fascicule illustrent remarquablement les approches interdisciplinaires, voire transdisciplinaires, qui constituent le fondement des programmes de recherche successifs d'AMAP depuis sa création. L'innovation s'appuie sur l'appropriation et/ou le développement de méthodes et d'outils puissants pour l'acquisition de données, l'analyse et la modélisation des plantes et des écosystèmes. Citons en particulier ceux faisant appel à la télédétection (TLS, imagerie multi- et hyper-spectrale, etc.), à la modélisation mathématique spatio-temporelle à évènements discrets ou continus, ou encore aux ontologies et aux méthodes d'apprentissage machine sur des grands jeux de données d'images.

A l'heure où nous écrivons cet éditorial, nous ne sommes pas sûr que cet événement aura lieu en présentiel ! Mais ce dont nous sommes certains, c'est de la motivation et de l'esprit de solidarité qui règnent à AMAP pour que ne cesse cet élan de recherche plus que jamais indispensable au service des grands enjeux auxquels nous devons faire face...

Bonne lecture...

La Direction : Thierry FOURCAUD et Raphaël PELISSIER

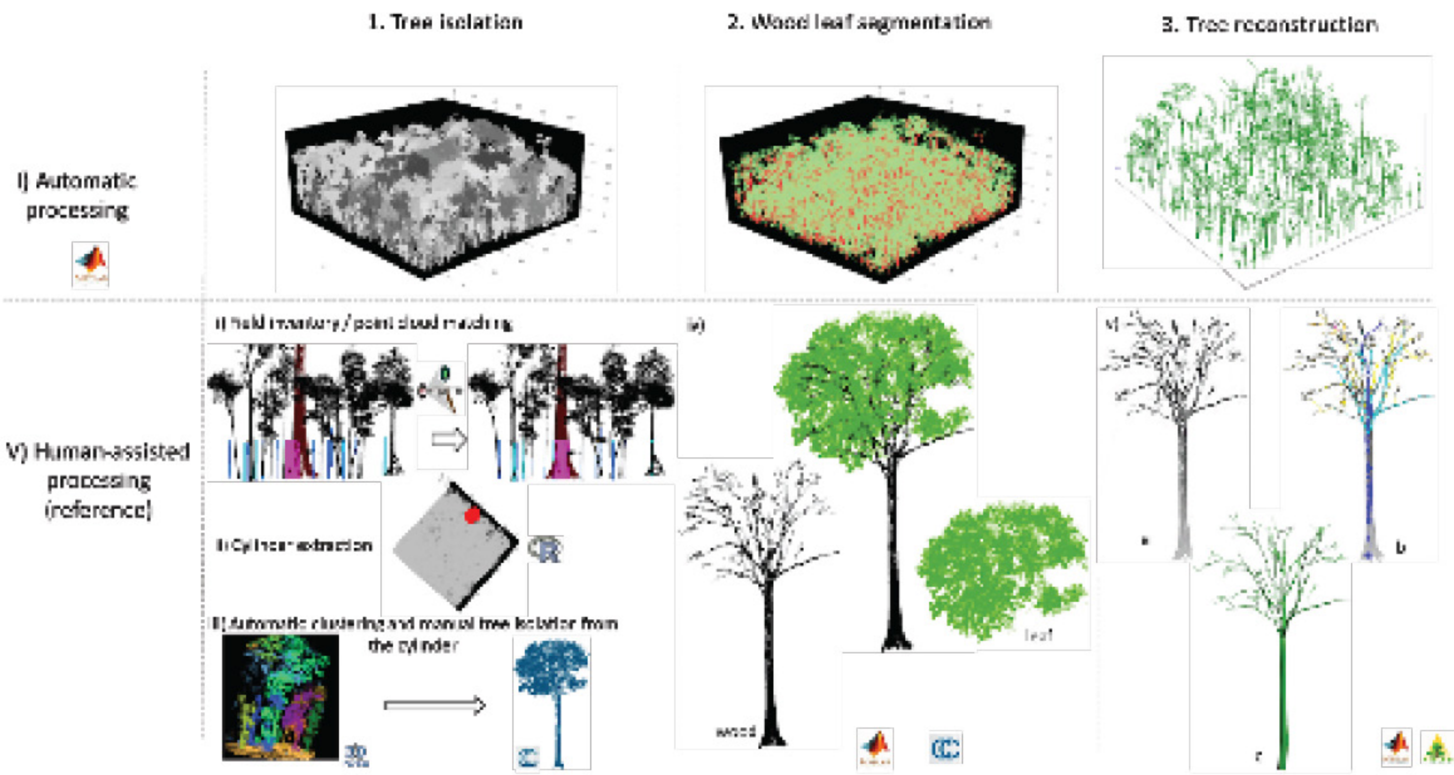

Figure 1. Summary scheme representing the automatic and human assisted processing chains. Logos represent the different softwares used at each step.

Evaluation of the performance of automatic processing chains to extract tree and plot metrics using TLS data in natural tropical forest

Presenter: Gislain II MOFACK

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Scientific Supervisors: Olivier MARTIN-DUCUP, Nicolas BARBIER, Pierre COUTERON & Bonaventure SONKE

Terrestrial LiDAR Scanning (TLS) data are of great interest in forest ecology and management because they provide detailed 3D information on tree and plot structure. Automatic procedures are increasingly used to process TLS data in order to extract individual trees along with a number of volumetric and architectural metrics over entire sample plots. With the advent of these algorithms, allowing fast processing of a large number of trees comes the risk of results of unknown reliability due to the absence of systematic control on the outputs. In the present study, we evaluated estimation errors at the tree and plot scale of four automatic extraction procedures on various metrics such as aboveground wood volume. For that purpose, we manually processed TLS data from 65 scans collected on a 1-ha plot of undisturbed tropical forest to serve as control data to be compared with automatic procedures. We obtained a set of 391 human-assisted processed trees as reference to evaluate the outputs of automatic procedures. Our results showed that fully automated procedures led to median relative errors on tree wood volume ranging from 39.4 % to 114.7 % depending on the procedure. When aggregating trees into plots, we found that one of the fully automated procedures led to mean error levels close to 10% at the 1-ha scale while the three others led to errors higher than 30%. For tree-level crown metrics, the median error for crown projected area ranged from 46.1 to 58.58 % and for crown hull volume from 71.5 to 88.39 %. We further focused on each step of the TLS data processing chain (i.e tree isolation, wood leaf separation and tree reconstruction), to quantify its contribution to the final error on wood volume. We found that isolating trees using human assistance divided the error on tree wood volume by almost ten (from 241.3 to 26.06 %). At the 1-ha plot scale, providing tree locations to the algorithm divided the error by three (from 33.67 to 11.58 %). Our results suggest that, in structurally complex tropical forests, fully automatic procedures may provide poorly reliable metrics at tree and plot scales when the outputs are produced without any human intervention, while limited human assistance inputs such as providing tree locations can greatly reduce the errors.

Keywords: Terrestrial LiDAR Scanning; forest; ecology; estimation errors

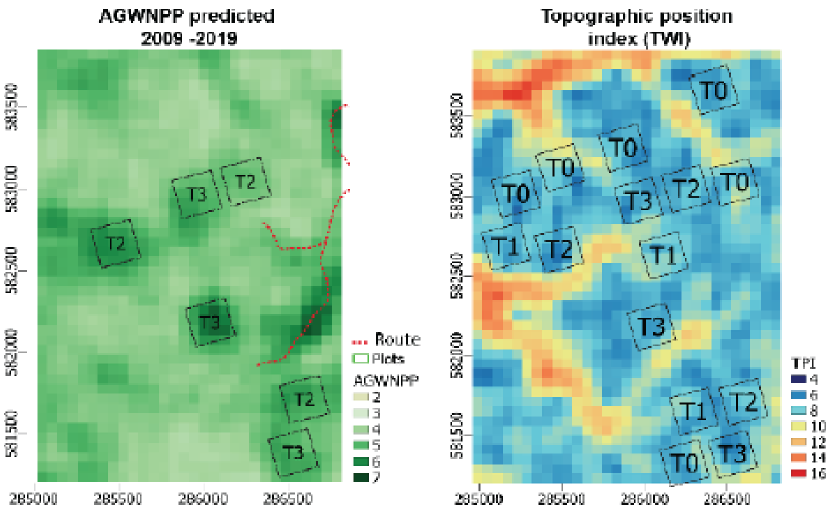

Figure 1. AGWNPP prediction map calculated from the canopy gain map from 2009 to 2019 at a spatial resolution of 60m; the shapefile of the plots are overlaid with the treatment label. Right: TWI for a resolution of 20m derived from the 2015 elevation map using the software GRASS: 7.8.2

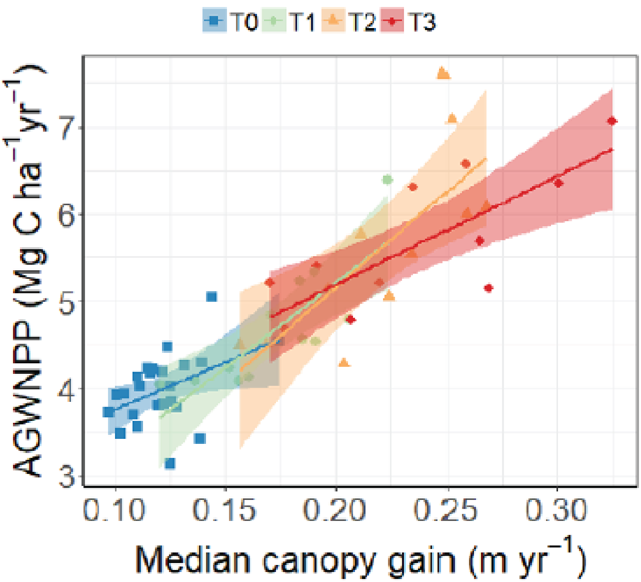

Figure 2. AGWNPP regression model, each point representing a 120 x 120 m graph. The different forest types are color-coded (T0: undisturbed forest, T1 to T3: felled on plots ordered by the increase in disturbance). The solid lines correspond to the regression line and the 0.95 confidence interval in shaded tones.

Contribution of multi-temporal LiDAR for estimating biomass fluxes: Productivity

Presenter: Claudia Milena HUERTAS GARCIA

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Scientific Supervisor: Grégoire VINCENT & Raphaël PÉLISSIER

Large-scale vegetation mapping, characterized by repeated airborne laser scans (ALS - LiDAR), should significantly improve our ability to model and map tropical forest carbon fluxes and stocks, as well as significantly improve our understanding of the determinants of spatial and temporal variation, reducing sources of uncertainty in global models of vegetation dynamics. (Lovenduski and Bonan, 2017; Vincent et al., 2014). Such studies would also provide data to simulate future impacts on biodiversity and ecosystem services. This thesis's general objective is to contribute to a better understanding of the dynamics and structure of tropical forests using available aerial LiDAR data on ~100 km2 of French Guiana.

In terms of dynamics, we found that it is reliable to model net epigenetic primary woody productivity (AGWNPP) from ALS data on a number of different plot sizes (5.8, 1.4, 0.4 ha) and temporal resolutions (10 years and 5 years and two years) in both natural and successive forests (for silvicultural practices) in Paracou Research Station. We first determined the most reliable and robust predictor derived from LiDAR to describe AGWNPP, selecting the Median Canopy Gain indicator. Regarding environmental factors, the spatial prediction revealed a strong correlation between primary productivity and Topographic position index (TWI). Likewise, a significant negative correlation was observed between the Median Canopy Gain and the mean wood density. Our results improve our understanding of forest growth's spatial patterns, providing a new perspective on large-scale monitoring of tropical forests, which is particularly essential for understanding factors influencing forest productivity and providing information for the analysis of interactions with environmental factors and alterations caused by climate change.

Lovenduski, N.S., Bonan, G.B., 2017. Reducing uncertainty in projections of terrestrial carbon uptake. Environ. Res. Lett. 12, 044020.

Vincent, G., Sabatier, D., Rutishauser, E., 2014. Revisiting a universal airborne light detection and ranging approach for tropical forest carbon mapping: scaling-up from tree to stand to landscape. Oecologia 175, 439–443.

Keywords: Canopy gain; forest dynamics; Airborne Lidar; modeling; tropical forests; productivity

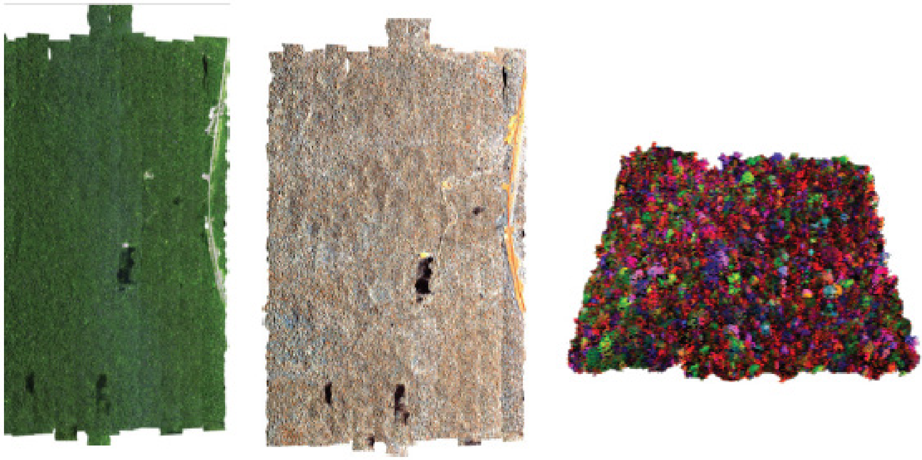

Figure 1. VNIR and VSWIR mosaics + LiDAR data used to segment crowns

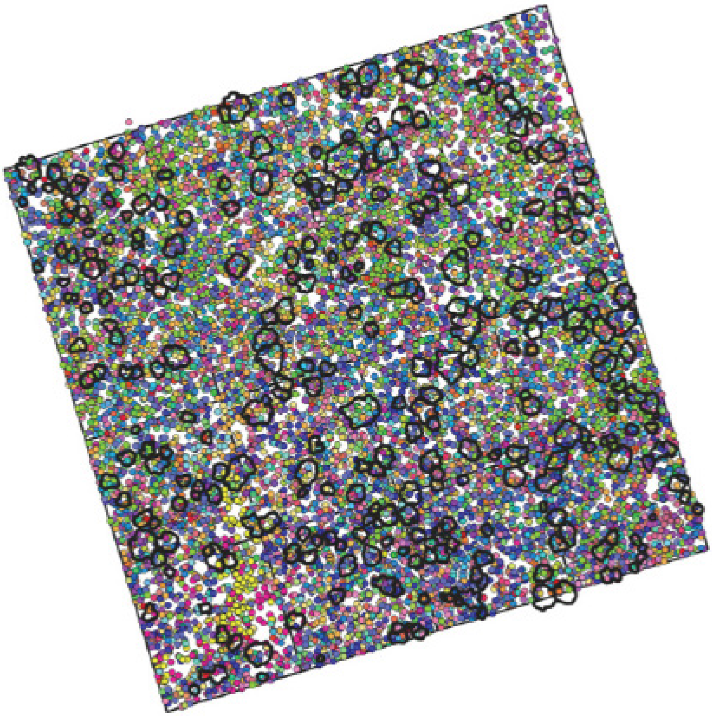

Figure 2. Botanical inventory of 2015 on a plot of Paracou. Each dot color corresponds to a diffe-rent species. We also see part of the crowns segmentved thanks to LiDAR on the plot

Mapping tropical forest diversity from multi- and hyper-spectral imagery

Presenter: Colette BADOURDINE

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Scientific Supervisors: Raphaël PÉLISSIER, Grégoire VINCENT & Jean-Baptiste FÉRET

Tropical forests are receiving increasing attention given the rapid loss of biodiversity due to the combined action of global warming and increasing anthropogenic pressure. There is a need to go beyond monitoring deforestation and to set up monitoring systems capable of assessing tropical forest degradation in terms of biodiversity.

