La spectroscopie proche infrarouge et la biodiversité : illustrations pour l'aide à l'identification taxonomique

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CCA NIRS AGAP

Groupes de travail
- Bois et Imagerie
- Construction
- Contrôle et Evaluation Non Destructive
- Ecologie du bois
- NIRS&Bois
- Rupture Bois
- Usinage Bois
- Xylogenèse
- Xylomat
- Xylothèque

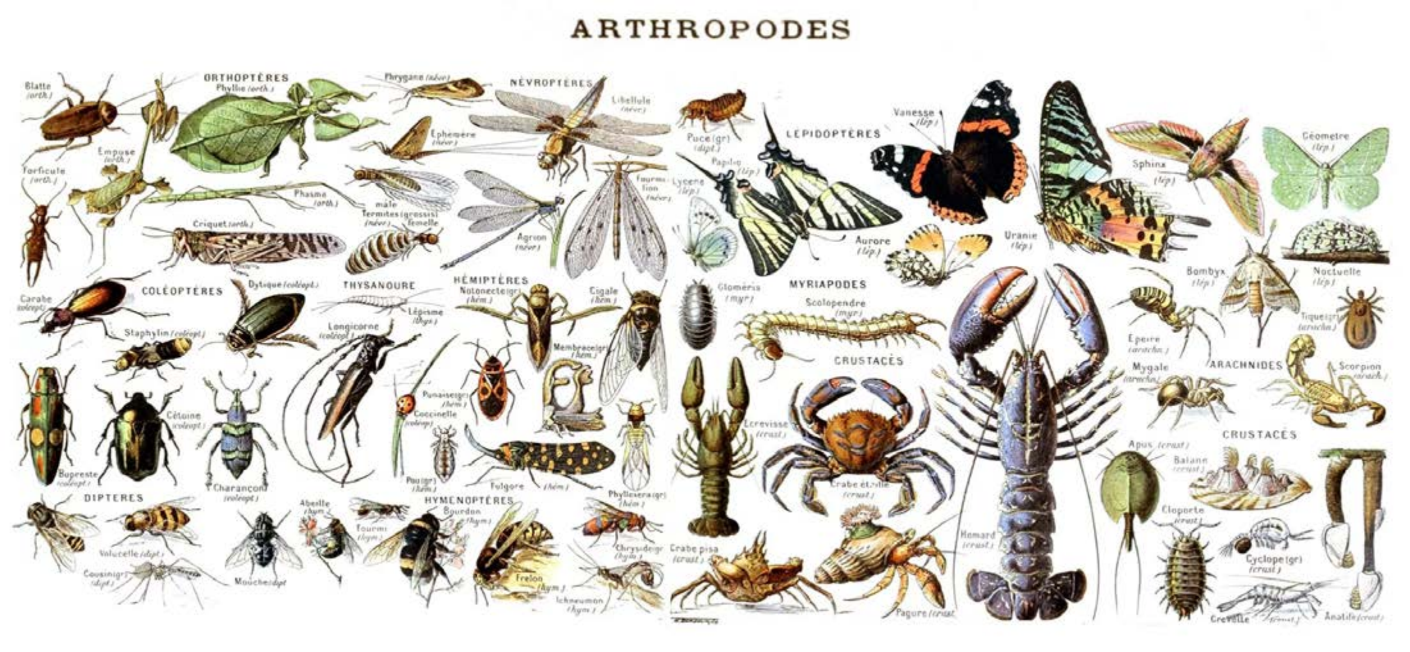
Taxonomie, systématique, à quoi sert de classer le vivant ?

Depuis toujours, les humains ont cherché à classer le vivant, faut dire que c'est très varié !

Pour ce faire, plusieurs disciplines scientifiques se sont développées

On va parler en quelques mots de :

- Systématique
- Taxonomie
- Clefs d'identification
- Nomenclature

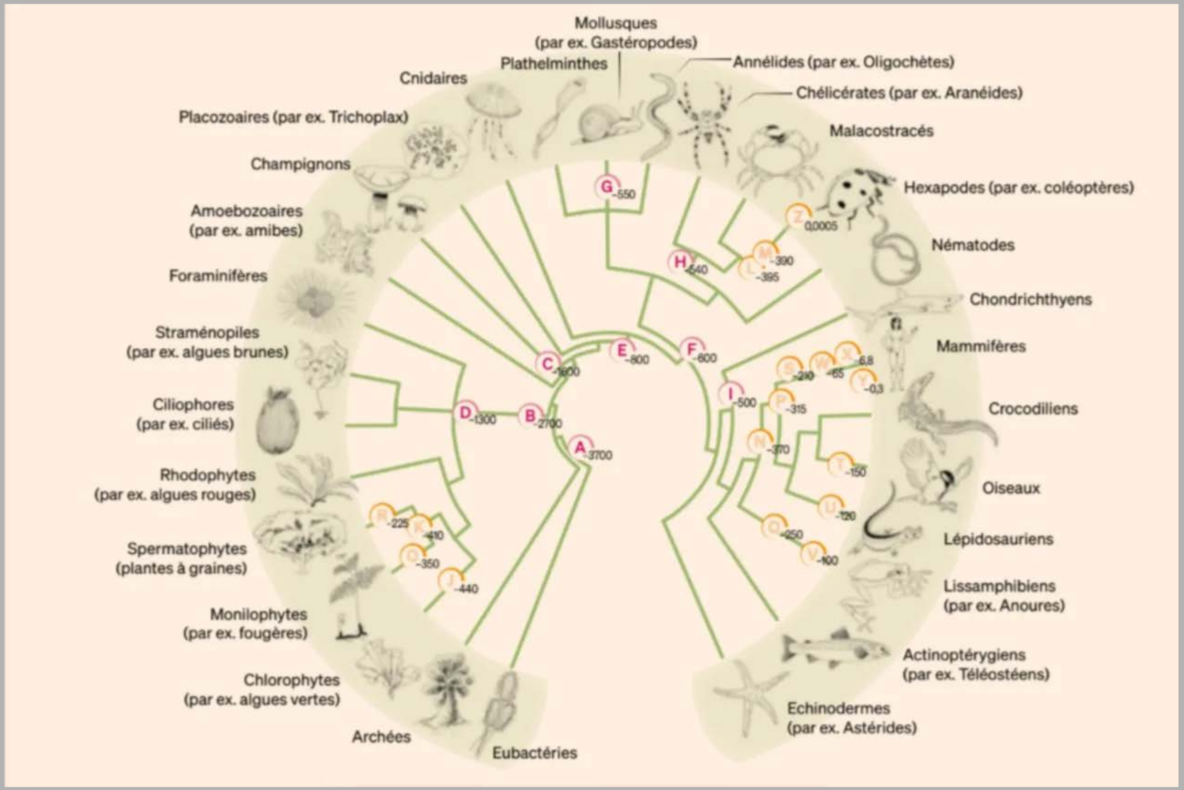


https://www.mnhn.fr/fr/taxonomie-systematique-a-quoi-sert-de-classer-le-vivant#footnote1_rmktusRF7C88NGS33hgi5zL3TJiAI8qksUqLBZyHU_u69mUfQf1QzD

La systématique, science de la classification, qui **met en place un système d'organisation des espèces**.

Aujourd'hui, elle cherche à **illustrer au mieux les relations de parenté entre toutes les espèces connues**.

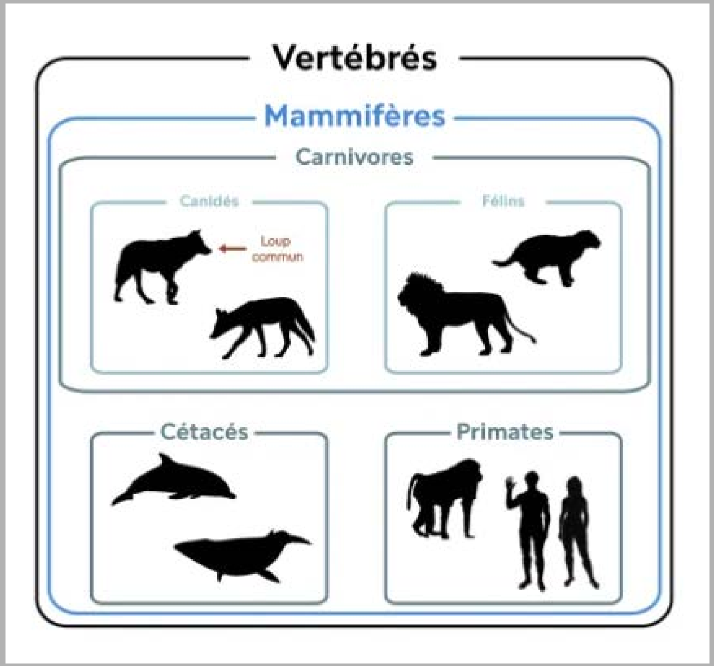
=> Arbre phylogénétique (cf arbre généalogique) qui établit juste qui partage quoi avec qui. Il raconte ainsi, à travers l'évolution, qui est apparenté avec qui.



Arbre du vivant d'aujourd'hui. Cette figure est une phylogénie : elle montre des degrés relatifs de cousinage.

https://www.mnhn.fr/fr/taxonomie-systematique-a-quoi-sert-de-classer-le-vivant#footnote1_rmktusRF7C88NGS33hgi5zL3TJiAI8qksUqLBZyHU_u69mUfQf1QzD

La taxonomie, science de l’organisation
qui permet de **regrouper les organismes** biologiques dans des boîtes d’après leurs **caractéristiques communes**. Chaque boîte = "taxon"



Les êtres vivants sont **réunis en fonction des caractères qu’ils ont en commun**, ces caractères doivent être **exclusifs :**

- Les humains et les chimpanzés font partie des primates, ils ont le caractère commun : le pouce opposable
- Les Vertébrés sont les animaux avec des vertèbres
- Les Mammifères sont les animaux à mamelles

https://www.mnhn.fr/fr/taxonomie-systematique-a-quoi-sert-de-classer-le-vivant#footnote1_rmktusRF7C88NGS33hgi5zL3TJiAI8qksUqLBZyHU_u69mUfQf1QzD