We use a botanical inventory where each trunk is identified on the ground as well as a partial inventory of the crowns segmented by LiDAR data on very high resolution images to explore the relationships between spectral and biological diversity (taxonomic and functional) in neotropical forests and its sensitivity to spectral and spatial resolution to help clarify the relevance and scope of a future hyperspectral satellite mission heralding an observation system to monitor the evolution of forest biodiversity.

Hyperspectral data, because of their high dimensionality, are complex: methodological needs are mainly related to the quality of the estimators and their resistance to noise, due to spectral and spatial variability of the observed elements. Therefore, we need to find the right approach to be able to make the link with the diversity measured on the ground and to determine what can be measured via spectral diversity.

The choice of a diversity metric requires a preliminary analysis in order to have a robust interpretation of the signal: knowing what is being measured when measuring pixel scale spectral diversity and what are the factors and components of spectral diversity. In a first analysis, we aim to estimate the intraspecific variability of species and delineated crowns and characterize the contribution of SWIR data on species inter/intra variability and separability.

Keywords: Hyperspectral ; LiDAR ; tropical forests ; modeling

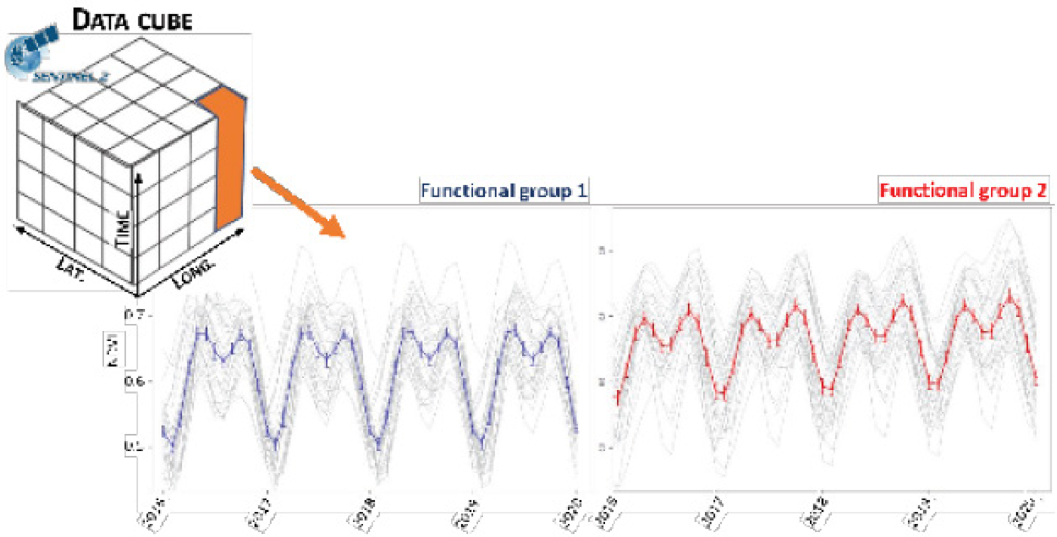

Figure 1. Time series of the spectral index «NDVI» (Sentinel-2 sensor) for two functional groups (red and blue)

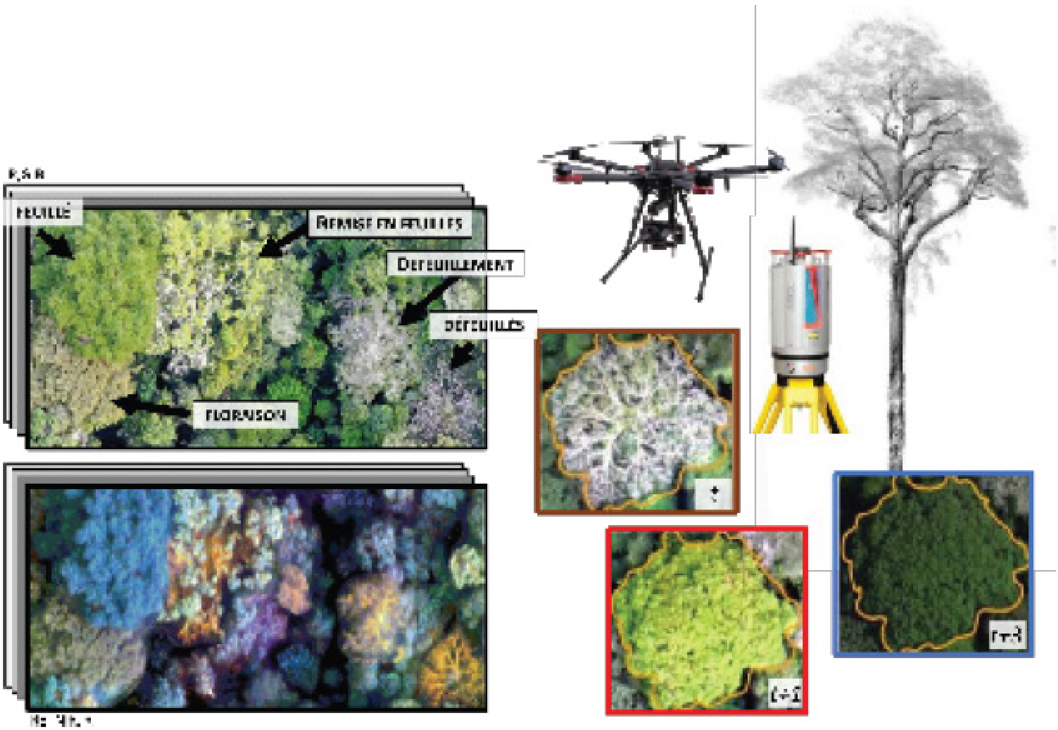

Figure 2. Repeated acquisitions of multispectral and LiDAR data allow following phenological events at the crown scale in order to better interpret the satellite signal.

Using dense optical time series to map the functional composition of tropical forests

Presenter: Pierre PLOTON

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Scientific Supervisor: Raphaël PELISSIER

Tropical forests provide essential ecosystem and economic services and play a key role in some global biogeochemical cycles, such as carbon and water. However, climatic and anthropogenic pressures could lead to changes in the functional composition of these forests, such as an increase in deciduous species in forest canopies (in response to longer drought periods) or in light, low wood density species, which characterize early successional states (in response to anthropogenic disturbances), which would ultimately result in significant modifications of services (e.g. carbon sequestration, timber production) and of primary biological functions (photosynthesis, respiration, transpiration). Documenting, understanding and predicting ongoing changes in the functioning of tropical forests is thus a major scientific challenge. By providing continuous and coherent information in space and time, satellite remote sensing is a crucial tool for meeting this challenge. Moreover, the increase in computing resources available to the scientific community (e.g., Google Earth Engine platform) coupled with the recent availability of very high spatial, temporal and spectral resolution optical satellite images now opens the way to the analysis of dense time series (DTS, Fig. 1) at scales sufficiently close to those of the objects (trees, stands) and processes (phenology) of interest. My project therefore aims to exploit the DTSs of very high resolution sensors to map the functional composition of forests in the tropics, and is based on two main axes : (i) to better understand the biophysical determinants of signal seasonality in tropical rainforests, in order to establish a method for mapping the functional composition of forests, and (ii) to validate the potential of the approach at regional scale. The first axis will be based on a detailed field-based description of changes in vegetation throughout the year, in experimental measurement sites, notably based on new technologies (LiDAR, UAV, Fig. 2). In the second axis, I will deploy the large-scale mapping method in Central Africa, and will use management inventory data covering c. 60,000 km² to adjust and evaluate the map.

Keywords: Tropical forests ; Phenology ; Functional composition ; spaceborne optical time series

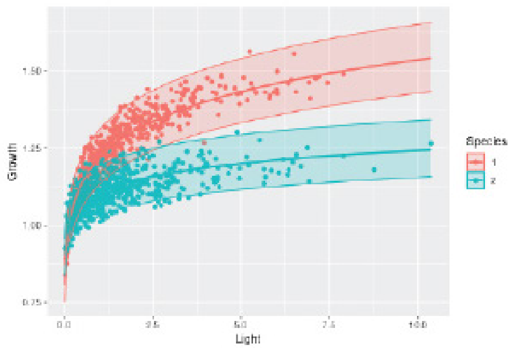

Figure 1. Intraspecific variability emerges from spatial heterogeneity even in clones.
Output of the theoretical model. The X-axis is an environmental variable (light for instance) and the Y-axis is a response to multiple environmental variables (growth for instance). Lines are the mean growth of each species and ribbons are the 95% intervals. Each colour represents a species.

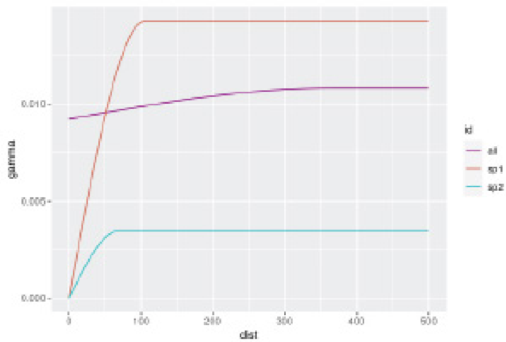

Figure 2. Growth is spatially autocorrelated when it results from spatially autocorrelated variables. Locally var intra < var inter.
Semivariograms of the growth simulated with the theoretical model. The X-axis is the distance between individuals and the Y-axis is the semivariance (half the mean of the squared differences of all pairs which are apart from this distance). The shape of the semivariograms indicates spatial autocorrelation of the data. Locally (here under 50 spatial units) intraspecific variability (blue, red) is smaller than interspecific variability (purple).

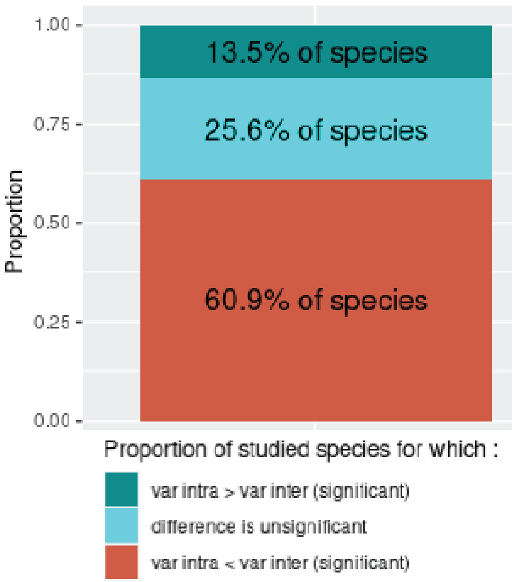

Figure 3. In Paracou, var intra < var inter in growth locally (<100m).
Only species with more than 20 individuals were considered. Heterospecifics were selected from a sample of 10000 individuals. The growth of pairs of individuals of the same plot and which were less than 100m apart was compared pairwise in order to compute the semivariance of conspecifics and of heterospecifics. These semivariances were compared thanks to a Mann-Whitney U test to assess significance.

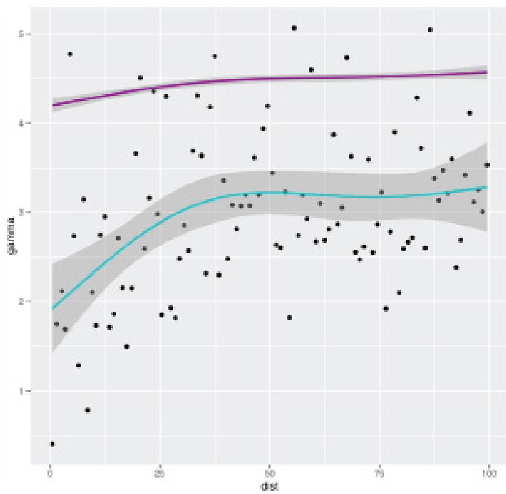

Figure 4. In Paracou, growth is a spatially autocorrelated variable
Example of a species (Carapa surinamensis) displaying spatial autocorrelation in the semivariogram of its growth (blue). The X-axis is the distance between trees and the Y-axis is the semivariance. Intraspecific variability is also smaller than interspecific variability (purple).

Role of intraspecific variability in species coexistence in tropical forests

Presenter: Camille GIRARD-TERCIEUX

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Scientifics Supervisor: Isabelle MARÉCHAUX, Raphaël PÉLISSIER & Ghislain VIEILLEDENT

Traveling through one hectare of tropical forest, it is possible to encounter several hundred different tree species. Understanding how such diverse species, competing for a limited number of resources, can coexist locally remains one of the oldest and most fundamental questions in ecology. Different mechanisms contributing to the maintenance of this diversity within communities have been highlighted. However, studies to date have largely neglected intraspecific variability, although it may account for a significant part of the variation between individuals within a community. Intraspecific variability is sometimes assumed to contribute to species coexistence through inversion of the local competitive hierarchy, and sometimes to limit stable species coexistence by mitigating interspecies differences. The mechanisms underlying such a positive or negative effect remain unclear and debated.

Another view of the intraspecific variability observed in the traits is that it is the result of the response of species to the multiple axes of the ecological niche, whether observed or not. Intraspecific variability would then be more the signature of the multidimensionality of the niche, rather than a blurring of differences between species. This vision has been developed for temperate forests and based on temporal responses, but a demonstration in a spatial framework and a test in tropical forests is lacking.

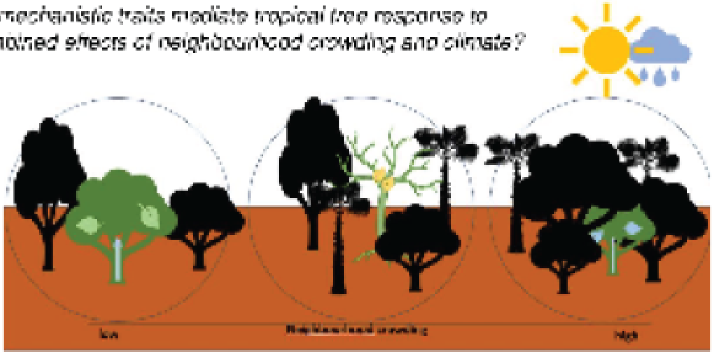
The aim of this PhD is to contribute to a better understanding of the nature of intraspecific variability and its role on the coexistence of species within tropical tree communities using different approaches (literature review, data analysis, modeling).

More specifically, the aim are to (i) synthesize the different hypotheses put forward in the literature on the role of intraspecific variability on coexistence, and analyze the different results obtained according to the way intraspecific variability has been considered; (ii) using a theoretical model, show that intraspecific variability can emerge from unobserved axes of the niche and be completely exogenous (as opposed to variability that emerges from intrinsic differences between individuals); (iii) test on real data sets the presence of spatial autocorrelation in growth and compare intra- and inter-specific variance locally; (iv) integrate intraspecific variability into several forest dynamics models based on real data and compare the results obtained with the different models. This will allow differences in results related to the structure of the models to be highlighted and discussed.