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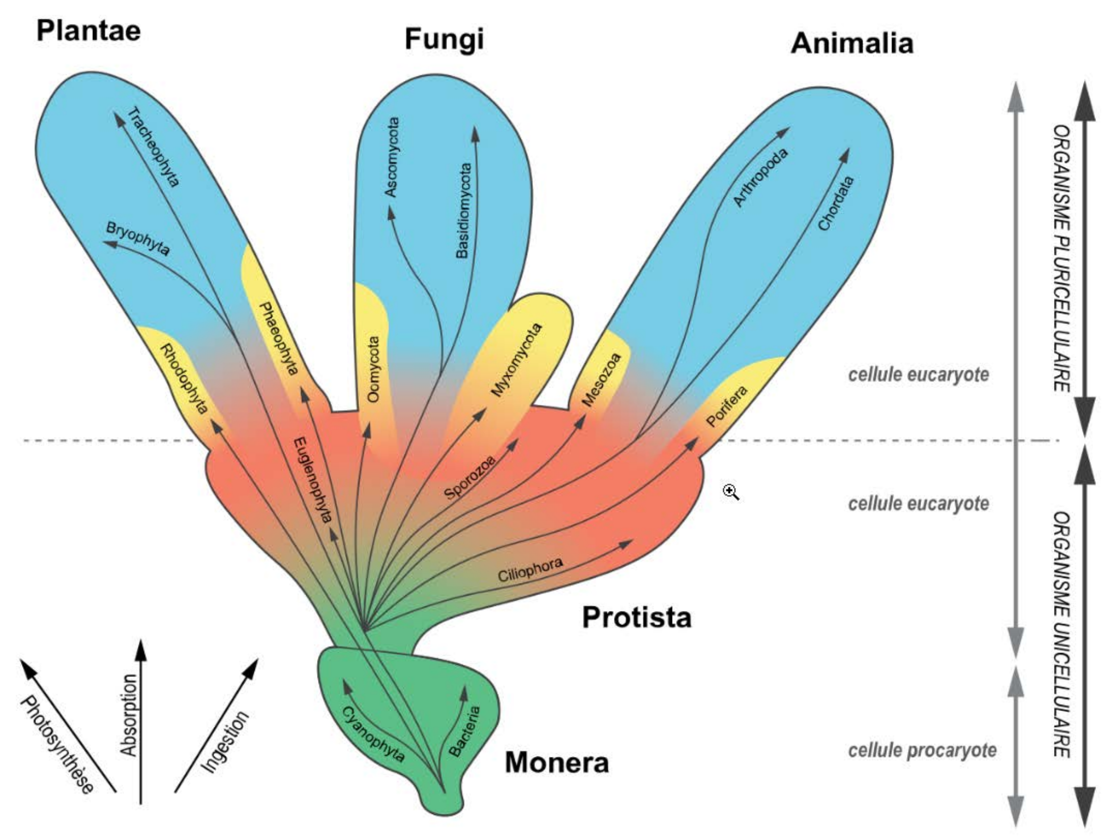

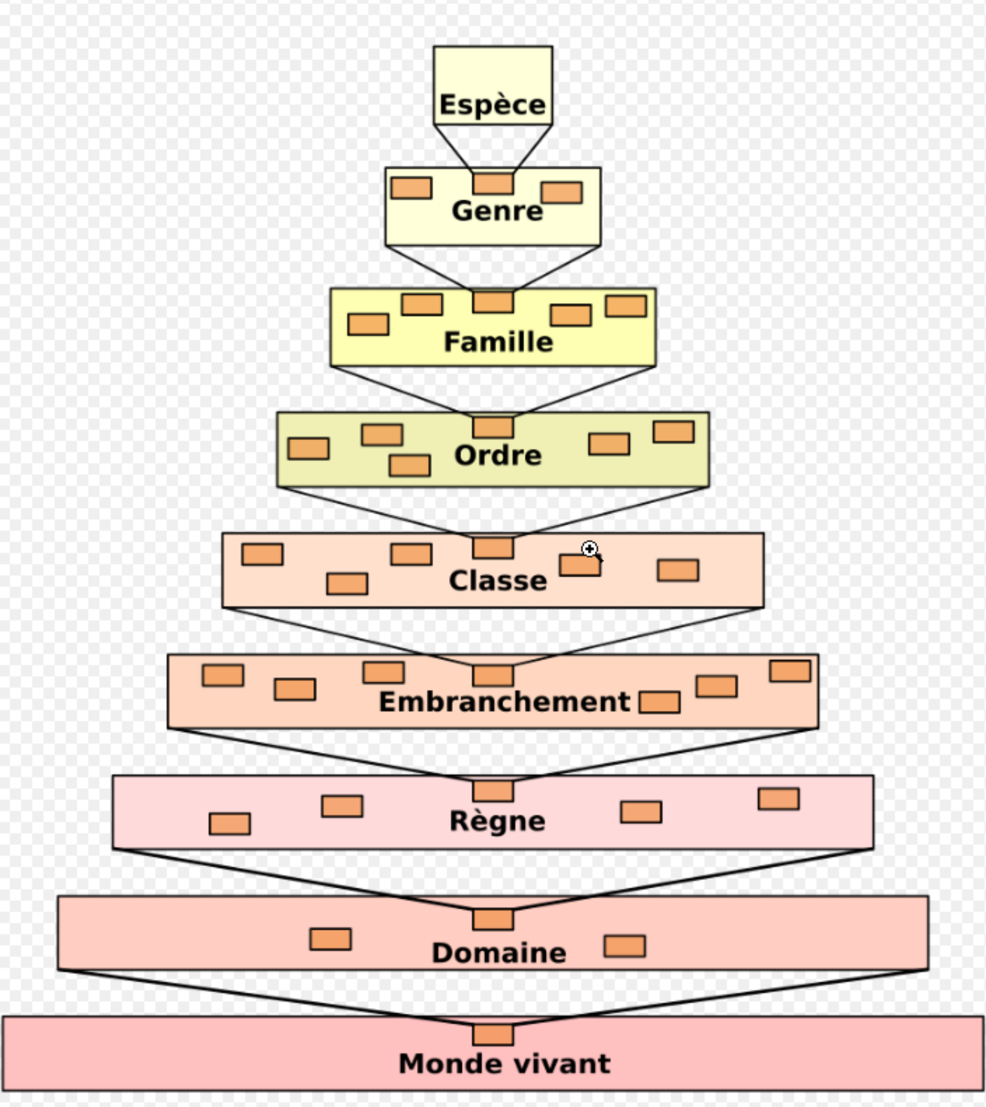

Du rififi dans les classifications

Nos classifications ont plus changé en quarante ans qu'elles n'ont changé durant les deux siècles précédents.
Les changements de classification tiennent compte de surprises phylogénétiques :

- La truite est plus apparentée à vous qu'à un requin, et par conséquent le concept de poisson a été invalidé et remplacé.
- Un crocodile est plus apparenté à une poule qu'à un lézard, les ressemblances globales sont parfois trompeuses !

Mais, rassurons-nous, l'arbre du vivant et sa classification phylogénétique ont confirmé d'autres groupes traditionnels, comme mammifères, oiseaux, vertébrés, échinodermes, mollusques, animaux, angiospermes.

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Science qui bouge les lignes régulièrement !!
Taxonomie stable / moins stable selon les groupes
« Références »

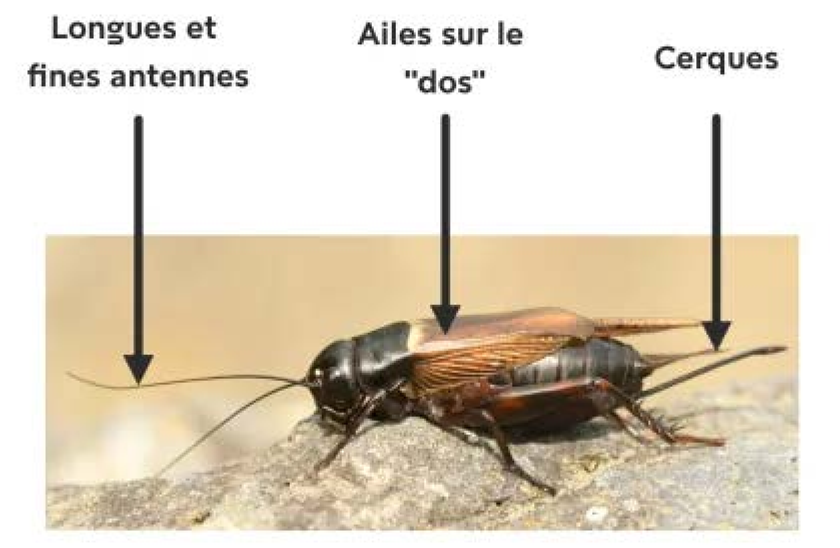
D’une année ça change !!! => quid de la référence ????

NIRS peut aider !!!!

UNE CLEF POUR MIEUX DISTINGUER

Pour trier les espèces, "**clef d'identification** suite de questions-réponses :
Cette espèce a-t-elle une queue ?
A-t-elle un museau ?
= > Chien et pas à un lézard

Ces outils permettent d'assigner un spécimen à un taxon, le plus souvent du niveau de l'espèce.



LA NOMENCLATURE, SCIENCE DE L'ATTRIBUTION DES NOMS

Une fois la classification proposée, et les boîtes faites en précisant quels sont les caractères communs et exclusifs, il faut **nommer ces boîtes**. Attention ! Ces noms ne sont pas donnés au hasard par les scientifiques, des règles ont été mises en place : c'est la nomenclature.

La nomenclature est la science de l'attribution des noms aux taxons.
Chaque nom répond à un code bien spécifique, celui du domaine concerné (zoologique, botanique, mycologique,…).
Ces codes, élaborés par des **Commissions internationales**, sont **universels**.
Généralement, les noms seront en **latin** pour que tous les scientifiques communiquent dans la même langue.

https://view.genially.com/5fbd0a07a5becd0d00486331/presentation-clef-de-reconnaissance-des-vegetaux-des-coulees-de-lave

Exemple : Aedes albopictus

https://fr.wikipedia.org/wiki/Aedes_albopictus

Classification

Règne	Animalia
Embranchement	Arthropoda
Classe	Insecta
Ordre	Diptera
Sous-ordre	Nematocera
Famille	Culicidae
Sous-famille	Culicinae
Genre	*Aedes*
Sous-genre	*Aedes* (*Stegomyia*)

Espèce

Aedes albopictus
(Skuse, 1894)

Synonymes

- *Culex albopictus* Skuse, 1894 (protonyme)
- *Stegomyia albopicta* (Skuse, 1894)

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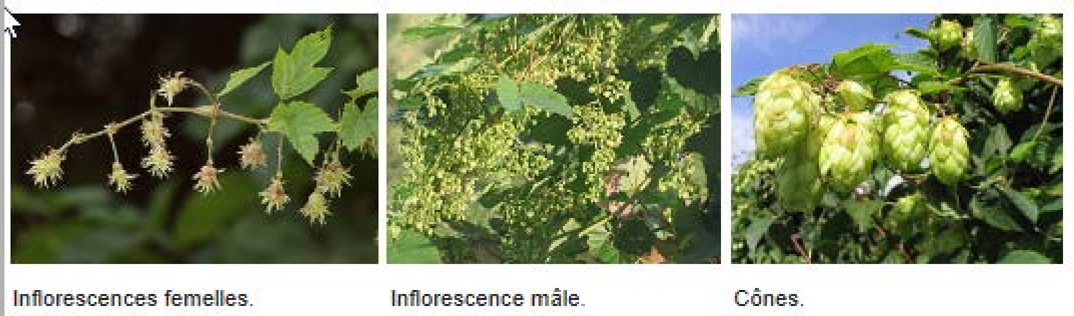
Exemple : Humulus lupulus

Classification ITIS	
Règne	*Plantae*
Sous-règne	*Viridiplantae*
Infra-règne	*Streptophyta*
Super-division	*Embryophyta*
Division	*Tracheophyta*
Sous-division	*Spermatophytina*
Classe	*Magnoliopsida*
Super-ordre	*Rosanae*
Ordre	*Rosales*
Famille	*Cannabaceae*
Genre	*Humulus*

Espèce

Humulus lupulus

L., 1753



Inflorescences femelles.

Inflorescence mâle.

Cônes.

https://fr.wikipedia.org

La spectroscopie proche infrarouge et la biodiversité : illustrations pour l'aide à l'identification taxonomique

Exemple : Musa

Classification de Cronquist (1981)	
Règne	*Plantae*
Sous-règne	*Tracheobionta*
Division	*Magnoliophyta*
Classe	*Liliopsida*
Sous-classe	*Zingiberidae*
Ordre	*Zingiberales*
Famille	*Musaceae*
Genre	
Musa L., 1753	
Classification APG III (2009)	
Clade	Angiospermes
Clade	Monocotylédones
Clade	Commelinidées
Ordre	*Zingiberales*
Famille	*Musaceae*

60 espèces

https://fr.wikipedia.org/wiki/Bananier

Exemple : Diospyros

Classification Tropicos

Règne	*Plantae*
Classe	*Equisetopsida*
Sous-classe	*Magnoliidae*
Super-ordre	*Asteranae*
Ordre	*Ericales*
Famille	*Ebenaceae*

Genre

Diospyros

L., 1753[1]

- *Diospyros adenophora*
- *Diospyros alboflavescens*
- *Diospyros ampullacea*
- *Diospyros areolata*
- *Diospyros argentea*
- *Diospyros barberi*
- *Diospyros barteri*
- *Diospyros bibracteata*
- *Diospyros bipindensis*
- *Diospyros blumutensis*
- *Diospyros borbonica*
- *Diospyros capricornuta*
- *Diospyros castanea*
- *Diospyros celebica*
- *Diospyros conformis*
- *Diospyros crassiflora*
- *Diospyros daemona*
- *Diospyros digyna*
- *Diospyros ebenaster*
- *Diospyros ebenum*
- *Diospyros feliciana*
- *Diospyros foxworthyi*
- *Diospyros gambleana*
- *Diospyros guianensis*
- *Diospyros ismailii*
- *Diospyros kaki*
- *Diospyros kamerunensis*
- *Diospyros katendei*
- *Diospyros kupensis*
- *Diospyros lotus* L.
- *Diospyros magogoana*
- *Diospyros melanoxylon*
- *Diospyros mespiliformis*
- *Diospyros minimifolia*
- *Diospyros monbuttensis*
- *Diospyros montana*
- *Diospyros ropourea*
- *Diospyros sandwicensis*
- *Diospyros seychellarum*
- *Diospyros shimbaensis*
- *Diospyros tessellaria*
- *Diospyros texana*
- *Diospyros transitoria*
- *Diospyros virginiana*

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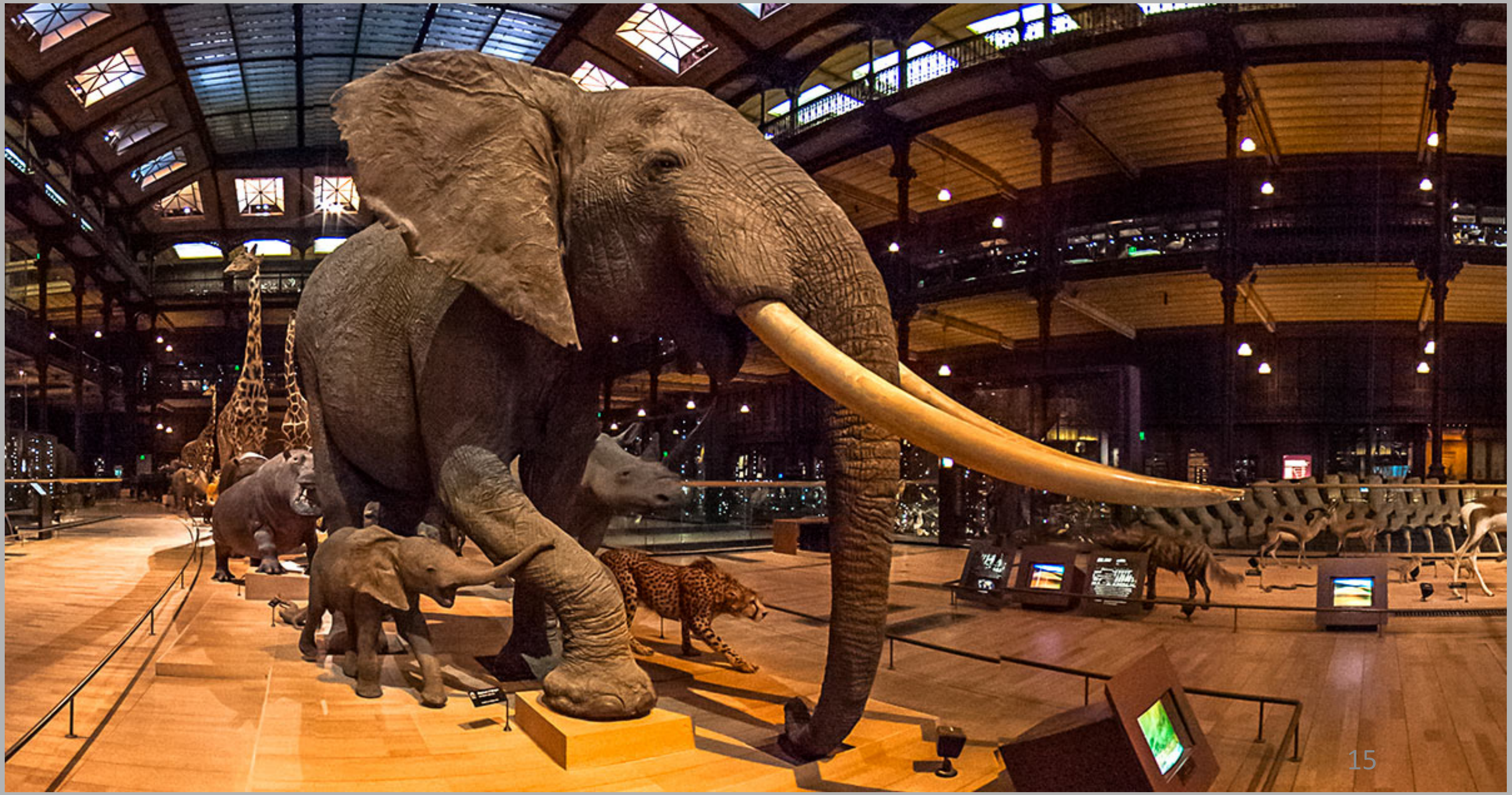
LES SPÉCIMENS "TYPE" ET LE RÔLE DES COLLECTIONS NATURALISTES

Un **spécimen "type"** est un spécimen sélectionné qui sert de **point de référence** lorsqu'une espèce, animale ou végétale, est **décrite** et **nommée** pour la première fois.
Conservation des spécimens => un outil de connaissance stable

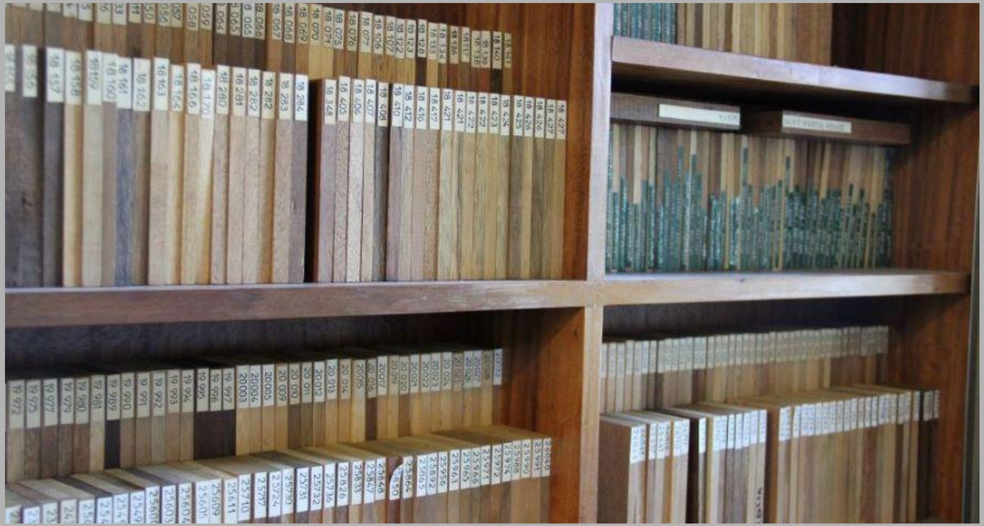
Muséum national d’Histoire naturelle et autres, herbiers



LES SPÉCIMENS "TYPE" ET LE RÔLE DES COLLECTIONS NATURALISTES

Une plante réelle (ou une ou plusieurs parties d'une plante ou un ensemble de petites plantes), morte et conservée dans un herbier
Champignons : carpophore/sporophore sec ou conservé dans un milieu idoine, une culture mycélienne etc..)
…

On parle de
⇒ Herbiers pour les plantes
⇒ Xylothèque pour le bois
⇒ Mycothèque
⇒ Discothèque ☺



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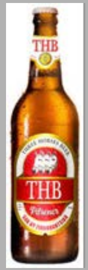
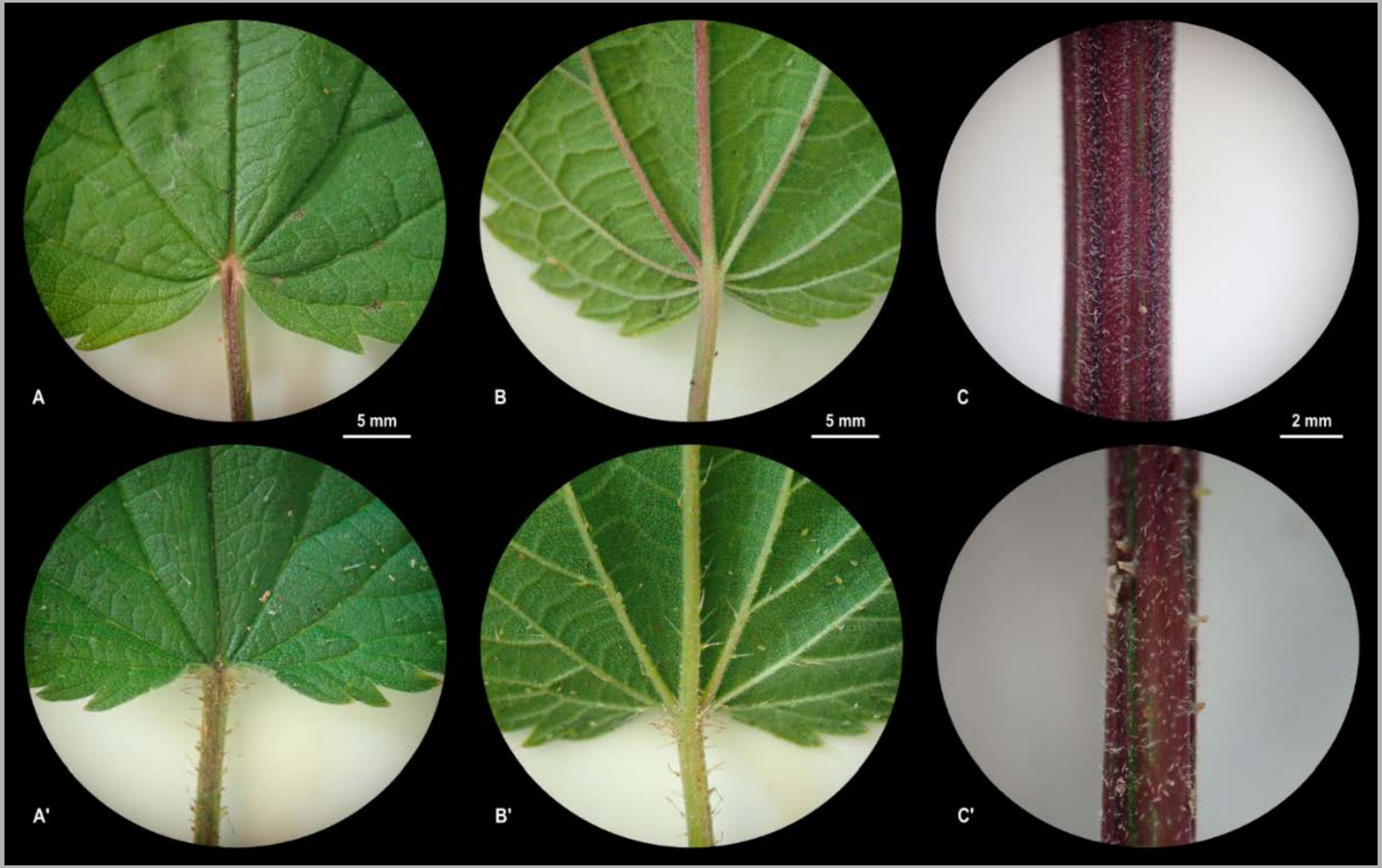
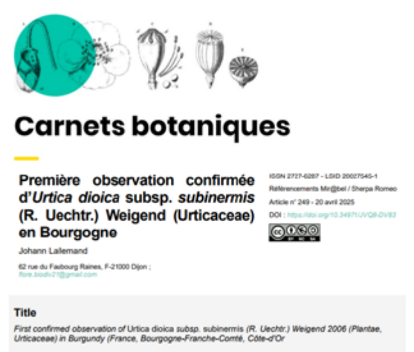