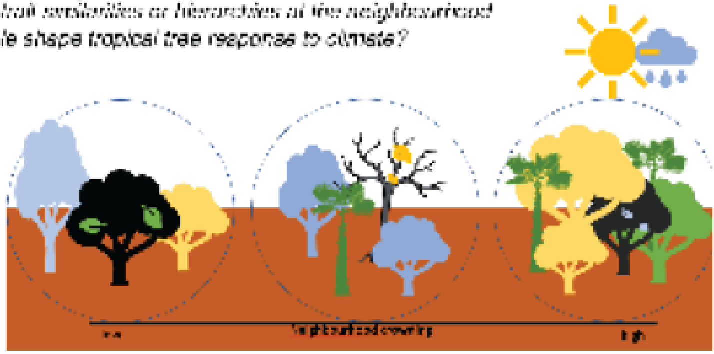
Preliminary results :
- A theoretical model shows that intraspecific variability in response variables can emerge from clones (individuals with the same parameters) in a heterogeneous environment and that is does not imply that the species niches overlap.
- A theoretical model shows that if the environmental variables that impact growth are spatially auto-correlated, then growth is also spatially auto-correlated, and that the differences between species result in intraspecific variability being locally smaller than interspecific variability.
- Analysis of the Paracou data confirms that growth is spatially auto-correlated, and that locally intraspecific variability is smaller than interspecific variability.

Keywords: Biodiversity ; Tree communities ; Demography ; Functional traits ; French Guiana

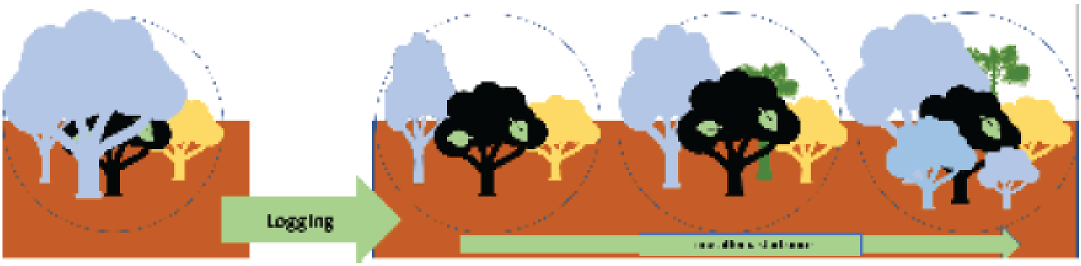
Do mechanistic traits mediate tropical tree response to combined effects of neighbourhood crowding and climate?



Do trait similarities or hierarchies at the neighbourhood scale shape tropical tree response to climate?



Does the relative importance of neighbourhood crowding and abiotic factors in driving tree performance change with time after disturbance?



The role of biodiversity on tropical forest response to climate and anthropogenic disturbance

Presenter: Daniela KREBBER

Email: daniela.krebber@gmail.com

Scientific Supervisors: Claire FORTUNEL, Géraldine DERROIRE & Eric MARCON

Understanding how global change impacts the biodiversity and functioning of tropical forest represents a major challenge for ecologists. In the face of rapid climate and land use changes, determining the separate and joint effects of multiple ecological drivers on tropical tree performance is crucial to better understand the mechanisms involved in forest dynamics and functioning. Together with intrinsic species characteristics, abiotic factors and biotic interactions influence individual tree performance. Although the role of biotic interactions and their potential to interact with abiotic factors in shaping communities has become apparent over the last decades, these drivers have mainly been studied separately. While biodiversity has been shown to relate to forest resilience to climate extremes and disturbance events on a global scale, its role in mitigating these effects at smaller scales remains unclear. Studies relating tree species diversity to drought effects have produced controversial results, revealing that diversity does not systematically reduce impacts of climate change in forests. While the biological mechanisms leading to variations in observed biodiversity effects between studies still remain unclear, differences in species strategies and complex interactions between neighbouring trees in combination with the environmental context are thought to play a key role. To better understand the influences of biodiversity on tropical tree response to global change factors, a promising way forward is to investigate the role of local biotic interactions in combination with a trait-based approach.

My Phd examines the role of biotic interactions between neighbouring trees in mediating tree response to climate and disturbance. I further aim to investigate in which context neighbourhood interactions may act as buffers or exacerbators of abiotic stressors. To this aim, I disentangle the separate and joint effects of neighbourhood crowding, climate and disturbance on individual tree performance (i.e. growth and mortality) using an individual-based and spatially-explicit hierarchical Bayesian modelling approach. I leverage species hydraulic traits that can be clearly connected to physiological processes shaping tree performance along abiotic and biotic gradients to capture interspecific differences in functional strategies. My project is based on a large dataset of 35 years of annual and biannual inventories of individual tree growth and mortality from the permanent forest plots at the Cirad experimental site of Paracou, French Guiana, France.

The main objectives of my work are thus (1) to model the joint response of tropical tree growth and mortality to neighbourhood crowding and abiotic drivers (i.e. climate and disturbance); (2) to investigate the role of mechanistic traits in governing interspecific variations in i) intrinsic tree performance, ii) treeresponse to climate and disturbance, iii) sensitivity to neighbourhood crowding; (3) to investigate how trait similarities and trait hierarchies at the neighbourhood scale mediate forest response to inter annual variations in climate; (4) to investigate if relative importance of neighbourhood crowding and abiotic drivers changes with the intensity and time since anthropogenic disturbance through logging.

Keywords: Biotic interactions; Tropical forest; Climate; Disturbance; Functional ecology; Bayesian Modelling

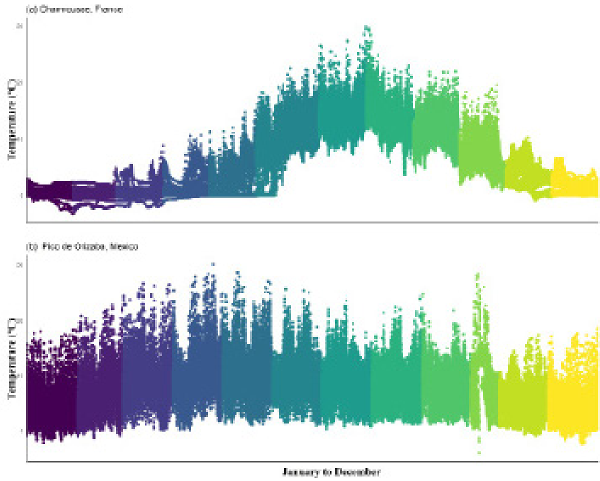


Figure 1. Daily temperature recorded every two hours at five centimeters below ground during 2018 -2019. (a) Chamrousse, France and (b) Pico de Orizaba, Mexico. Color represents each month from January to December.

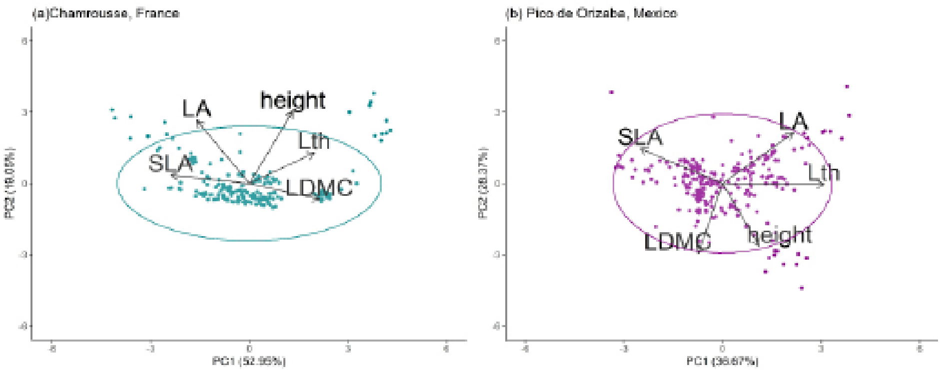


Figure 2. Principal component analysis (PCA) of functional traits by site. (a) Chamrousse, France for all 11 plant species selected. (b) Pico de Orizaba, Mexico for all 13 plant species selected. Plant functional traits are SLA (specific leaf area, m2 kg-1); LDMC (leaf dry-matter content, g g-1); leaf thickness (mm); LA (leaf area, cm2); and plant height (cm).

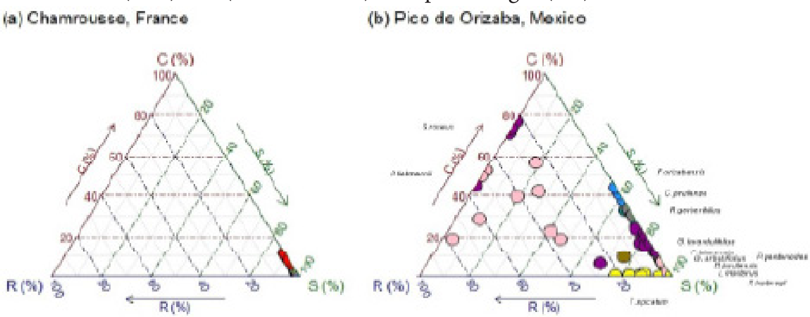


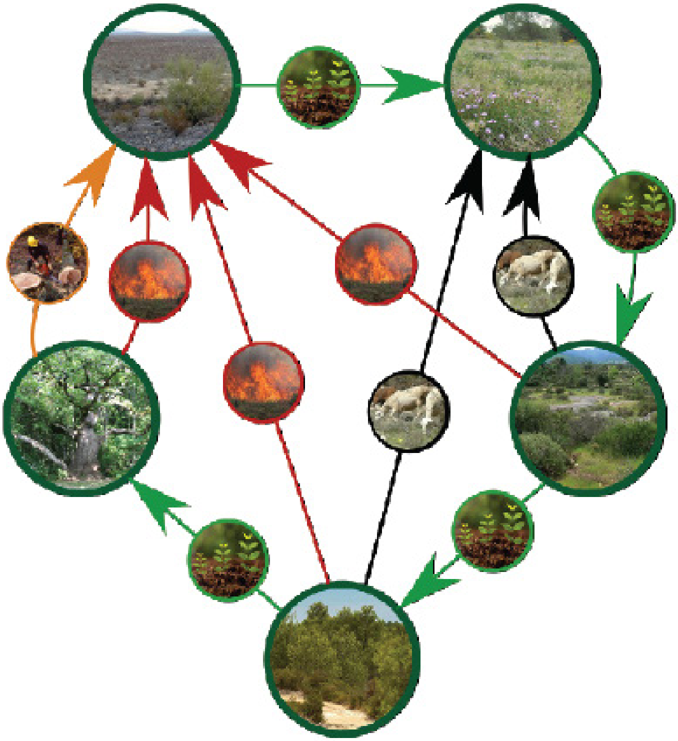
Figure 3. Grime's CSR scheme. (a) Chamrousse, France. Functional trait values for all 11 species. (b) Pico de Orizaba, Mexico. Functional trait values for all 13 species. Each colored dot represents the value of an individual

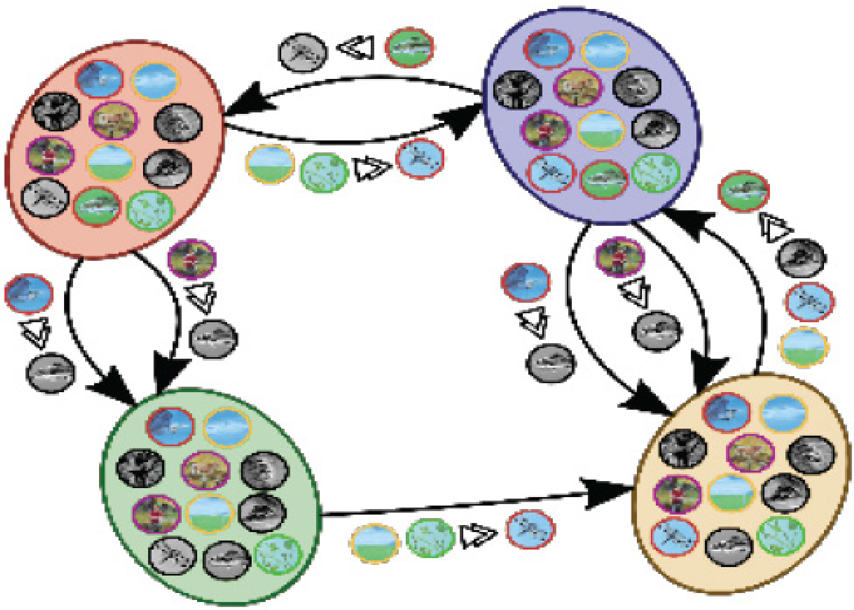
Plant-functional responses along temperate and tropical (sub)alpine altitudinal gradient

Presenter:	Nereyda Nathalie CRUZ MALDONADO
Email:	nerecruz@gmail.com
Scientific Supervisors:	Fabien ANTHELME

At higher elevations in temperate and arctic environments, intraspecific functional variability in (sub)alpine plants shifts towards a higher tolerance to abiotic constraints. To investigate whether the same shift occurs in the (sub)alpine tropics, we measured five aboveground functional traits of plants from 13 species along an elevation gradient in Mexico and 11 species in France. The five traits were specific leaf area, leaf dry-matter content, leaf thickness, leaf area, and plant height in 24 species, represented five growth forms: forb, rosette, shrub, tree, and tussock grass. The main objective of this thesis is to identify common patterns and dissimilarities in the functional responses of (sub)alpine plants along an elevational gradient of 1 000 m in a temperate mountain (Chamrousse, France) versus in a tropical mountain (Pico de Orizaba, Mexico). We tested two main hypotheses (H1) Trait-elevation variation is not homogenous among species because of great variability in growth forms, and (possibly) the more-diversified biogeographic origins of species in Tropical Mexico. Our second hypothesis, which concerns the differences between plant strategies in the two ecosystems, requires more explanation. Within particular habitats, plant-strategy differentiation (which may result from intraspecific trait variation) can in turn be responsible for niche differentiation, thereby determining whether species coexist within a habitat or not. We reasoned that plant-strategy differentiation in tropical mountains may be greater than in temperate ones because of the temperate mountains' durable winter snow cover. That cover not only prevents plants from growing or accessing light for a large part of the year, but also homogenizes the landscape, and leaves only a short growing season. In contrast, the absence of durable snow cover in tropical mountains, plus the lack of a marked seasonality, allows plants in those ecosystems freer access to microsites such as rocks and corners. The plants thus have greater opportunity to interact, even as the large daily temperature variations drive plant species to the limits of their genetic adaptation and phenotypic plasticity. Therefore, our second hypothesis (H2) is that plant species from temperate mountains have a similar strategies (specifically, stress-tolerant ones) while species in tropical (sub)alpine ecosystems develop a range of strategies to adapt to climatic stress and different functional responses. As a preliminary result we found that that trait-elevation patterns varied strongly among the species and growth forms. Trait-elevation patterns for species of tropical origin differed from those of temperate-origin species. The patterns of plant organization that we found along the elevation gradient suggest that such data must be considered carefully when drawing worldwide scenarios of how (sub)alpine biodiversity will respond to climate warming.