La difficulté de distinguer les espèces entre elles





Carnets botaniques

Première observation confirmée d'*Urtica dioica* subsp. *subinermis* (R. Uechtr.) Weigend (Urticaceae) en Bourgogne

Johann Lallemand

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Références Mir@bel / Sherpa Romeo
Article n° 249 - 20 avril 2025
DOI : https://doi.org/10.34971/JVQ8-DV83

Title

First confirmed observation of Urtica dioica subsp. subinermis (R. Uechtr.) Weigend 2006 (Plantae, Urticaceae) in Burgundy (France, Bourgogne-Franche-Comté, Côte-d'Or

Différence de pilosité limbe face supérieure, face inférieure et tige de la subsp. ***subinermis*** (A-B-C) et la subsp. dioica (A'-B'-C') ; V Schoenfelder, CC-BY-NC-ND.

https://sbocc.fr/publication/premiere-observation-confirmee-durtica-dioica-subsp-subinermis-r-uechtr-weigend-urticaceae-en-bourgogne/

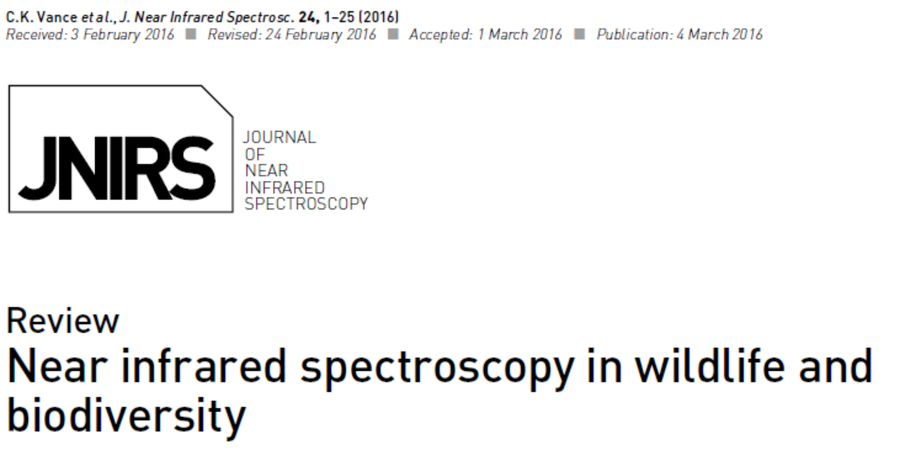
La difficulté due au manque d’experts => les présentations qui vont suivre

La difficulté due au manque d’experts …. Et d’autres facteurs

© LEFRED THOURON

Proche infrarouge au chevet de la biodiversité

Proche infrarouge au chevet de la biodiversité



C.K. Vance *et al.*, *J. Near Infrared Spectrosc.* **24**, 1–25 (2016)
Received: 3 February 2016 ■ *Revised: 24 February 2016* ■ *Accepted: 1 March 2016* ■ *Publication: 4 March 2016*

JNIRS JOURNAL OF NEAR INFRARED SPECTROSCOPY

Review

Near infrared spectroscopy in wildlife and biodiversity

If efficiency in the time and cost allocated to sample analysis was the only advantage of NIR spectroscopy in wildlife and biodiversity research, **it would be a significant contribution**.

However, it is the **non-invasive, non-destructive collection of a bio-physical "snapshot"** which can be obtained in situ and correlated with any number of quantitative or qualitative constituents of interest in our samples that **provides the greatest value from NIR spectroscopy in this discipline**.

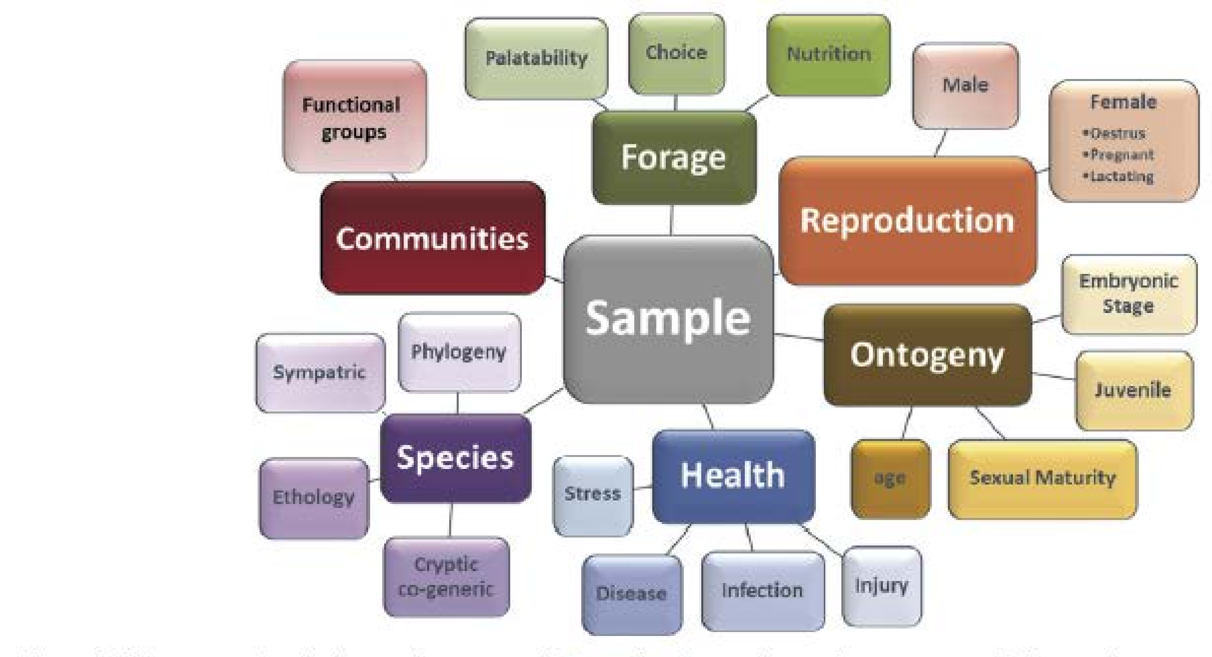


Figure 1. NIR spectra of a single sample captures information that can be used to answer multiple questions.

The **versatility of NIR spectroscopy to instantly capture pertinent information** from all types of biological materials, **from all sorts of species and repeatedly across spatial and temporal scales** are just a few of the features which contribute to its power in facilitating research in these fields.

Vance *et al. 2016.* Review Near infrared spectroscopy in wildlife and biodiversity *J. Near Infrared Spectrosc*. 24, 1–25

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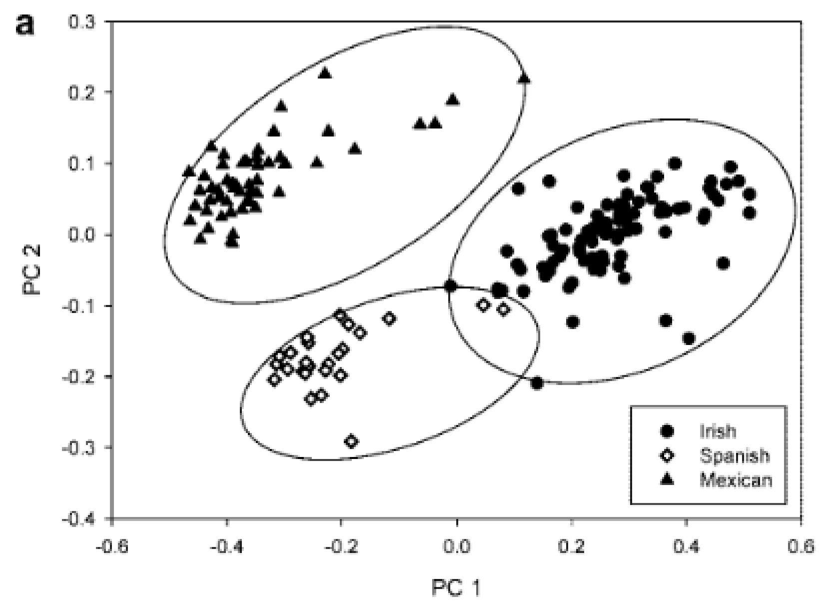
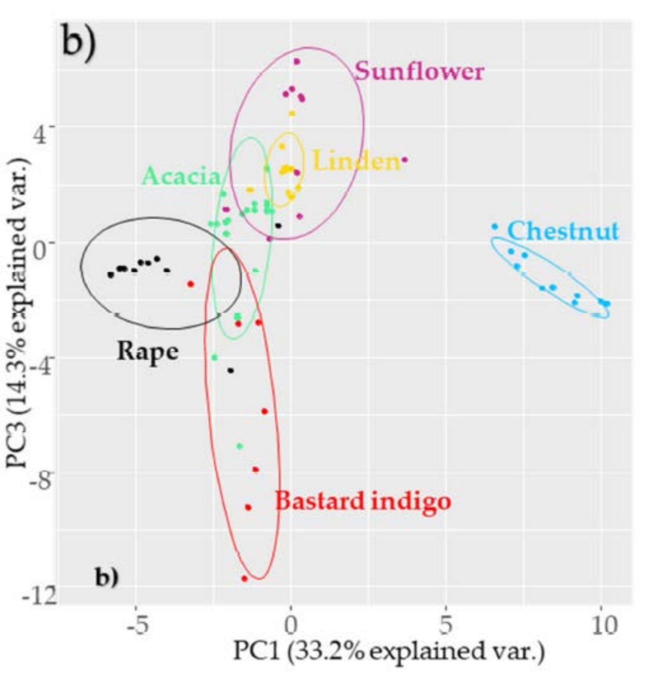
Honey geographical origin



PCA scores plot of Irish, Spanish, and Mexican honey samples (raw spectral, 1100–2498 nm)

Woodcock et al. 2007 Journal of Agricultural and Food Chemistry

Honey botanical origin



Bodor et al. 2021 Molecules

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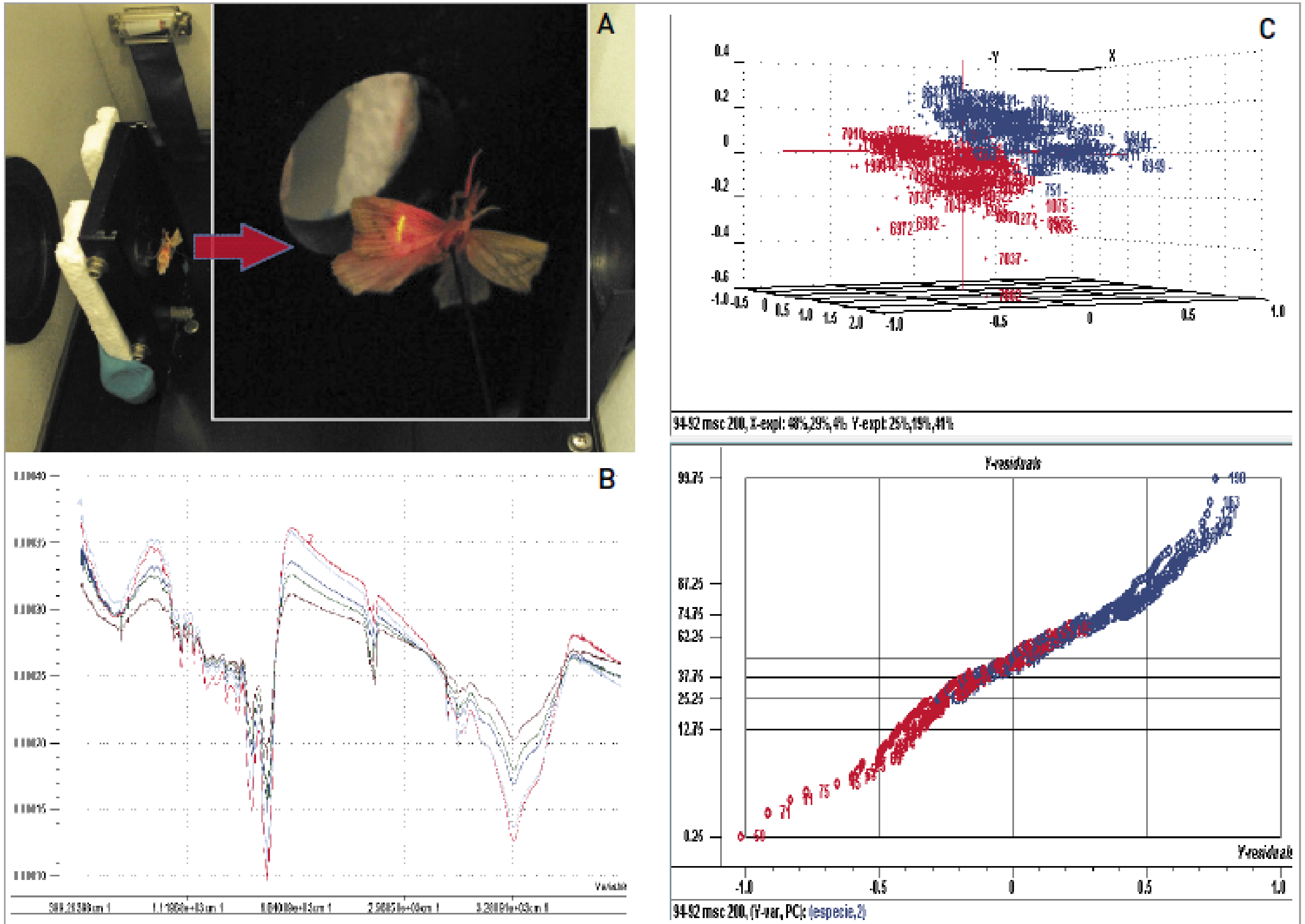

Figure 3. NIR spectra of butterflies. (A) A pinned specimen of a neotropical butterfly in an NIR spectrophotometer. In detail, the area on the anterior wing where transmission spectra were obtained. (B) Pre-processed transmission IR spectra obtained from the anterior wing of five specimens of butterflies. The spectral range is in the near and middle infrared region (from left to right). (C) Multivariate calibration and validation using PLS on spectra from wings of dozens of specimens of two cryptic species of neotropical butterflies.

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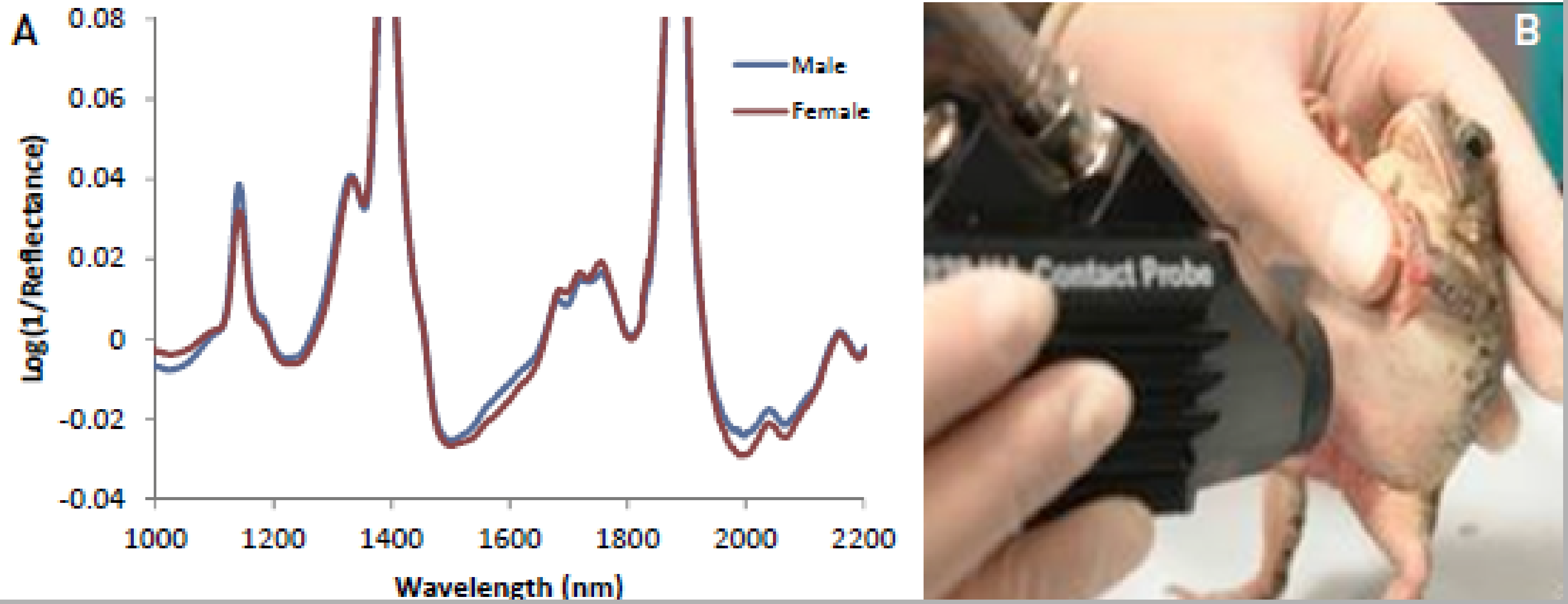
Figure 5. Using NIR spectroscopy to determine sex of individials of monomorphic amphibian species. (A). Average NIR spectra collected from male (*n* = 21) and female (*n* = 21) Mississippi gopher frogs (*Rana sevosa*). Spectra are mean centred, MSC path length corrected and first derivative GAP function with nine points. (B) Collection of NIR spectra from surface skin of live amphibians.[63]



LES MÉTHODES COMPLÉMENTAIRES ALTERNATIVES A LA TAXONOMIE

Méthodes morphologiques (classiques)

1. Morphologie externe : forme, taille, couleur des feuilles, fleurs, fruits, graines.
2. Anatomie interne : structure des tissus (ex. : nervation foliaire, poils glandulaires).
3. Palynologie : étude des grains de pollen.
4. Cytologie : observation des chromosomes (nombre, forme, taille).

Méthodes biochimiques

5. Chimiotaxonomie : analyse des composés secondaires.
6. Profil en acides phénoliques ou terpénoïdes.

Méthodes moléculaires

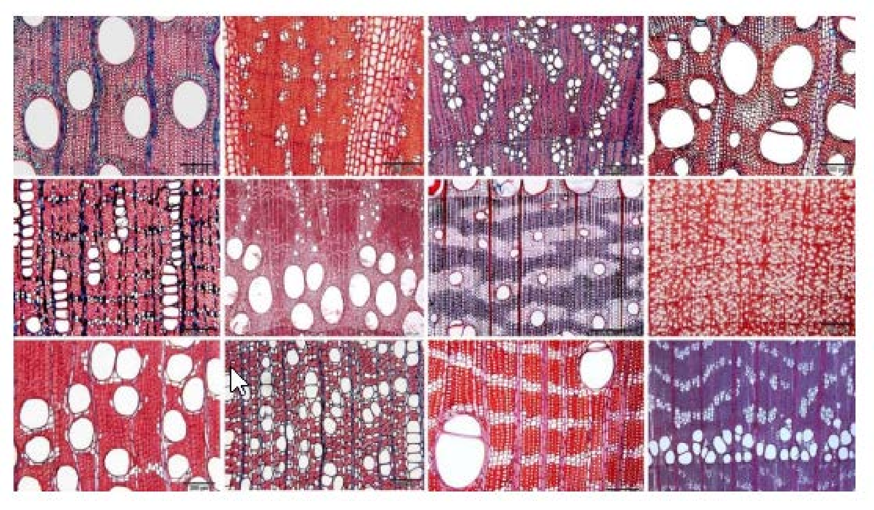
7. Barcoding ADN : séquençage de gènes standardisés (ex. : *rbcL*, *matK*, *ITS*).
8. RFLP (Restriction Fragment Length Polymorphism).
9. AFLP, SSR, ISSR : marqueurs moléculaires génétiques.
10. NGS (Next Generation Sequencing).

Méthodes écologiques et géographiques

11. Écologie comparative : niche écologique, altitude, type de sol.
12. Biogéographie : distribution spatiale et endémisme.

Méthodes expérimentales complémentaires

13. Hybridation contrôlée : tester la compatibilité reproductrice.
14. Culture in vitro : pour observer les réponses morphogénétiques.
15. Test de germination ou de croissance comparative.