Keywords: Growth form; Leaf functional traits; Plant height; Temperate vs. tropical; Plant-strategy differentiation





Possibilist analysis of discrete models of ecosystems using symbolic methods

Presenter: Colin THOMAS

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Scientific Supervisors: Franck POMMEREAU & Cédric GAUCHEREL

The dynamic of an ecosystem can be represented by a state and transition graph : a set of nodes and edges linking the possible states of the ecosystem (see the figures on the left for examples). From the early studies on plant community succession (Clements, 1916) to the management of natural park in the USA (Westoby, 1989), this formalism is usually used as a representation of empirical data. We propose to generate such state and transition graphs from a model based on discrete events. Those models generate huge graphs (thousands or millions of states) that require specific analysis. The lack of analysis tools may also be responsible of the absence of detailed state and transition graph based on empirical data (Walker and Westoby 2020).

Such formalism has been used for decades in computer science to represent the possible executions of a software. The state and transition graph is generated from the source code, and is tested on some specifications. The usual approach, called model checking, tests if a bug can happen during the execution of the computer program (for example if the Ariane navigation software can force the space shuttle to aim the ground, or if a missile launcher software can fire on itself...). Those methods are able to test complex properties on state and transitions graph of millions of nodes.

The main objectives of this thesis are :

(1) To apply model checking methods to ecosystem state and transition graph, in order to test if the trajectories of the ecosystem always verify a given property (by analogy with the absence of bug).

(2) To develop a new analysis tool representing the differences between “buggy” and “bugless” executions (computer science focuses on the presence or absence of bugs, while ecology in interested in the causes of the branching between different trajectories).

Keywords: State and Transition models; Ecosystem dynamic; Succession; Community assembly; Model checking.

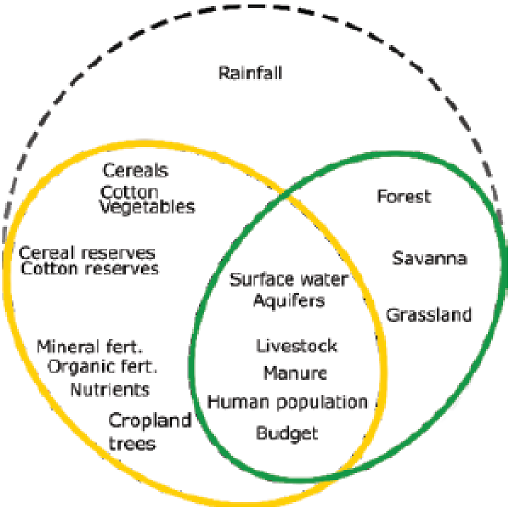

Figure 1. Synthesis of the variables in the model of West-African village. Dotted circle represent the system, orange circle the Cropland area and its variables, in green the Rangeland area and its variables, and the intersection the common variables to both sub-systems.

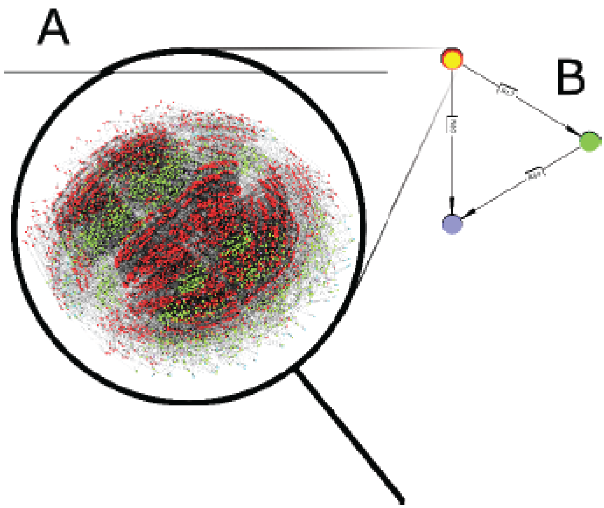

Figure 2. Food secure part of the system dynamics (subspace). A) Full view of the subspace. Here, each node corresponds to a state of the system, and each link to a change in the system state. B) Merged view of the subspace. Each node corresponds to a stable food secure functioning of the system, while links correspond to transitions between different food secure types of functioning

«L'écosystème dans tous ses états»: using discrete-event models to uncover food secure trajectories in West-African social-ecological systems

Presenter: Maximilien COSME

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Social-ecological modelling is an ever-growing field of research. Starting in the early 20th century, modelling techniques have multiplied with the rise of computer sciences, being used for theoretical explorations, decision-help or environmental impact assessment. This plurality of uses is associated to a plurality of conceptual frameworks, and modellers may need to explicit the theoretical foundations behind their tools.
After a brief overview and discussion about ecological models families, I will propose some theoretical and empirical justifications to a new kind of models in ecology. These, called discrete-event models, have been extensively used in systems biology to study chemical reaction and gene-protein networks, comprising hundreds of discrete variables and interactions. Based on discontinuous system changes, they compute all the possible trajectories, keeping track of causal pathways (sequences of appearance/disappearance of biological or ecological components). They have a great potential to store and synthesize knowledge about interactions and their outcomes. Just as in biology, where they are used for identifying therapeutic targets, we will defend their potential relevance in socio-ecosystem management.

Models outputs consist of up to billions of states, and thus need a well-adapted analysis tool. As these outputs represent non-deterministic system dynamics, temporal logic is a good candidate as it allows talking about time non-deterministically. Temporal logic has been traditionally used by computer scientists to check software properties. Their use in biology dates back to the early 2000's, where suites of biological questions have been formally expressed. I will try to argue that temporal logic could help ecologists to formalize key concepts in ecology (e.g. food security or ecological niche).

Finally, I will show early results of the application of this kind of models to understand the determinants of food security in a village in Burkina Faso (Fig. 1), identifying the various food secure regimes of the system (Fig. 2).

Keywords: Discrete-event models; Social-Ecological Systems; Temporal logic; Possibilism; Food security; System trajectories

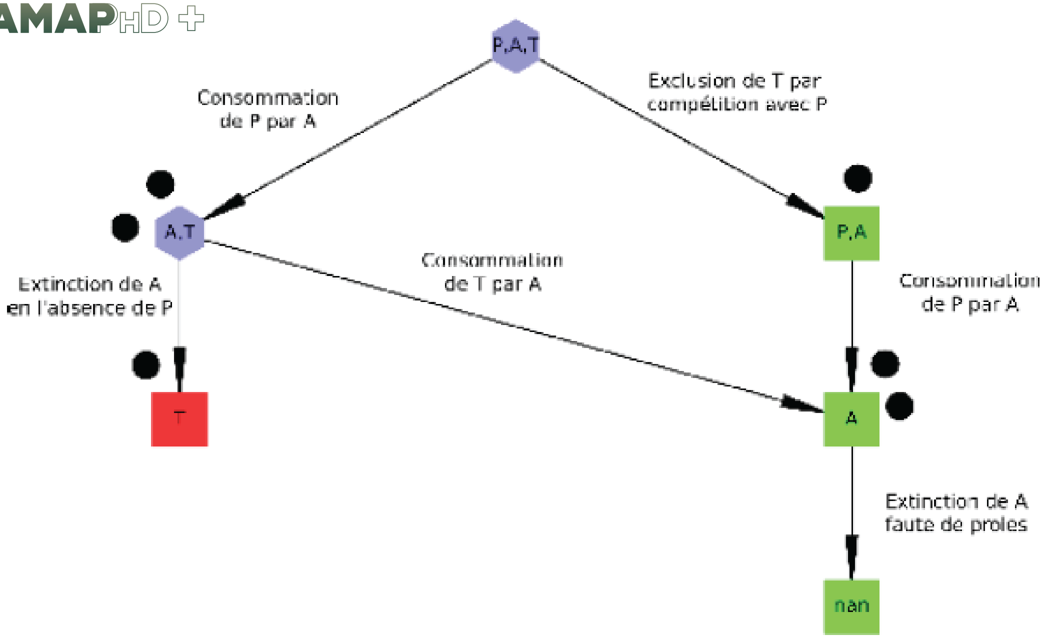

Figure 1. States graph describing the possible dynamics of a three-protists system (species initials are denoted A,P, T) Each node corresponds to a given state of the system defined by the species that are present in it ; arrows indicate the transitions between these states. Black dots correspond to the final results of six experiments, all starting from the P, A,T state.

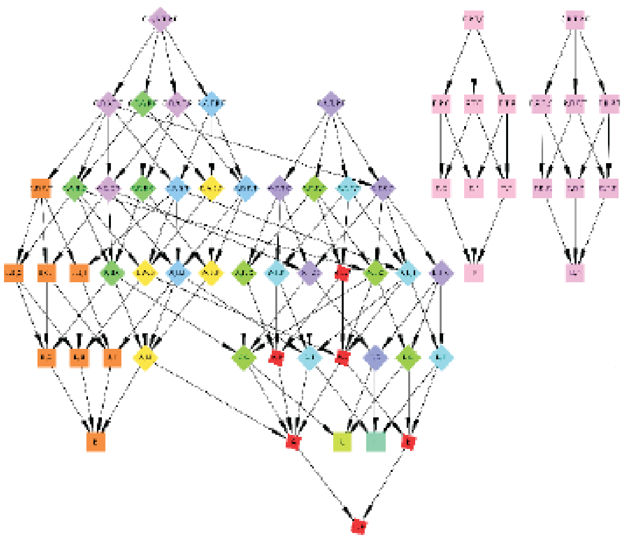

Figure 2.States graph describing all the possible dynamics for a trophic network containing six protists (A, B, C, E, T, P), between every possible state.

Discrete-event models as a way to explore non-reproducible behaviour in ecological networks

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Scientific Supervisor: Cédric GAUCHEREL

Real-life ecological systems display stochastic behaviour. However, the differential equations widely used to compute the dynamics of ecological networks are usually unable to take into account this part of their behaviour, because they are deterministic. In addition, these models rely on a large amount of parameters that are often difficult to measure precisely.

Using qualitative and possibilistic models based on transition rules, we are able to characterize all possible transformations that a given ecological network can undergo[1]. While we cannot access fine details of the system's dynamics, it allows us to obtain a complete map of the system's possible trajectories.

We applied this model to a set of experiments that studied the survival or collapse of communities of protists[2]. Based on the knowledge of pairwise inter-specific interactions, we are able to efficiently predict the set of possible outcomes and to identify which community compositions lead to divergent results, as well as the corresponding bifurcations in the system's trajectory.

[1]Gaucherel and Pommereau, Methods in Ecology an Evolution 10, no. 9 (2019): 1615-27

[2]Weatherby, Warren, and Law, Journal of Animal Ecology 67, no. 4 (1998): 554–66.

Keywords: Ecological networks ; Qualitative models ; Protists

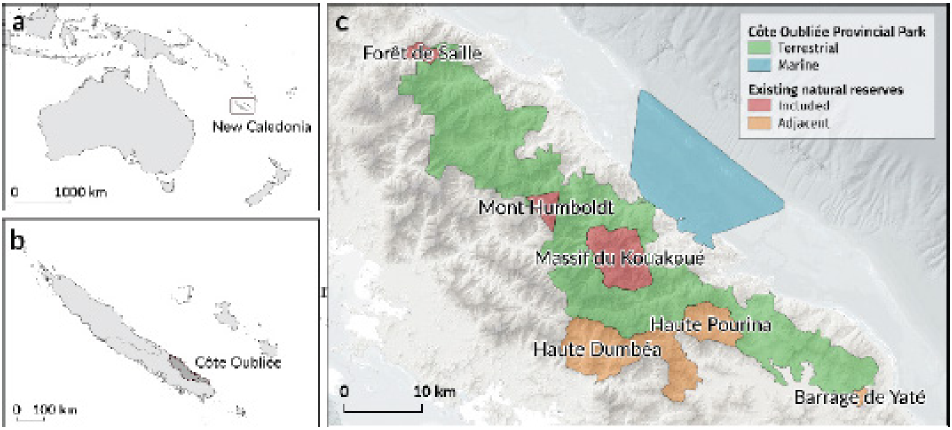

Figure 1. (Justeau-Allaire et al. 2020) : (a) Location of New Caledonia. (b) Location of the "Côte Oubliée" area. (c) Map of the "Côte Oubliée – Woen Vùù – Pwa Pereeù" provincial park, with included and adjacent existing natural reserves.]

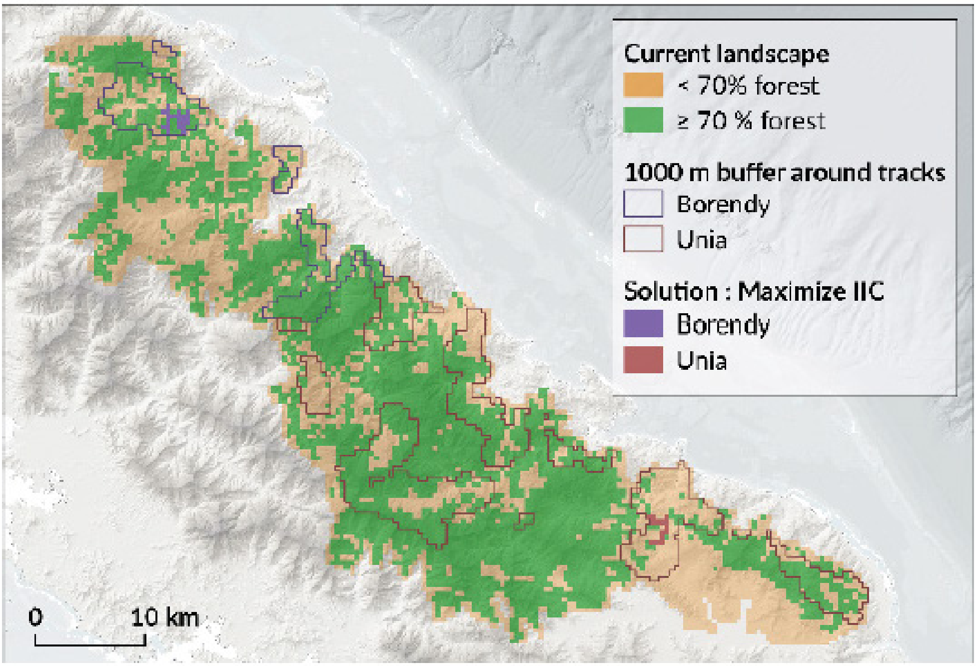

Figure 2. (Justeau-Allaire et al. 2020) : Mapping of a solution maximizing the integral index of connectivity (IIC).]

Constrained optimization of landscape indices in conservation planning to support ecological restoration in New Caledonia

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Scientific Supervisors:	Philippe BIRNBAUM & Xavier LORCA

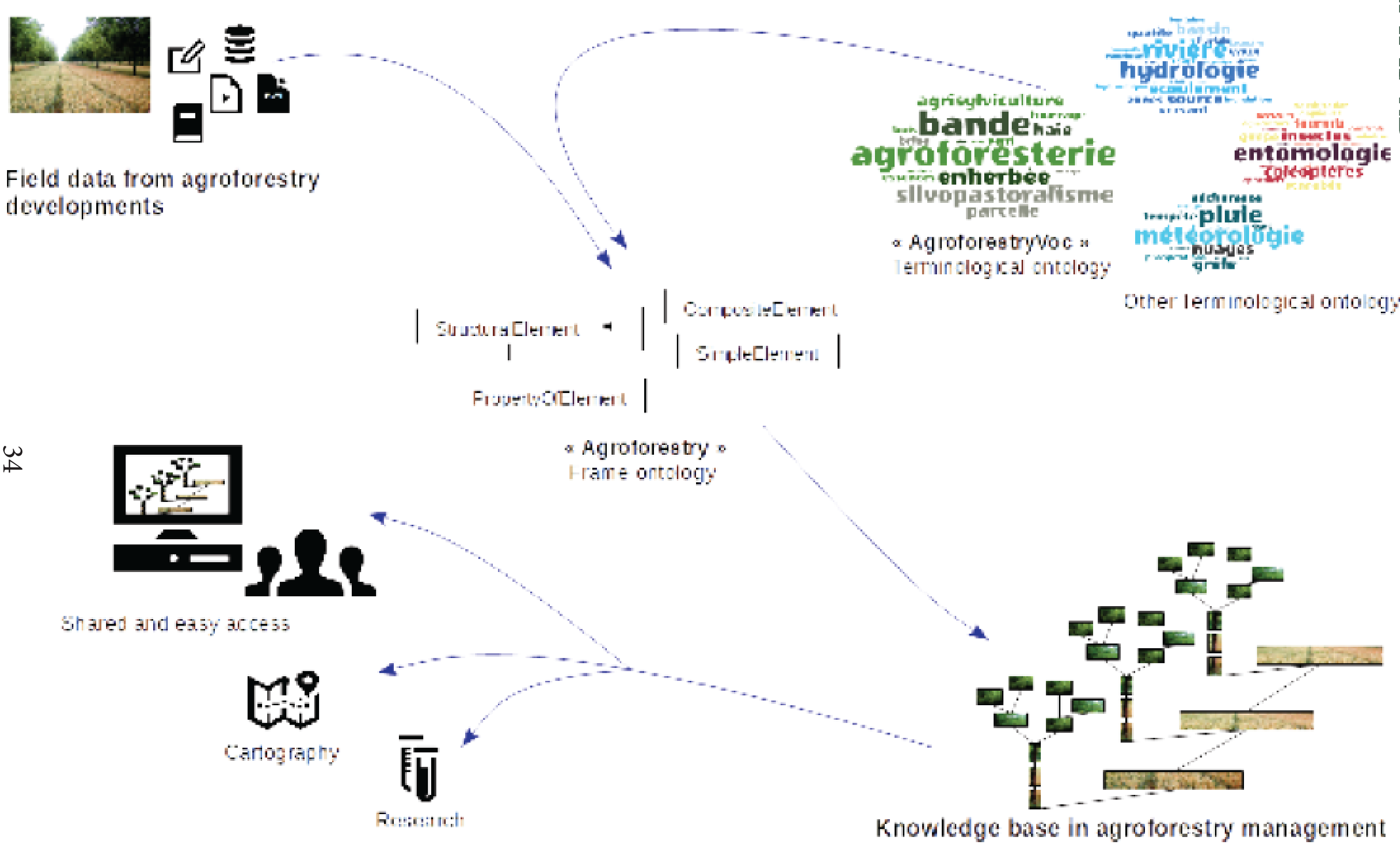
Curbing habitat loss, reducing fragmentation, and restoring connectivity are frequent concerns of conservation planning. In this respect, the incorporation of spatial constraints, fragmentation, and connectivity indices into optimization procedures is an important challenge for improving decision support.

In an article accepted in Journal of Applied Ecology (Justeau-Allaire, Vieilledent, Rinck, Vismara, Lorca and Birnbaum; 2020), we presented a novel optimization approach developed to accurately represent a broad range of conservation planning questions with spatial constraints and landscape indices. Relying on constraint programming, a technique from artificial intelligence based on automatic reasoning, this approach provides both constraint satisfaction and optimality guarantees.

We applied this approach in a real case study to support managers of the ``Côte Oubliée -- `Woen Vùù -- Pwa Pereeù'' provincial park project, in the biodiversity hotspot of New Caledonia. Under budget, accessibility, and equitable allocation constraints, we identified restorable areas optimal for reducing forest fragmentation and improving inter-patch structural connectivity, respectively measured with the effective mesh size (MESH) and the integral index of connectivity (IIC). MESH is a measure of landscape fragmentation which is based on the cumulative patch sizes distribution. Maximizing it in a reforestation context favours fewer and larger forest patches. On the other hand, IIC is a graph-based inter-patch connectivity index based on a binary connection model. Its maximization in a reforestation context favours restoring structural connectivity between large patches.

Synthesis and applications: Our work contributes to more effective and policy-relevant conservation planning by providing a spatially-explicit and problem-focused optimization approach. By allowing an exact representation of spatial constraints and landscape indices, it can address new questions and ensure whether the solutions will be socio-economically feasible, through optimality and satisfiability guarantees. Our approach is generic and flexible, thus applicable to a wide range of conservation planning problems such as reserve or corridor design.

Keywords: Systematic conservation planning; Restoration; Connectivity; Fragmentation; Constraint Programming; New Caledonia, Reforestation.



Schematic diagram of ontology-based modelling for agroforestry management

An ontological approach to data management in agroforestry

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Scientific Supervisors: Isabelle MOUGENOT & Alexia STOKES

Data from field observations acquired in partnership with several categories of actors (foresters, farmers, breeders, etc.) as part of agroforestry experiments have been accumulating for many years now. The management and reuse of this data is made difficult by the multiplicity of media and formats used and by the diversity of the actors and their language. In addition, agroforestry studies require systemic approaches to better understand, for example, agroforestry operations' response mechanisms to climate change, pests and soil pollution. This implies linking up with other fields of knowledge such as climatology, zoology or pedology.

To help the agroforestry community in the exploitation and sharing of their data, in order to report on the evolution and effectiveness of the developments they have carried out, we propose as a first objective, to set up a knowledge model (an ontology) dedicated to agroforestry. This ontology will serve as the basis for capitalizing and sharing data in agroforestry.

A second objective is to link agroforestry data with other data sets in other knowledge areas such as the environment and territories. For example, an agroforester manager should be able to easily compare the selling price of standing timber in his region for different tree species that he would be likely to plant on his agroforestry plot.

The dual challenge of sharing and interconnecting data in agroforestry brings us closer to what is currently practiced within the "semantic web" with different tools and methods to promote the sharing of open and linked data sources. Semantic web technologies provide standard procedures for describing and accessing resources on the web. The linked data is exploited and enriched by technologies such as RDF, SPARQL, OWL and SKOS. We reuse semantic web standards and exploit a range of terminological ontologies to provide an open and flexible knowledge model that can reflect the complexity of data already collected in agroforestry. This new model will be able to connect to other knowledge models already present on the Web. Agroforestry expertise linked to other expert areas on the web will facilitate the creation of decision support tools and thus provide new solutions to agroforestry practice.

Keywords: Agroforestry, ontology, semantic web.

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Predicting tree species vulnerability to climate change in the tropical forest of French Guiana using joint species distribution models

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Scientific Supervisors: Pierre COUTERON, Ghislain VIEILLEDENT

Climate change risks having a strong impact on tropical forests through changes in species distribution and community composition. Species distribution models (SDMs) are commonly used in ecology to predict the ecological niche of a species and its vulnerability to climate change but they do not take into account interactions between species and very often consider only an environmental filter to predict the occurrence of species (abundance or probability of occurrence). Joint Species Distribution Models (JSDMs), which have recently emerged in ecology, allow to take into account interactions between species to predict their occurrence. This approach is particularly interesting for rare species which can borrow information from other more abundant species. These models provide a conceptual framework for integrating phylogeny or functional traits to explain differences in occurrence between species. JSDMs have known a rapid expansion in recent years with the development of several libraries to fit this type of model according to different statistical approaches (R packages HMSC, gjam, BayesComm, BORAL, or s-jSDM). However, these libraries may have some limitations, they do not all allow (i) the processing of large data-sets, (ii) extrapolation between observation sites to obtain predictive maps, (iii) the handling of presence only data (typical of herbarium data for example) or missing data.

The main objectives of this thesis are : (i) to explain the differences in vulnerability of species to climate change from a functional and phylogenetic point of view and (ii) to predict changes in species ranges and tree community composition in French Guiana under climate change. This project relies on the development of the R package named jSDM (https://ecology.ghislainv.fr/jSDM) to overcome the limitations of existing libraries for fitting joint species distribution models . The jSDM package includes a Gibbs sampler with block sampling of parameters, implemented in C++, it is optimized and allows the estimation of parameters for large datasets in a limited time. Additional functions will be developed in order to (i) integrate phylogeny and functional traits as explanatory factors for differences in occurrence between species and (ii) to be able to spatially extrapolate occurrences between surveyed sites to obtain predictive maps.

Keywords: Tropical ecology; Biodiversity; JSDM; Climate change; Functional traits and phylogeny; Bayesian hierarchical models; Monte Carlo Markov Chain; Gibbs sampling

Figure 1. Agroforestry system design workshops (Copyright UMR AbSys)

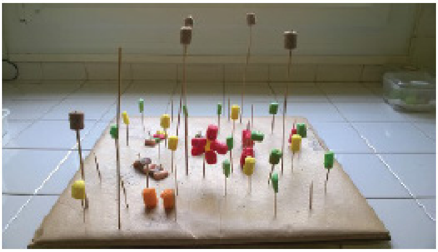

Figure 2. Mockup resulting from an agroforestry system design workshop (Copyright UMR AbSys)

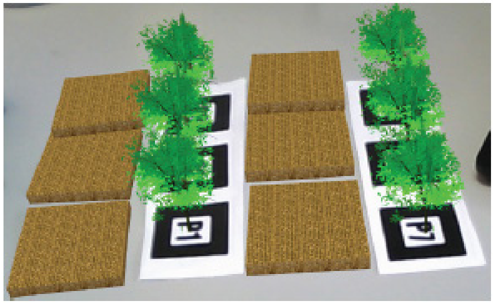

Figure 3. Picture from the prototype create by A. Tallaa (Copyright A. Tallaa).

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Augmented reality to support agroforestry systems design

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Conventional agriculture has numerous drawbacks such as a decrease in biodiversity and soil quality (Reganold et al., 1987). An alternative is to switch to agroforestry. Agroforestry is a farming method where crops, trees and sometimes animals share the same land (Dupraz et Liagre, 2008). This method offers advantages as it improves carbon capture, soil and water quality and biodiversity (Jose, 2009) while maintaining productivity.

The design of an agroforestry system is a complex task that involves a wide range of choices in terms of species, spatial organization, crop management under various local constraints. In order to facilitate agroforestry system design, co-design workshop (Berthet et al., 2016) are organized to find the optimal combination of crop and trees according to the interests of all actors. Figure 1 shows such a co-design workshop where actors move markers corresponding to the trees or crops in the parcel. However, it is difficult to integrate the time dimension into this system design process.

Technologies such as augmented reality (AR) may overcome this difficulty. AR is a "technology that superimposes a computer-generated image on a user's view of the real world, thus providing a composite view" (Oxford English Dictionary). AR is seldom used in agriculture. In the proposed work to design of agroforestry systems, AR is useful in two situations. First, in a co-design workshop, users can move real markers for the spatial dimension and the evolution of the elements can be simulated by the virtual objects. In addition, this technology is a facilitator of exchanges between the actors in the design session. Second, in situ, producers will be able to visualize the virtual evolution of their plot.

Consequently, the objective of this PhD is to identify the AR-based methods that will help farmers to design an agroforestry system and, in particular, help them to imagine the future aspect and functioning of their system. This problem implies others questions about the representation of elements and constraints. An important question is how to express the constraints (physical, functional) through a visual or sound effect? Another question is how to normalize the description of a scene? A second type of possible results is the collection and sharing of each expert's knowledge on soil, crop, tree, ecosystem services, legal aspects etc....

Keywords: Augmented reality, agroforestry, plain graph visualization, knowledge representation, GUI, decision support tool

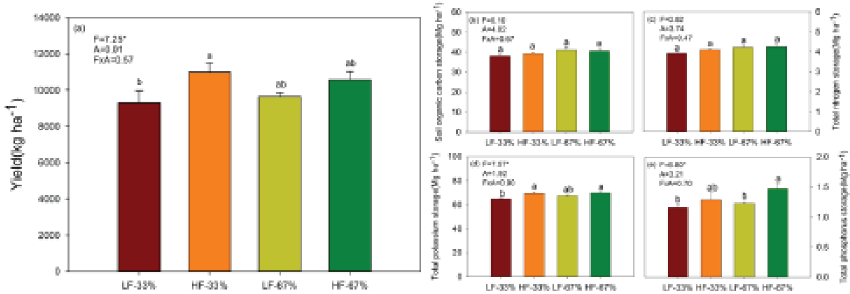

Figure 1. The productivity and fertility of different frequencies and amounts straw mulching treatments (a) Corn yield, (b) SOC storage, (c) TN storage, (d) TK storage, (e) TP storage. F values from a two-way ANOVA on the effect frequency (F) and amount (A) and their interactions (F × A) are also presented, significance levels are as follows: *P < 0.05. Different letters indicate significant difference at P < 0.05 by LSD.

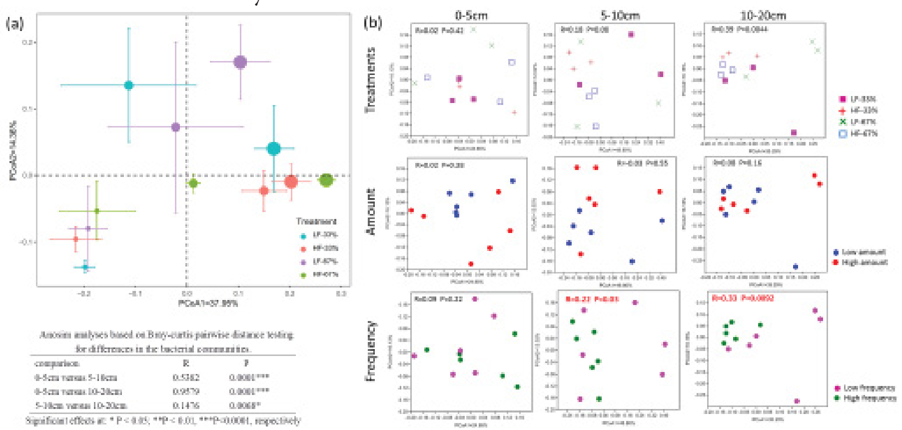

Figure 2. (a) Principal coordinates analysis (PCoA) of soil bacterial community composition based on Bray-curtis distance. The increasing gradient of the symbols' size indicates the samples from surface to bottom layer. (b) Principal co-ordinates analysis (PCoA) of the bacterial communities in soil layers considering treatments, straw mulching amount, straw mulching frequency. Analyses of similarities (R) with the associated P value are shown.

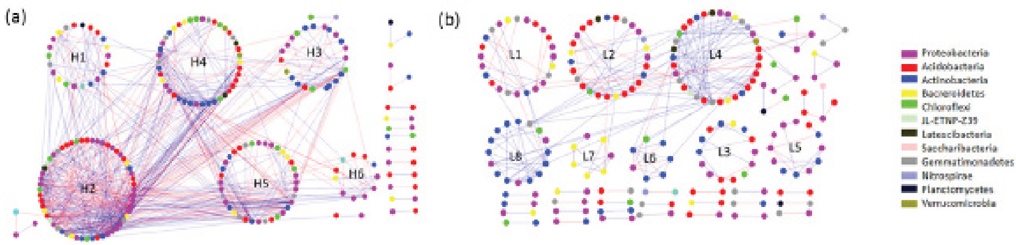

Figure 3. Overview of the bacterial networks in the high frequency (a), and low frequency (b) soil samples. Node colors indicate different phyla. Red lines between nodes (links) indicate negative interactions, whereas blue lines indicate positive interactions.