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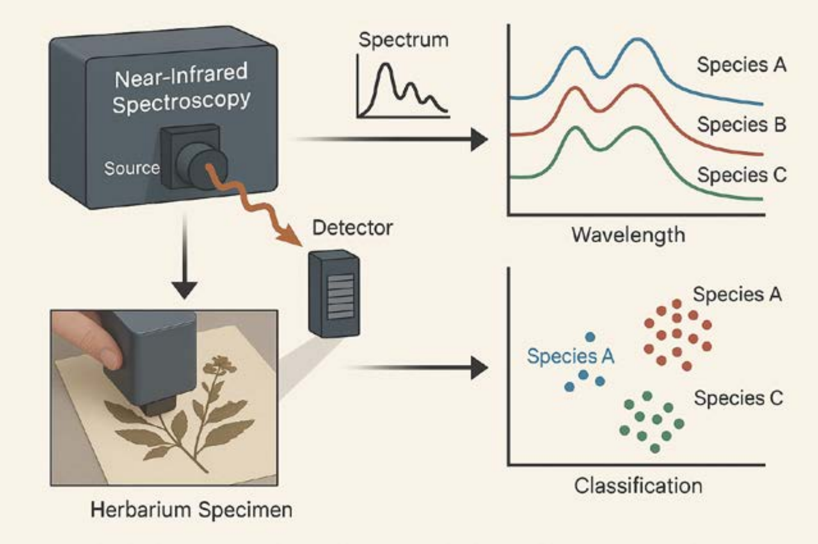
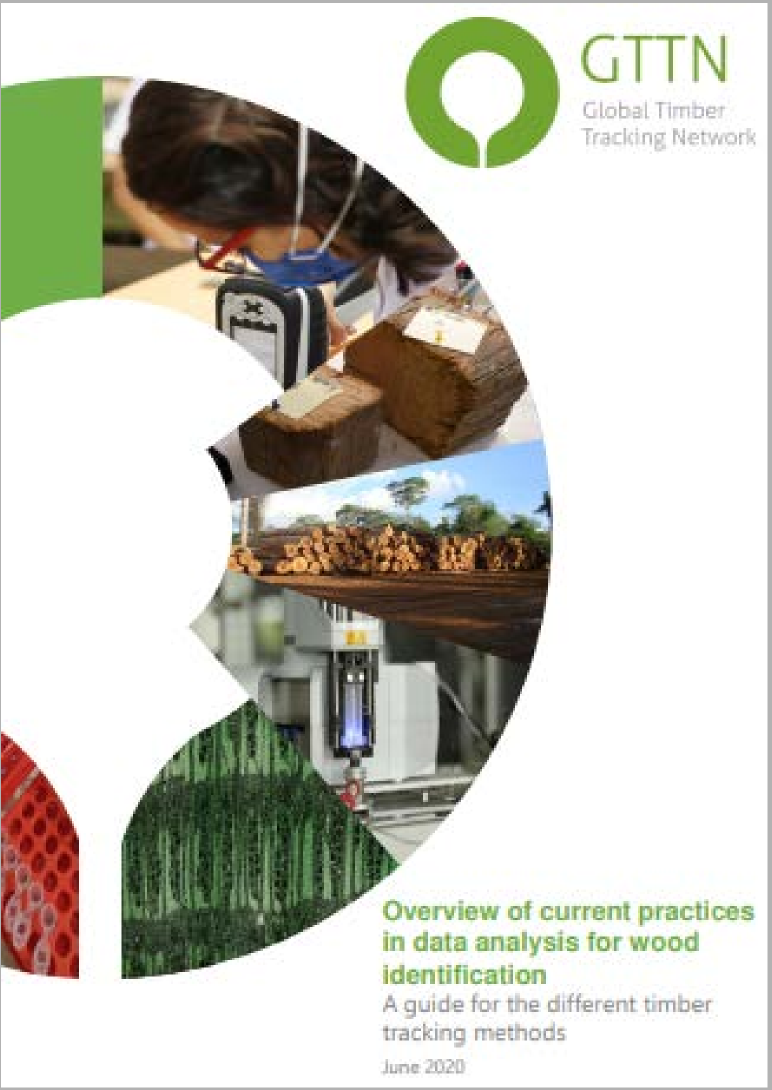
⇒ Spectroscopie
- **⇒ UV (bois depuis très longtemps)**
- **⇒ NIR**

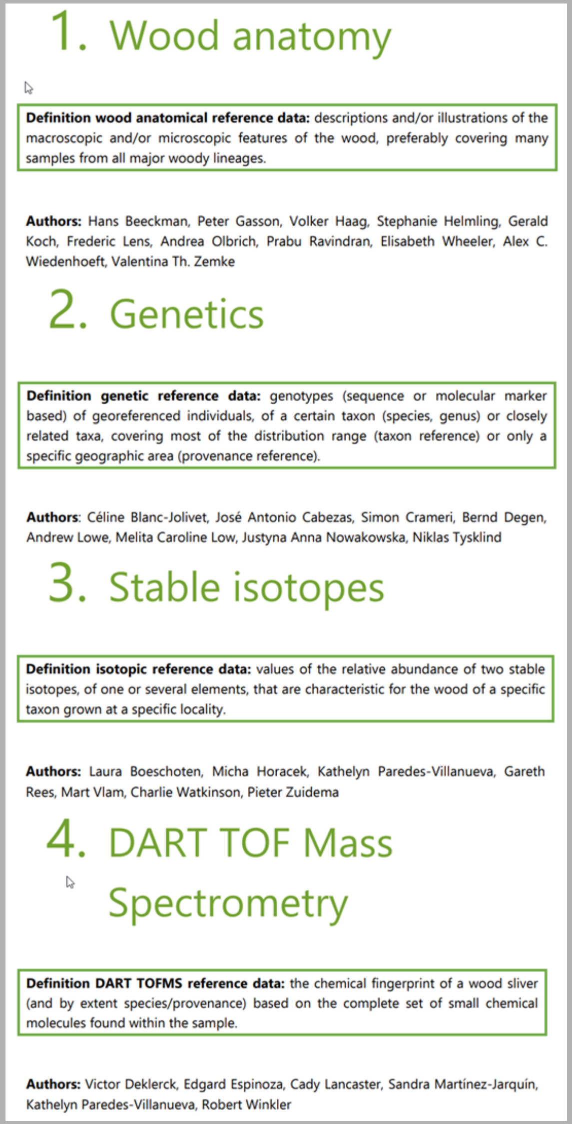


La spectroscopie proche infrarouge et la biodiversité : illustrations pour l'aide à l'identification taxonomique



GTTN
Global Timber Tracking Network

Overview of current practices in data analysis for wood identification
A guide for the different timber tracking methods
June 2020



1. Wood anatomy

Definition wood anatomical reference data: descriptions and/or illustrations of the macroscopic and/or microscopic features of the wood, preferably covering many samples from all major woody lineages.

Authors: Hans Beeckman, Peter Gasson, Volker Haag, Stephanie Helmling, Gerald Koch, Frederic Lens, Andrea Olbrich, Prabu Ravindran, Elisabeth Wheeler, Alex C. Wiedenhoeft, Valentina Th. Zemke

2. Genetics

Definition genetic reference data: genotypes (sequence or molecular marker based) of georeferenced individuals, of a certain taxon (species, genus) or closely related taxa, covering most of the distribution range (taxon reference) or only a specific geographic area (provenance reference).

Authors: Céline Blanc-Jolivet, José Antonio Cabezas, Simon Crameri, Bernd Degen, Andrew Lowe, Melita Caroline Low, Justyna Anna Nowakowska, Niklas Tysklind

3. Stable isotopes

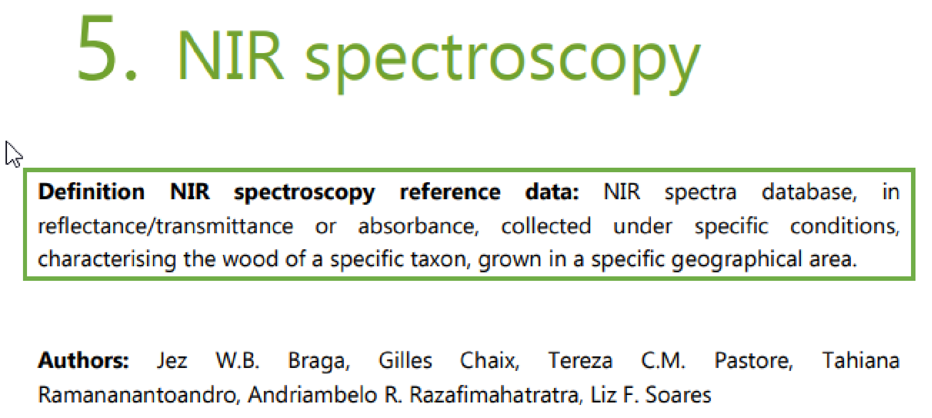
Definition isotopic reference data: values of the relative abundance of two stable isotopes, of one or several elements, that are characteristic for the wood of a specific taxon grown at a specific locality.

Authors: Laura Boeschoten, Micha Horacek, Kathelyn Paredes-Villanueva, Gareth Rees, Mart Vlam, Charlie Watkinson, Pieter Zuidema

4. DART TOF Mass Spectrometry

Definition DART TOFMS reference data: the chemical fingerprint of a wood sliver (and by extent species/provenance) based on the complete set of small chemical molecules found within the sample.

Authors: Victor Deklerck, Edgard Espinoza, Cady Lancaster, Sandra Martínez-Jarquín, Kathelyn Paredes-Villanueva, Robert Winkler



5. NIR spectroscopy

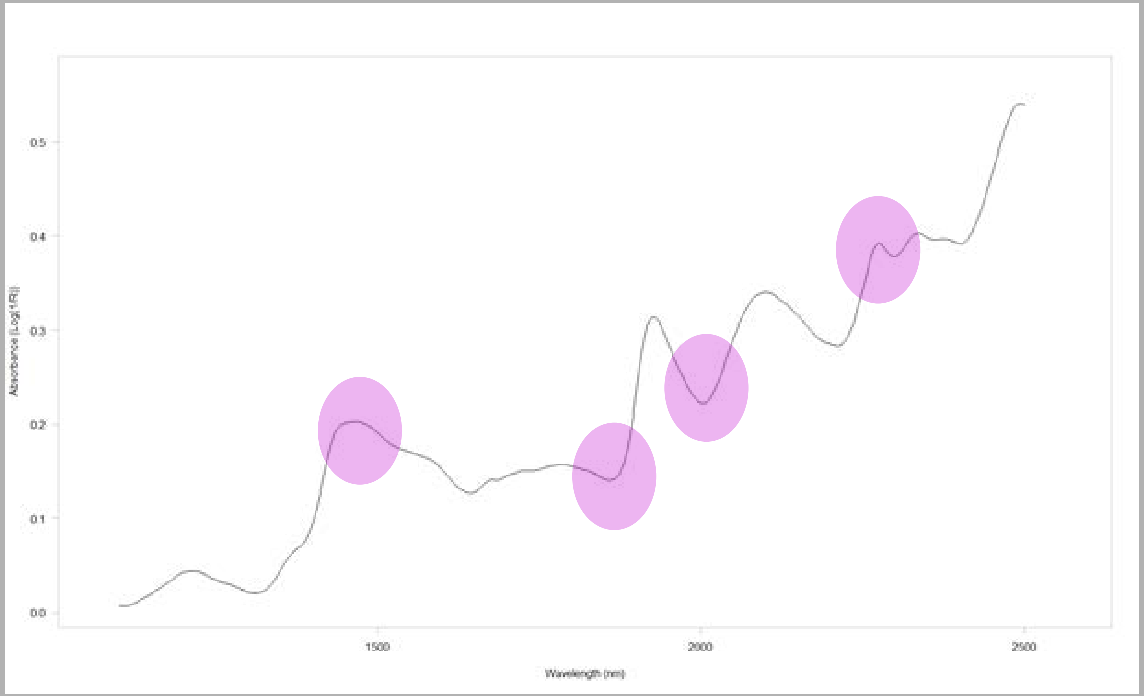
Definition NIR spectroscopy reference data: NIR spectra database, in reflectance/transmittance or absorbance, collected under specific conditions, characterising the wood of a specific taxon, grown in a specific geographical area.