High frequency of straw mulching regenerates healthy soil towards sustainable agriculture in China Mollisol

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Scientific Supervisors: Chao LIANG & Zhun MAO

The mollisol in northeast China has been severely degraded in the past several decades due to long-term excessive conventional tillage practices. Although straw mulching serves as a manageable, efficient practice that has been widely used to restore soil health and sustain ecosystem, it is unclear how changing the frequency and quantity of straw mulching in a long run affects soil ecosystem and it remains elusive regarding the underlying mechanisms associated with the feature and response of belowground microbiome in the process. Here, we explored straw mulching effects on bacterial community by 16S rRNA sequencing analysis, as well as physiochemical parameters and crop yield, under two frequencies (high frequency with continuous mulching per year and low frequency with interval mulching every three years) and two amounts (low amount, 33% and high amount, 67%) of corn straw mulching in a 10-year no-till experiment. We found that frequency of straw mulching significantly affected bacterial community structure in deeper soil, where at 5-10 cm high frequency of straw mulching showed significantly higher bacterial diversity and richness than low frequency. The complex and close-knit co-occurrence network of bacterial community in high-frequency straw mulching soil was associated with predominated copiotrophs and preferentially metabolic functions; while the simple and loose co-occurrence network together with oligotrophs and potential function involving in cell process in low-frequency straw mulching soil. High frequency of straw mulching maintained the soil organic carbon storage, improved the stocks of soil total potassium and phosphorus, and enhanced the crop productivity, which all are independent of whether low or high amount of straw mulching was applied. Together, suggesting that low amount with high frequent straw mulching (HF-33%) is efficient way to improve soil bacterial community condition and optimize straw resource use. Our research revealed that frequency must be considered when making reasonable straw management to efficiently improving soil health.

Keywords: Straw mulching; Frequency and amount; Bacterial community structure; Co-occurrence network; Carbon source availability

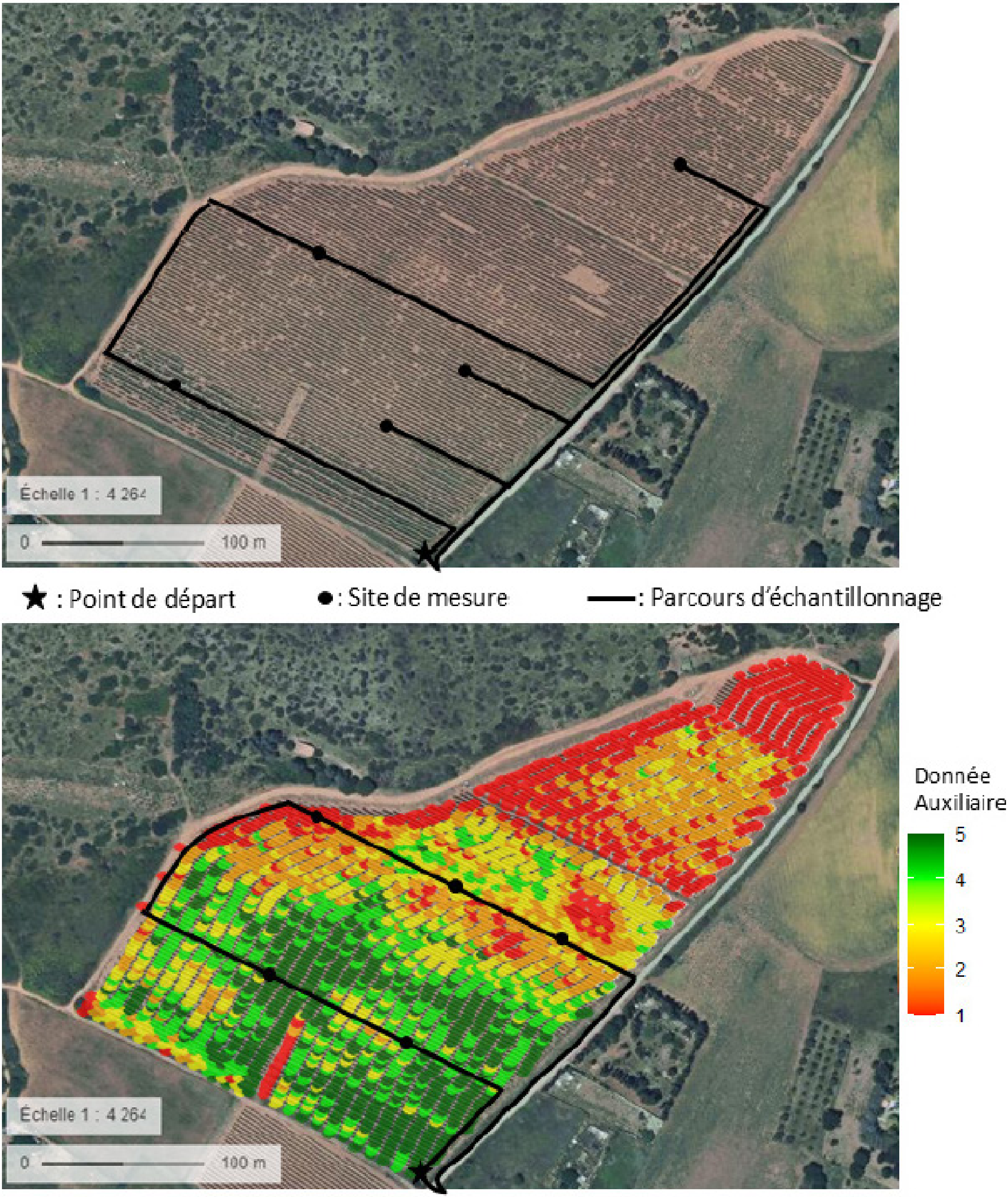

Figure 1 : Illustration of two sampling routes across a vineyard (Villeneuve-les-Maguelones, France) :

At the top, a route that does not take into account the constraints of displacement (random sampling).

At the bottom, a route taking into account (i) the information provided by an auxiliary data and (ii) the travel constraints.

Optimisation du parcours intra-parcellaire pour l'échantillonnage en production végétale

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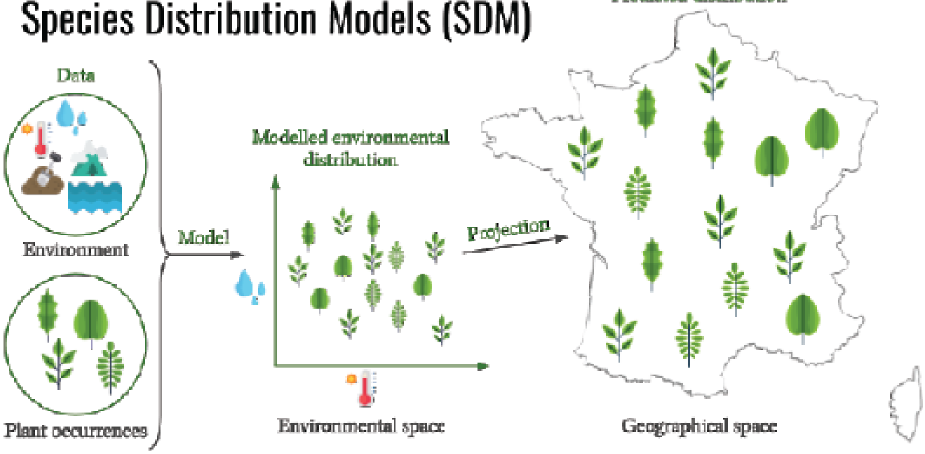
Scientific Supervisors: Bruno TISSEYRE; Philippe VISMARA & Gilles LE MOGUEDEC

In crop production, cultural practices (management of sowing, inputs, harvesting, etc.) are reasoned based on the information available to farmers. Accordingly, estimation methods by sampling constitute a set of essential tools in the acquisition of information at the scale of the plot, the crop management unit, in order to better reason inputs. Based on a sample of observations carried out at a few measurement sites, these methods allow inferential estimation of the properties of the distribution of values for the entire plot. Recent work proposes new sampling methods, integrating auxiliary data with high spatial resolution such as remote sensing images obtained by UAV, aircraft or satellite. These data are accessible at a lower cost and provide exhaustive information on the spatial variability of the plots that can improve the accuracy of the estimate by improving the choice and positioning of observation sites. Various scientific works have proposed approaches to sampling oriented on the auxiliary database in agriculture. Although providing interesting results, these methods do not take into account the sampling effort (time, distance) required to access the measurement sites and are therefore difficult to apply in a production context. The objective of this thesis is to propose new tools for sampling in crop production based on the use of auxiliary data, in order to address the double issue of the precision of the estimate and the sampling effort. To meet these challenges, several constraints and criteria, both statistical and agronomic, are identified. The sampling routes are then optimized and selected according to the chosen criteria. The originality of this work lies in the resolution of an agronomic sampling problem by combining methodologies from two very different scientific fields: stochastic approaches aimed at characterizing a large number of candidates (potential sampling sites) as well as computer optimization approaches such as constraint programming or operational research algorithms to identify a solution sample among a large number of possibilities. Ultimately, the proposed approach could constitute a decision support tool allowing to adapt sampling to each plot with the objective of simultaneously improving the quality of prediction with the minimum sampling effort.

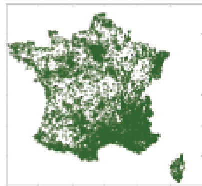
Keywords: Sampling; Precision agriculture; Crop production; Estimation

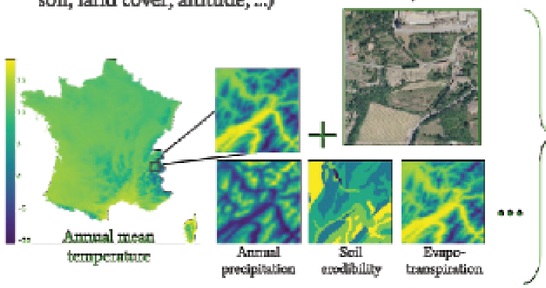
Species Distribution Models (SDM)

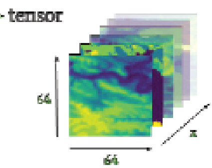


Data

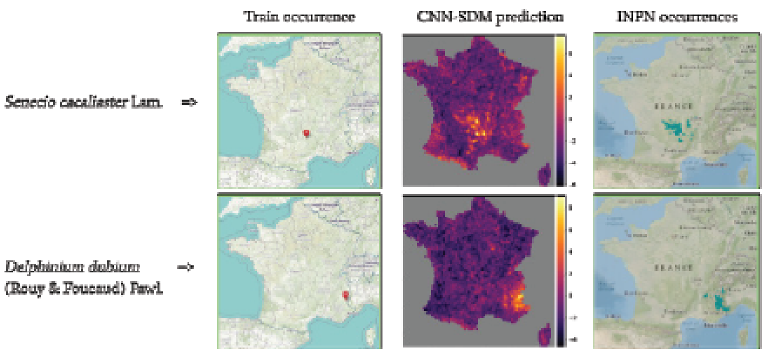
- Environmental rasters (temperature, precipitation, soil, land cover, altitude, ...)
- Remote sensing imagery (R, G, B, Near-IR)
- Training data: occurrences (presence only)







Rare species prediction



Interpretability of distribution models of plant species communities learned through deep learning - application to crop weeds in the context of agro-ecology

Presenter: Benjamin DENEU

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Scientific Supervisors: Alexis JOLY; François MUNOZ; Pierre BONNET & Maximilien SERVAJEAN

The modeling of interactions between biodiversity, landscape and agricultural practice is one of the major challenges of agro-ecology. Very recently, environmental species distribution models based on deep neural networks have begun to emerge. These first experiments showed that they could have a strong predictive power, potentially much better than the models used traditionally in ecology. One of their advantages is that they can learn an environmental representation space common to a very large number of species so that the prediction performance can be stabilized from one species to another. A first objective of the thesis will be to extend such transfer learning principle to the context of agro-ecology. In particular, data characterizing the landscape and the agricultural practices will be integrated for the prediction of crop weeds and/or associated functional traits. The second objective of the thesis will be to remove the lock on the interpretability of these models in order to deduce new tangible knowledge in agro-ecology. This will include qualifying the environmental representation space learned by the neural network in its terminal layers, typically the last layer of description on which the final linear regression or classification is based. The variables (neurons) in this representation space necessarily correspond to deterministic ecological and environmental patterns, but their exact nature is totally unknown. In the case of the deep agri-environmental models targeted in the thesis, these patterns will also integrate information from the landscape and agricultural practices. Their analysis will provide a better understanding of whether or not massive integrative approaches, based on a wide variety of input data, are needed, or whether they should focus on certain key factors.

Keywords: Species distribution modeling, Agro-ecology, Deep Neural Networks, Transfer learning, Interpretability, Interactions, Landscape, Agricultural Practice, Biodiversity, Crop Weeds.

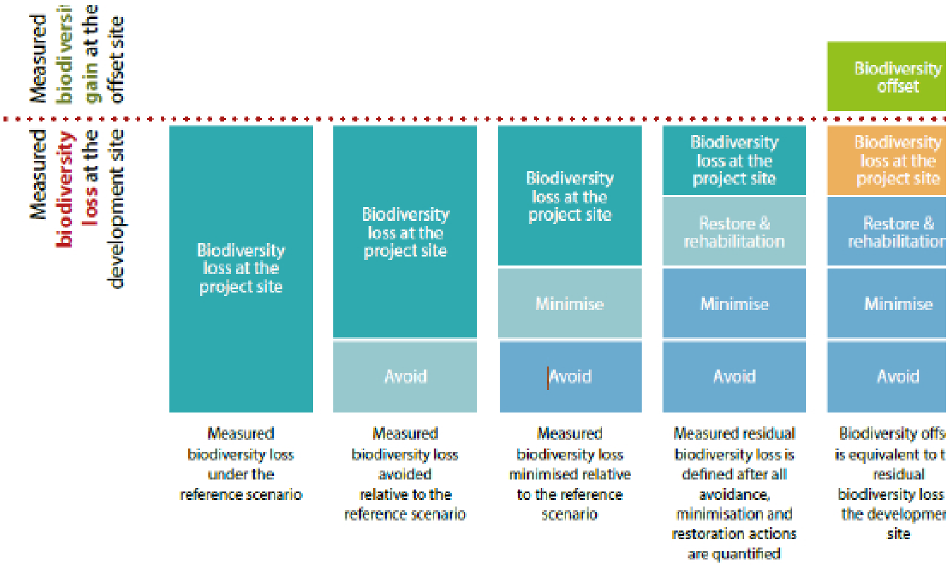

Figure 1 : the Mitigation Hierarchy (OECD, 2016)

Figure 2 : natural saxauls (Haloxylon ammodendron) forest, Mongolia

Supporting ecological compensation for mining projects in the arid zones of Central Asia: an approach in terms of ecosystem services

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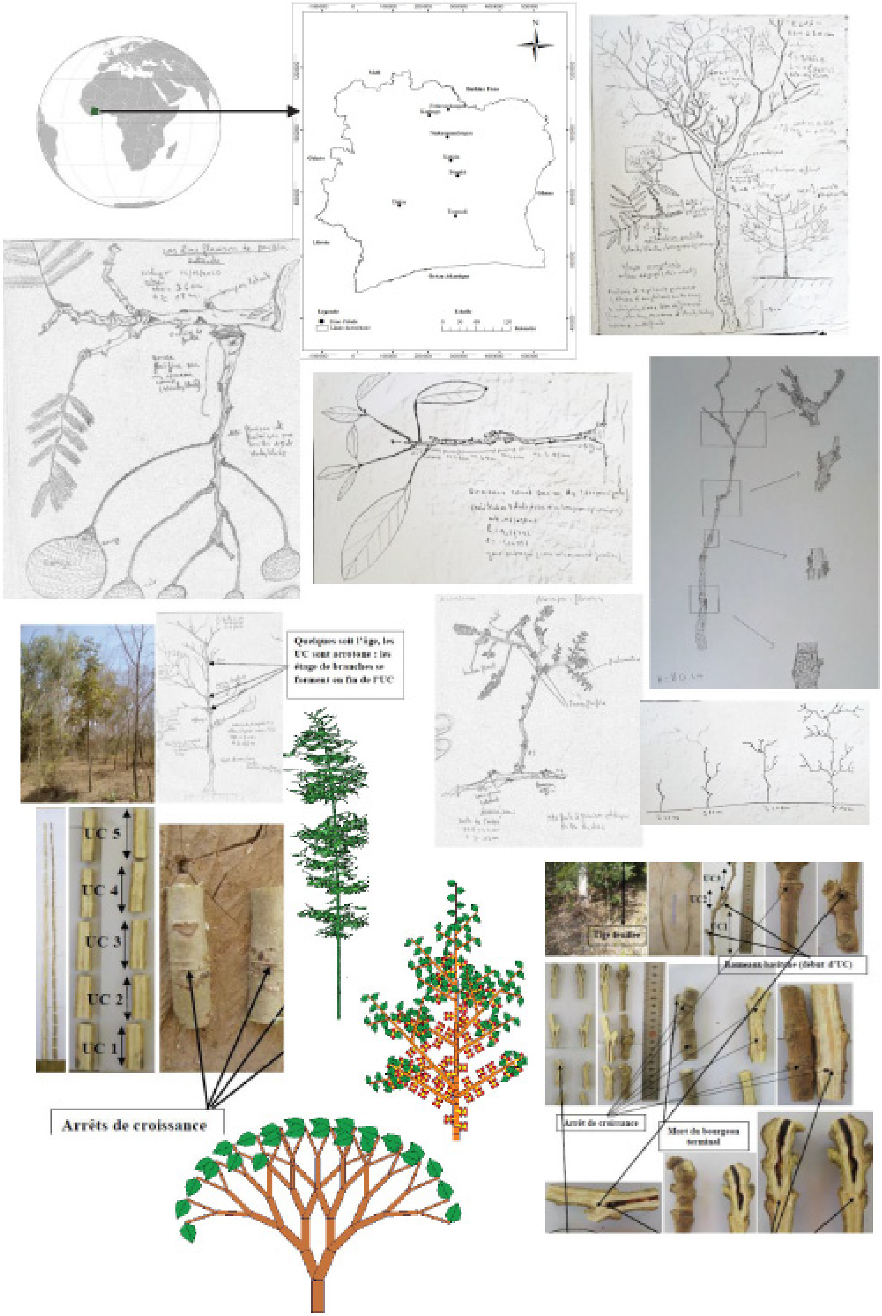
The arid ecosystems of Central Asia provide many ecosystem services that benefit the local populations and the multi-species pastoral livestock of these territories. In addition, the subsoils of these areas are rich in minerals, hence significant mining activity. Mining projects require an Environmental Impact Assessment, a study which describes the impacts on the environment and recommends measures against them. Among those measures, there is in the following order (i) Avoiding; (ii) Minimizing; (iii) Restoration; (iv) Compensation: it is the "Mitigation Hierarchy". All these measures aim to achieve the « No Net Loss », or even the « Net Gain » of biodiversity. In Central Asia, the method recommended for the ecological compensation is the monospecific planting of saxauls (Haloxylon ammodendron and Haloxylon persicum), which are woody xerophyte occurring in the arid zones of Central Asia. Planting is carried out on the same area as the impacted area, or even double it, at high densities. This method raises questions, particularly with regard to the technical success of the plantation, the impact on ecosystems and their services, and the acceptance by local communities. Thus, this thesis aims to support ecological compensation in Central Asia, more precisely in Mongolia, Kazakhstan and Uzbekistan, via an ecosystem approach.

The first objective is to quantify the ecosystem services provided by grazing land in the arid zones of Central Asia. For this purpose, interviews are conducted with local populations and other stakeholders in order to identify the ecosystem services of interest. Subsequently, ethnobotanical surveys and field measurements are carried out in order to study the link between vegetation and ecosystem services. The second objective is the evaluation of different practices that can improve the provision of those services, such as planting or defensive measures. Each identified option is analysed according to its feasibility conditions. Interviews with local populations are conducted to assess the acceptance of these practices. Finally, as a third objective, this thesis aims to propose a tool for the assessment of ecological compensation scenarios, in order to quantify the level of provision of ecosystem services and to assess the economic cost and the level of acceptance for each scenario.

Keywords: Ecological compensation; Ecosystem services; Central Asia


Quelques soit l'âge, les UC sont acrotone : les étage de branches se forment en fin de l'UC
UC 5
UC 4
UC 3
UC 2
UC 1
Arrêts de croissance
Tige feuillée
Rameaux latéraux (début d'UC)
Arrêt de croissance
Mort du bourgeon terminal

Architecture and growth modelling of savannah agroforestry species native to Côte d'Ivoire

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Scientist Supervisor: D. Sélastique AKAFFOU; Sylvie SABATIER; Marc JAEGER; Philippe DEREFFYE; Yves CARAGLIO; Henri KOUASSI & Jérôme DUMINIL

Reforestation and agroforestry are the two options favoured by Côte d'Ivoire to restore its forest area and conserve its wood resources. Khaya senegalensis, Pterocarpus erinaceus and Parkia biglobosa are three indigenous savannah forest species with multiple uses. The heavy exploitation of these species exposes them to a loss of diversity that could lead to their eventual extinction. Integrating them into agroforestry programmes is a solution for their conservation and sustainable use. This study is being conducted with the aim of optimising the cultivation of these three species and promoting their agroforestry potential. Architectural analysis (development sequence and morphology of growth units/module) from seedlings to old trees will be carried out. The work will take place along a South-North drought gradient in Côte d'Ivoire in order to understand and determine the intra-specific architectural variability. In a second step, a retrospective analysis of growth will allow the past growth of the trees to be traced using morphological markers left behind by growth stoppages due to dry seasons. In this way, the architectural diagram of each of these species will be established. Finally, organ measurements captured in Multiscale Trees Graph format and analysis of the tops of the three species will be carried out at different ages in the nursery. These measurements will be used to model the growth and development of the target species using the GreenLab structure-function model. Hidden parameters such as organ source-sink relationships, leaf resistance, common pool and production area will be obtained. These data will guide the choice of progeny or plants for planting, the ideal planting density, the itinerary and cultivation management of these three species.

Keywords: Côte d'Ivoire, Khaya senegalensis, Pterocarpus erinaceus et Parkia biglobosa, Architecture, modelling.

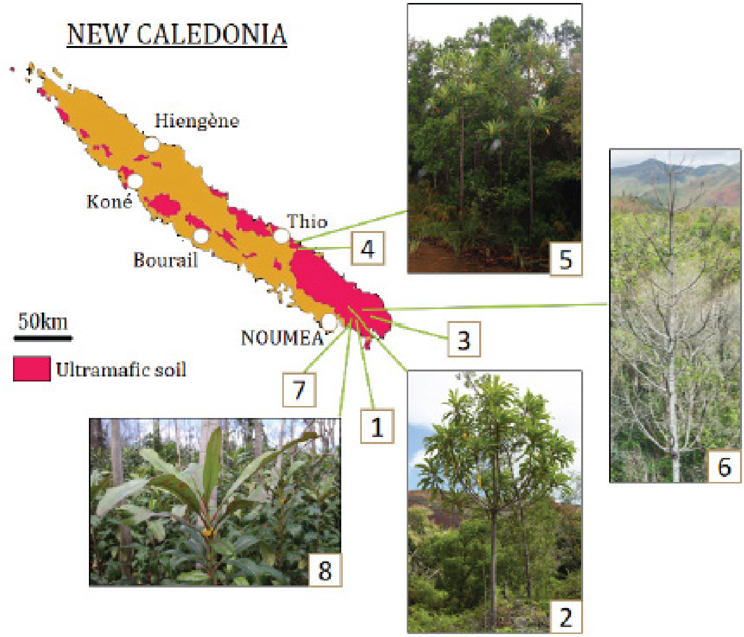

Figure 1. Location of Cerberiopsis candelabra sampled and debited. The growth of the individuals and their phenology was entirely reconstructed a posteriori using morpho-anatomical markers.

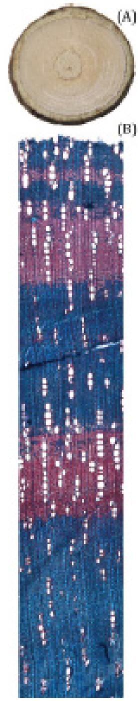

Figure 2. Cross section in the trunk for (A) macro- and (B) microscopic observations of C. candelabra wood rings.

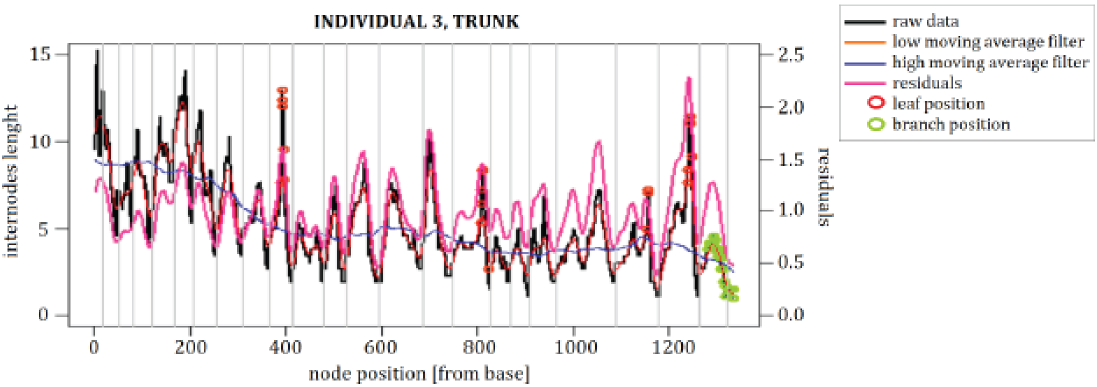

Figure 3. Variations in internodes length along the individual 3 main axis. Wood rings (vertical grey bars) are located at the short internodes succession level. Individual 3 is twenty-four years old if wood rings production is on an annual rhythm.

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The adaptative significance of monocarpy in woody perennial plants : investigation around the genus Cerberiopsis

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Monocarpy refer a life history in which a single great effort of sexual reproduction is directly associated with the death of the entire plant. The existence of monocarpic long-lived branched trees has long been intriguing. Recent studies investigate the evolutionary benefits of this strategy, which in many respects could appear suicidal [1] in perennial trees.

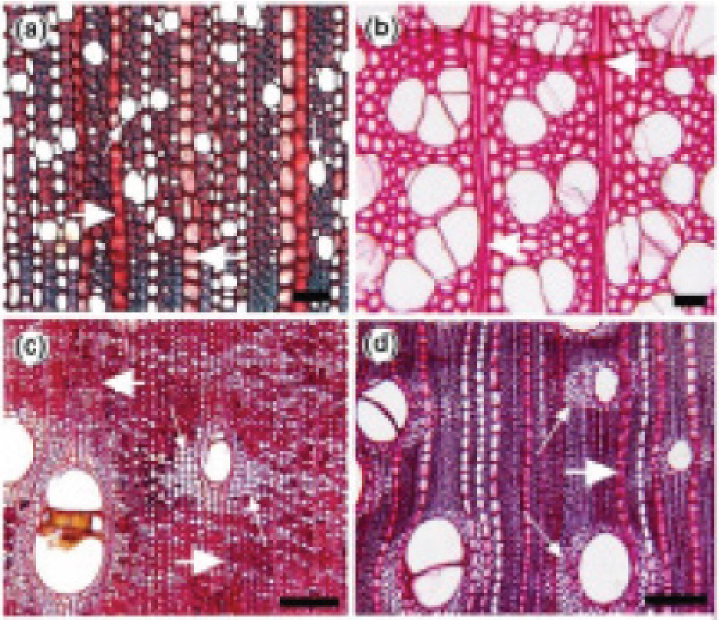
In this first study, we focus on the rhythmicity of Cerberiopsis candelabra development. This large tree endemic to New Caledonia is the only monocarpic species of its genus. Our objective is twofold: (i) to study the phenology of the processes underlying the development of this species and (ii) to evaluate the possibilities of obtaining the growth trajectories of individuals by a dendrochronological approach.

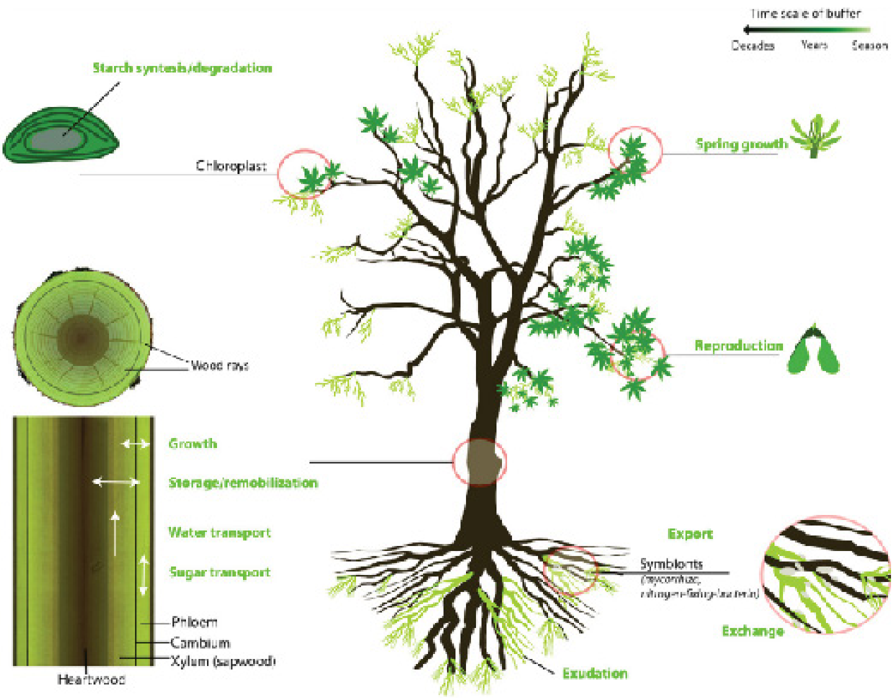
The phenology of a plant defines the temporality of recurring biological events, or phases, of a plant’s life [2]. Thanks to the identification and measurement of morpho-anatomical markers, we have reconstructed the ontogeny of individuals retrospectively. Length of internodes, pith surfaces and number of wood rings are several markers that allow us to retrace the plant’s life in space and time.

The reading of wood rings enables us to associate a relative temporality to these fluctuations. Phenology of individuals may be studied in the light of habitat’s seasonal conditions if the rhythm of wood-ring production can be associated with an annual temporality. Our first results identify complexes of morpho-anatomical markers whose variations are synchronous. They designate a rhythmic and annual growth with polycyclism.