Authors: Jez W.B. Braga, Gilles Chaix, Tereza C.M. Pastore, Tahiana Ramananantoandro, Andriambelo R. Razafimahatratra, Liz F. Soares

Proche infrarouge au chevet de la biodiversité

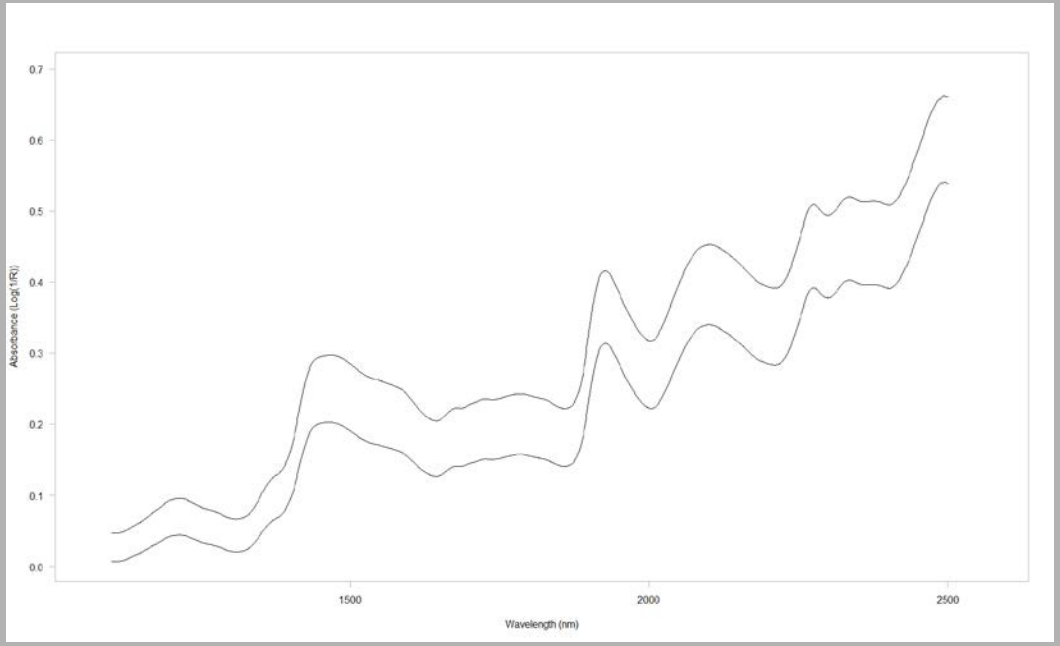
Spectra = fingerprinping (chemical fingerprinting)

Specific and unique for each sample



Proche infrarouge au chevet de la biodiversité

Spectra = fingerprinping (chemical fingerprinting)
Specific for each sample

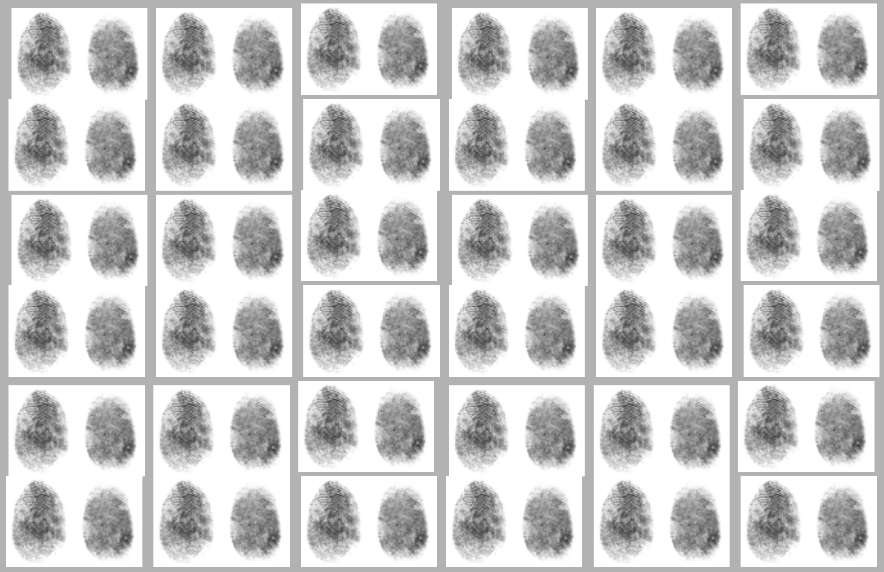


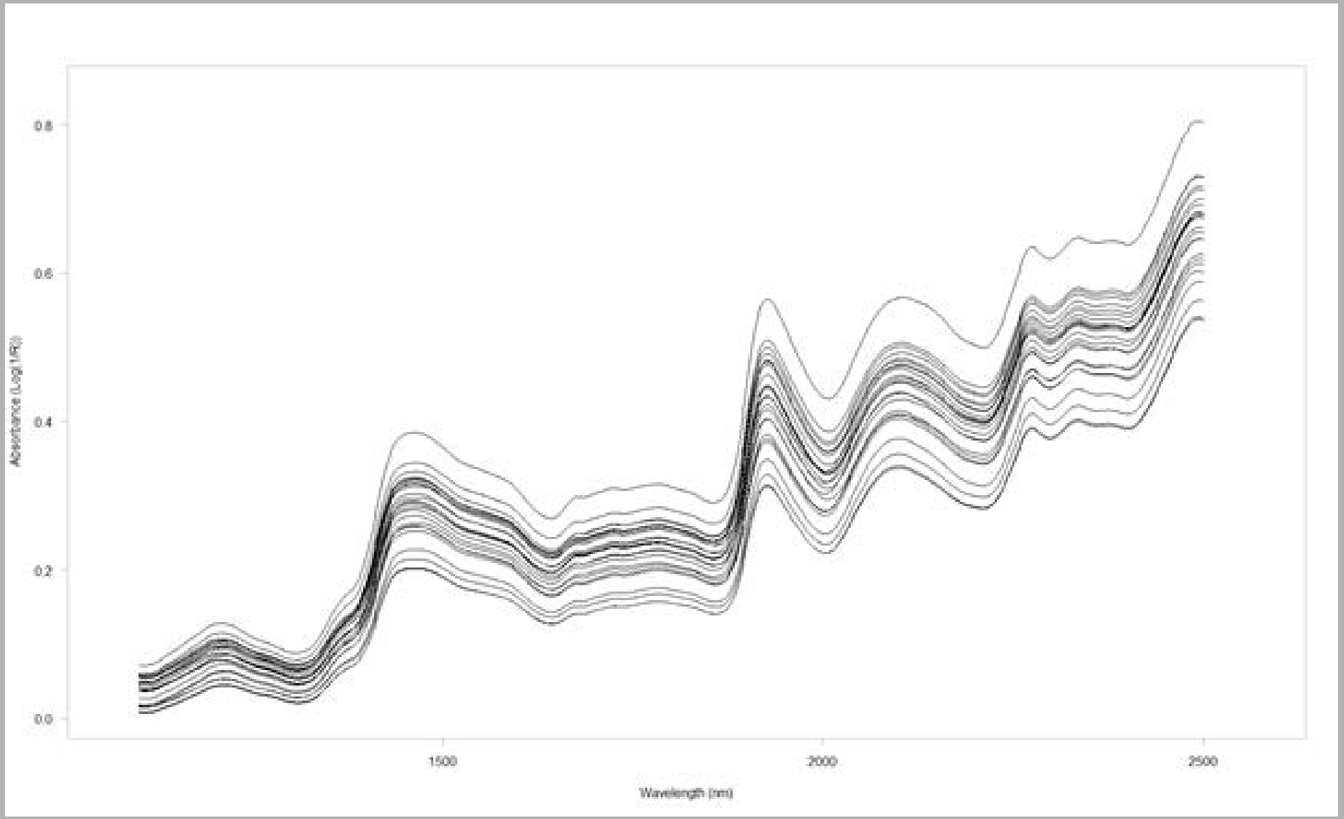
=> To discriminate

Proche infrarouge au chevet de la biodiversité

Spectra = fingerprinping (chemical fingerprinting)

Specific for each sample



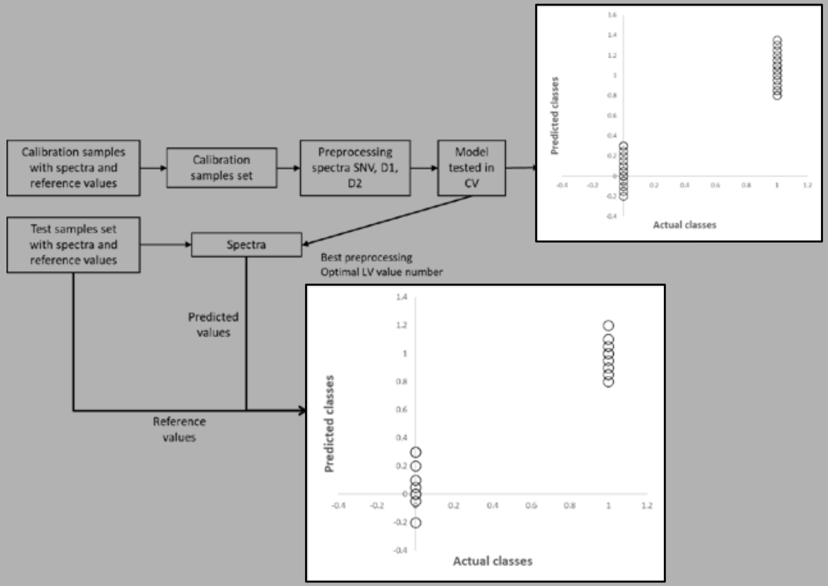


=> To calibrate

Proche infrarouge au chevet de la biodiversité

Principal criteria for a discriminante analysis evaluation

Calibration and validation processes for qualitative traits (0 or 1 / YES or NO)

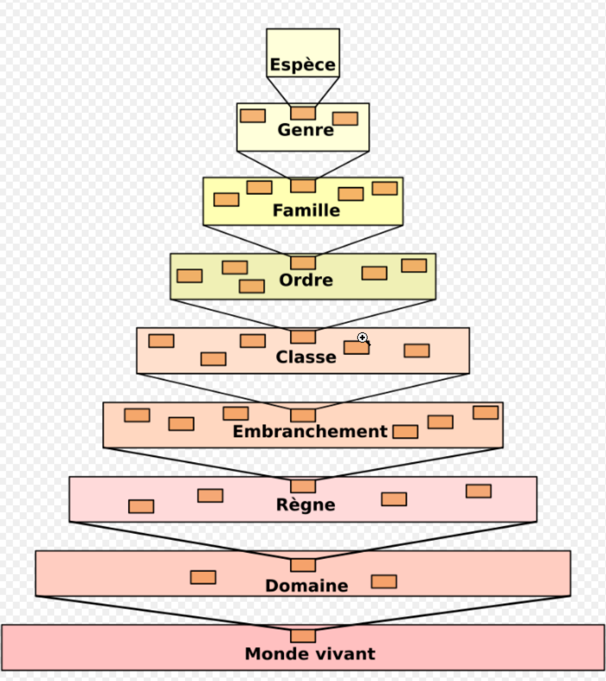


n=165	Predicted: NO	Predicted: YES	
Actual: NO	TN = 50	FP = 10	60
Actual: YES	FN = 5	TP = 100	105
	55	110	

Accuracy:	50+100/165	“Overall, how often is the classifier correct?”
Error rate:	5+10/165	“Overall, how often is it wrong?”
Sensitivity/Recall:	100/105	“When it's actually yes, how often does it predict yes?”
Precision:	100/110	“When it predicts yes, how often is it correct?”