Retrospective analysis of the development of the sampled trees seems to indicate that there could exist a significant diversity of growth trajectories in Cerberiopsis candelabra. This diversity could be modulated by the constraints imposed by the wide range of habitats occupied by the species. For a monocarpic tree, adaptability to environmental conditions is essential to lower the probability of pre-breeding mortality.

Keywords: Monocarpy; Phenology; Markers; Growth trajectory; Dendrochronology


(a)
(b)
(c)
(d)


Time scale of buffer
Decades
Years
Season
Starch syntesis/degradation
Chloroplast
Spring growth
Wood rays
Reproduction
Growth
Storage/remobilization
Water transport
Sugar transport
Phloem
Cambium
Xylem (sapwood)
Heartwood
Export
Symbionts
Exchange
Exudation

Linking structural traits, non-structural carbohydrate and tree ecological strategies in different climates

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Scientific Supervisors:	Alexia STOKES, Pascale MAILLARD & Zhun MAO

Functional traits have been examined in detail for several tree organs, but the relationship between traits, successional gradient and ecological strategies is poorly understood. The concept of an economics spectrum is currently used to describe the investment of a given species into different organs, depending on their position along an ecological succession gradient. It is now necessary to link functional traits of trees with knowledge of their ecological strategy and test whether similar strategies exist across different biomes. Results will help us better understand how different tree species can quickly colonise disturbed land, or maintain a position as a climax species in the canopy. Pioneer species that colonise a site rapidly must also mobilise energy from stored non-structural carbohydrates (NSC), which are stored in parenchyma cells. Nevertheless, climax species need to maintain their position in the canopy and may require large quantities of NSC and parenchyma for defence mechanisms. Moreover, study shows that the amount of axial parenchyma is related to vessel diameter and species with a high axial parenchyma fraction tend to have wide vessels, with most of the parenchyma packed around vessels. As yet, no specific relationships between ray parenchyma and any other anatomical traits (such as vessel size or density) have been found. Nor is it known if there is a relationship between ray parenchyma and ecological strategy of a species. A meta-analysis of existing data on functional traits, parenchyma volume and NSC will be performed to help disentangle relationships between all parameters. Extra analyses will be performed in the field along successional gradients (pioneer and climax) in three biomes (tropical rainforest, Mediterranean garrigue and temperate montane). A full characterization (climate, vegetation and soil variables) will be performed at each field site and 20 tree species per biome will be examined at the end of growing season, with three replicates per tree. The final outcome aims to find links between tree traits, carbohydrate supply and allocation and ecological strategies with regard to successional status in different biomes.

Keywords: Biomes; Ecological strategies; Functional traits; Non-structural carbohydrate; Ray and axial parenchyma; Successional gradient; Vessels

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Ecological strategies of African lianas in stable and disturbed environments: Bio inspiring models for soft robotics

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Scientific Supervisors: Nicholas ROWE, Maxime RÉJOU-MÉCHAIN & Sylvie GOURLET-FLEURY

The natural and post-perturbation dynamics of tropical forests are more and more studied in order to understand the response capacity of these forests to climate change and human disturbances. In recent years, an increasing number of studies have pointed out the importance of lianas in forest dynamics, through their negative impact on tree productivity (Van der Heijden and Philips, 2009; Ingwell and al, 2010; Tymen and al, 2016). In Neotropical forests, the relative abundance of lianas seems to increase significantly under the combined effects of climate change and anthropogenic disturbances (Philips et al, 2002; Schnitzer and Bongers, 2011; Laurance and al, 2014). Such an increase could have negative consequences on the carbon sequestration potential of these forests and on the sustainability of timber exploitation, a key economic activity in many tropical countries. However, the lack of data acquired on African forests in particular, makes very uncertain the pantropical nature of this increase (Schnitzer and Bongers, 2011) and the real impact of lianas in natural dynamics and tree stand recovery in the long term.

Moreover, these lianas, often considered as parasites, possess a wide range of strategies for colonizing different environments and adapting to different environments (Dalling and al, 2012; Chalmers and Turner, 1994). This diversity of strategies is translated into a diversity of structural and functional traits, interesting not only for understanding the distribution of species according to forest structure but at a broader multidisciplinary level, for the development of new innovative structures for new technologies, particularly in robotics (Must and al, 2019; Burris and al, 2018; Mazzolai and al, 2014; Mazzolai and Mattoli, 2016). Indeed, field and laboratory work on the functional characteristics of these climbing plants provide new information, in particular on the “search stems”, the self-supporting part of the plant, and the different attachment systems they possess. This work is particularly important nor only to better understand the mechanisms underlying this increase but also to provide new structural and functional concepts on how growing robotic artefacts can safely navigate in unstructured environments.

Thus, there are two main objectives. First, to understand the influence of liana communities on the natural and post-disturbance dynamics of tree stands and to understand the consequences for silvicultural management. Second, to generate knowledge on the structural and functional characteristics of lianas in order to better understand the different strategies of liana colonization and to feed the development of a new type of soft robotic technologies.

Keywords: Tropical ecology; Lianas; Forest dynamics; Functional traits; Biomimetic; Soft-robotic

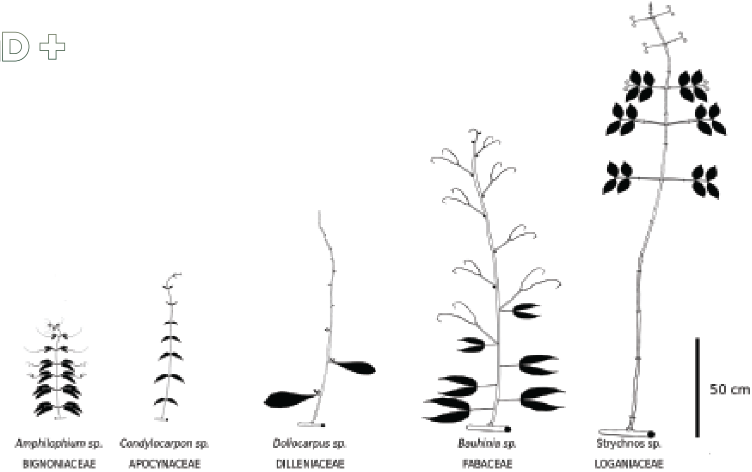

Figure 1. Morphological diversity of searcher shoot with tropical examples from French Guiana : from a small void crosser and tendril climber as Amphilophium sp. to a large void crosser and hook climber as Strychnos sp.

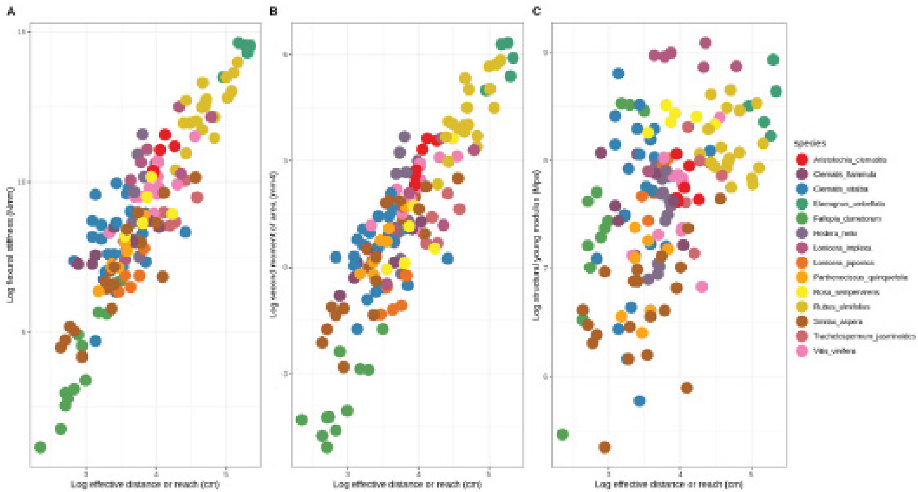

Figure 2. Functional variability of the crossing void performance of climbing plants from the vinicity of Montpellier. Three biomechanical traits measured at the base of searching stem are showed in function of the effective distance than a searcher shoot can cross in a self-supporting phase (variables are log transformed) : (A) Flexural stiffness EI (Nmm-1), the overall mechanical properties of the basal stem. ; (B) Second moment of area (mm4), the geometrical parameters of EI ; (C) Structural young modulus (Mpa), the material characteristics parameters of EI.

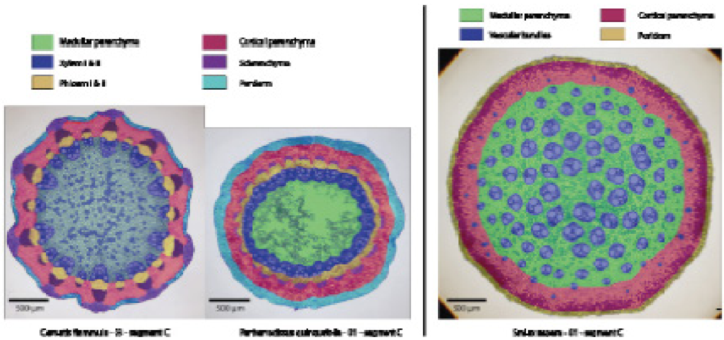

Figure 3. Anatomical variability at the base of searcher shoot : three contrasted examples from the vinicity of Montpellier.

Space exploration strategies and functional diversity of tropical climbing plants: towards bioinspired applications in soft robotics

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Scientific Supervisors: Nicholas ROWE & Patrick HEURET

Climbing plants contribute greatly to the biodiversity and functioning of tropical forest ecosystems, notably by playing a major role in the dynamics of forest succession. Among these climbing forms, the polyphyletic group of lianas is currently recognized as expanding in the Neotropics. Considered in many studies as structural parasites, their influences on biogeochemical cycles are manifold and have a negative impact on atmospheric carbon storage over long time scales. Given their complex and unpredictable life histories, there is no satisfactory method to quantify their volume, dimensions and biomass which are of great importance for the calibration of dynamic global vegetation model and the climate change prediction. Moreover, their architectural development and the ways in which they perform their hydraulic and biomechanical functions remain scarcely understood.
On the other hand, the H2020 GrowBot project proposes a disruptively new paradigm of movement in robotics inspired by the moving-by-growing abilities of climbing plants. In fact, growth strategies of lianas are inspiring models to develop robotic artifacts able to (1) negotiate voids and anchor to supports at lower structural cost; (2) explore and colonize complex and unstructured environments and (3) survive to critical mechanical perturbations through dissipative bauplans and self-repair mechanisms.
In order to enhance new perspectives in ecology and soft robotic, the main objectives of this thesis are twofold:

1) Investigate the structural and functional diversity of climbing plants by characterizing the variability of searcher shoots in space and time and by defining functional groups based on exploration criterias.

(2) Collaborate with mathematicians, engineers and roboticians of the H2020 GrowBot project in order to develop bio-inspired robotic artifacts capable of growing and functioning like a plant.

Keywords: Climbing plants; Lianas ; Searcher shoot; Biomechanics; Anatomy; Plant architecture; Biomimetic; Soft-robotic

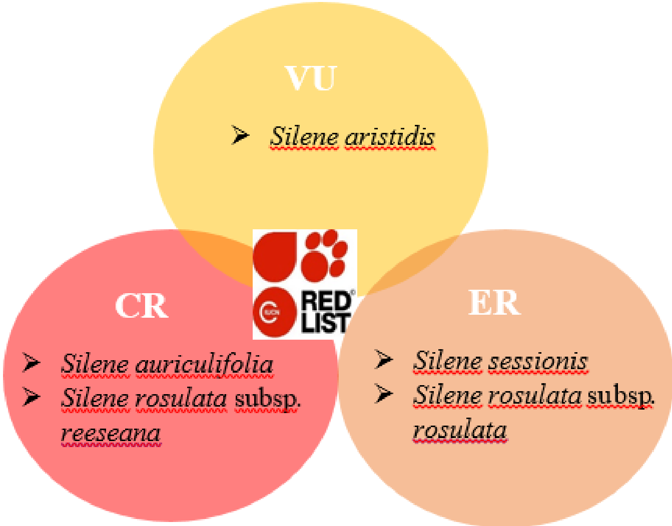

Figure 1: The retained status of the targeted species according to the IUCN criteria categories version 3.1 (2001).

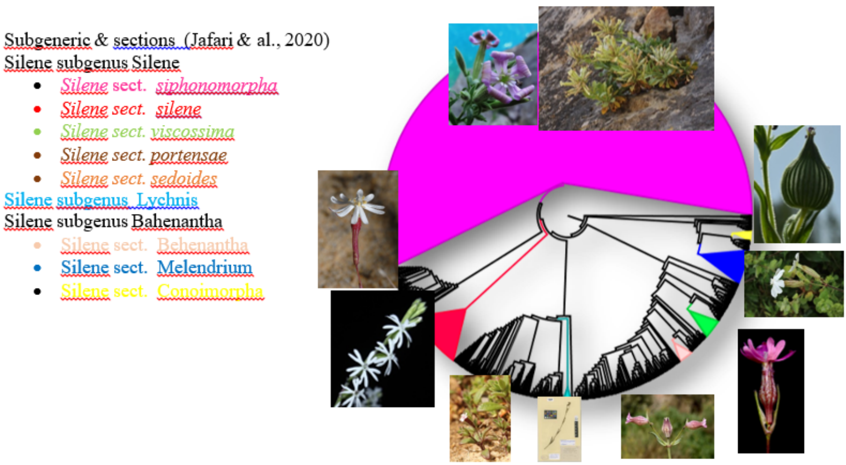

Figure 2: Infragenetic classification of the genus silene in North Africa

Taxonomy and biogeography of the genus Silene (Caryophyllaceae) in North Africa

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Scientific Supervisors: Mohamed SAHNOUNE (UAM Bejaia, Algeria), Errol VELA (INRAE, UMR AMAP,Montpellier, France), Bengt OXELMAN (GGBC, GU Gothenburg, Sweden)

Silene is the taxonomically largest genus of the family *Caryophyllaceae*, It estimated to contain about 870 species world-wide. Its diversity is mainly allocated to the temperate region of northern hemisphere particularly in the Mediterranean area and the Middle East.

In North Africa, Silene is floristically the most diverse of all plant genera. It is represented by 144 taxa with 56 strictly endemic to Marrocco, Algeria, Tunisia, Libya or the Canary Islands. These taxa are not or very little studied from taxonomic, phylogenetic and biogeographic points of view. Thus, a taxonomic and biogeographic revision is urgently needed to develop new identification tools for North African Silene species.

The targeted taxa for the biogeographical study are *Silene sessionis*, *S. aristidis* and *S. auriculifolia*. *Silene rosulata* subsp. Reeseana, subsp. rosulata and were defined, then prospected and the distribution was updated. The assessment of their conservation status was established according to the IUCN Criteria and Categories version 3.1 (2001) and it had been validated according to the official IUCN Red List process. Urgent measures are needed to minimize the impacts of the human threats and *ex situ* conservation seems necessary.

Multiple alignments of c. 1800 internal transcribed spacer (ITS) and c. 1200 plastome rps16 sequences are generated. Gene trees and species tree are together with morphological data used to derive novel taxonomic delimitations and define the position of the North African species according to the new classification of Silene proposed by Jafari *et al*. (2020).

Keywords: *Silene*, IUCN assessment, infragenetic classification, threats, endemic

Rendez-vous à l'Amapéro afin d'échanger, se rencontrer et partager sur vos différents sujets.
L'organisation d'AMAPhD+ 2020 vous souhaite une bonne journée.