Proche infrarouge et taxonomie

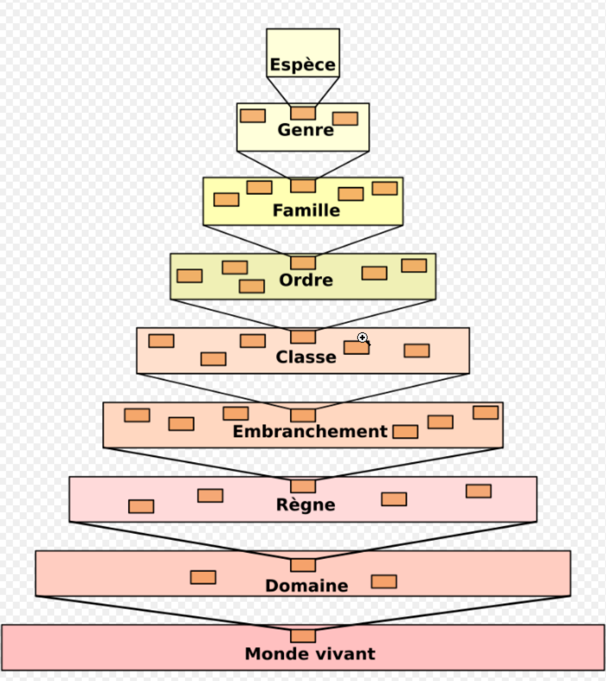
La spectroscopie proche infrarouge et la biodiversité : illustrations pour l'aide à l'identification taxonomique

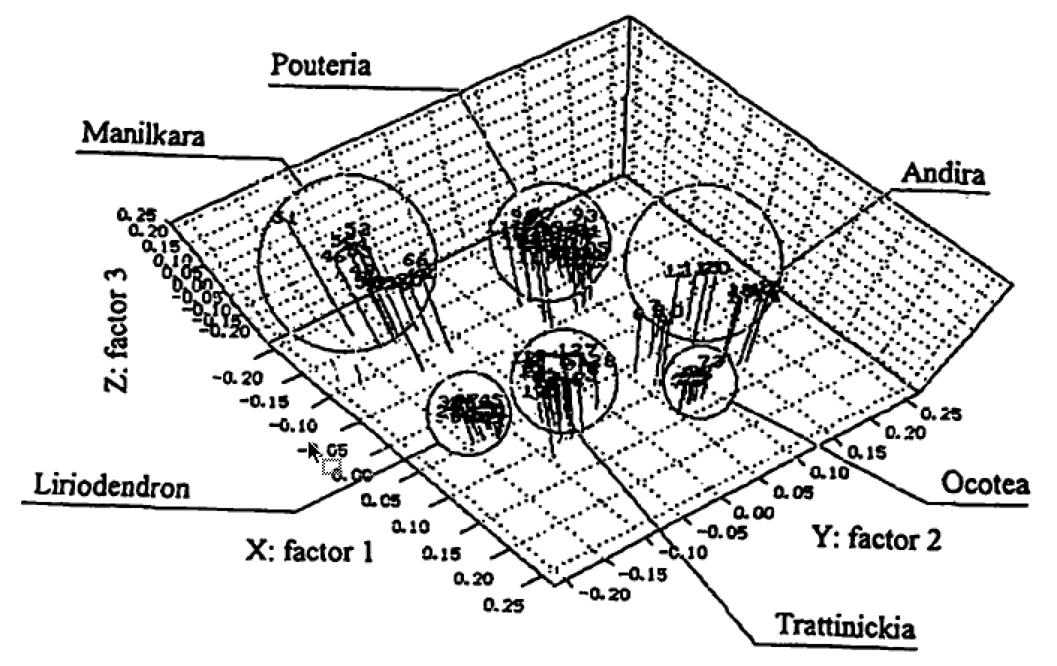


Mais aussi :

Sous espèces
Cultivar
Provenance
Hybrides
Stress

La spectroscopie proche infrarouge et la biodiversité : illustrations pour l'aide à l'identification taxonomique

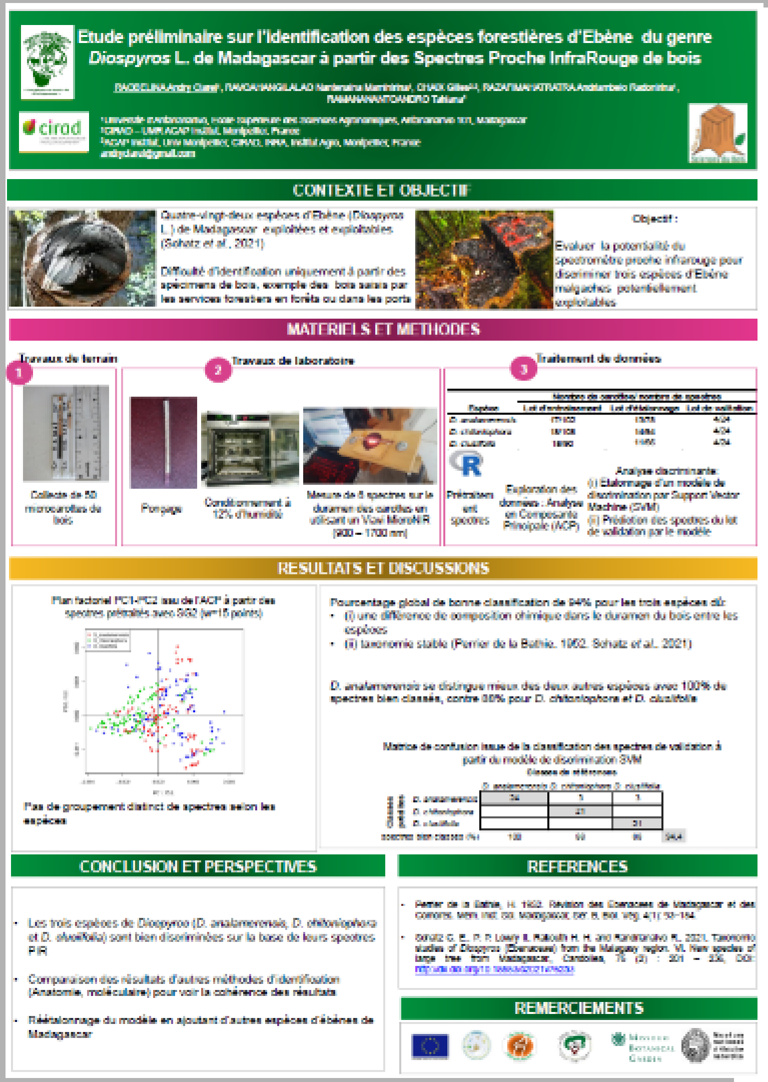




Mais aussi :

Sous espèces
Cultivar
Provenance
Hybrides
Stress

Nir spectroscopy for species identification – spectra on core samples



Etude préliminaire sur l'identification des espèces forestières d'Ebène du genre *Diospyros* L. de Madagascar à partir des Spectres Proche InfraRouge de bois

RAOBELINA Andry Clarel¹, RAVOAHANGILALAO Nantenaina Maminirina², CHAIX Gilles²,³, RAZAFIMAHATRATRA Andriambelo Radonirina¹, RAMANANANTOANDRO Tahiana¹
¹Université d'Antananarivo, Ecole Supérieure des Sciences Agronomiques, Antananarivo 101, Madagascar
²CIRAD – UMR AGAP Institut, Montpellier, France
³AGAP Institut, Univ Montpellier, CIRAD, INRA, Institut Agro, Montpellier, France
andryclarel@gmail.com

CONTEXTE ET OBJECTIF

Quatre-vingt-deux espèces d'Ebène (*Diospyros* L.) de Madagascar exploitées et exploitables (Schatz et al., 2021)

Difficulté d'identification uniquement à partir des spécimens de bois, exemple des bois saisis par les services forestiers en forêts ou dans les ports

Objectif :

Evaluer la potentialité du spectromètre proche infrarouge pour discriminer trois espèces d'Ebène malgaches potentiellement exploitables

MATERIELS ET METHODES

1 Travaux de terrain

Collecte de 50 microcarottes de bois

2 Travaux de laboratoire

Ponçage

Conditionnement à 12% d'humidité

Mesure de 5 spectres sur le duramen des carottes en utilisant un Viavi MicroNIR (900 – 1700 nm)

3 Traitement de données

Prétraitement spectres

Exploration des données : Analyse en Composante Principale (ACP)

Analyse discriminante :
(i) Etalonnage d'un modèle de discrimination par Support Vector Machine (SVM)
(ii) Prédiction des spectres du lot de validation par le modèle

RESULTATS ET DISCUSSIONS

Plan factoriel PC1-PC2 issu de l'ACP à partir des spectres prétraités avec SG2 (w=15 points)

Pas de groupement distinct de spectres selon les espèces

Pourcentage global de bonne classification de 94% pour les trois espèces dû:
- (i) une différence de composition chimique dans le duramen du bois entre les espèces
- (ii) taxonomie stable (Perrier de la Bathie, 1952, Schatz et al., 2021)

D. analamerensis se distingue mieux des deux autres espèces avec 100% de spectres bien classés, contre 90% pour *D. chitoniophora* et *D. olacifolia*

Matrice de confusion issue de la classification des spectres de validation à partir du modèle de discrimination SVM

CONCLUSION ET PERSPECTIVES

- Les trois espèces de *Diospyros* (*D. analamerensis*, *D. chitoniophora* et *D. olacifolia*) sont bien discriminées sur la base de leurs spectres PIR
- Comparaison des résultats d'autres méthodes d'identification (Anatomie, moléculaire) pour voir la cohérence des résultats
- Réétalonnage du modèle en ajoutant d'autres espèces d'ébènes de Madagascar

REFERENCES

- Perrier de la Bathie, H. 1952. Révision des Ebenacées de Madagascar et des Comores. Mém. Inst. Sci. Madagascar, sér. B, Biol. Vég. 4(1): 93–154.
- Schatz G. E., P. P. Lowry II, Rakotoarison H. H. and Randrianaivo R., 2021. Taxonomic studies of *Diospyros* (Ebenaceae) from the Malagasy region. VI. New species of large tree from Madagascar. Candollea, 76 (2) : 201 – 230. DOI: http://dx.doi.org/10.15553/c2021v762a3

REMERCIEMENTS

SVM

Classes de références

Classes prédites

	abrahamii	baronii	chapelieri	chlorocarpa	greveana	humbertii	mollis	monticola	orientalis	purpurascens	
abrahamii	18					1					
baronii		12	5				5	4	3	3	
chapelieri			4								
chlorocarpa			2	19	2	9				1	
greveana			1		6				1		
humbertii	6					5		1			
mollis							7			1	
monticola						1		25		6	
orientalis				5	2	2		6	67	6	
purpurascens					2				1	19	
%	75,0	100,0	33,3	79,2	50,0	27,8	58,3	69,4	93,1	52,8	70,5

Andry Clarel RAOBELINA 2021, HelioSPIR

Nir spectroscopy for provenance classification – spectra on dried and grounded leaves

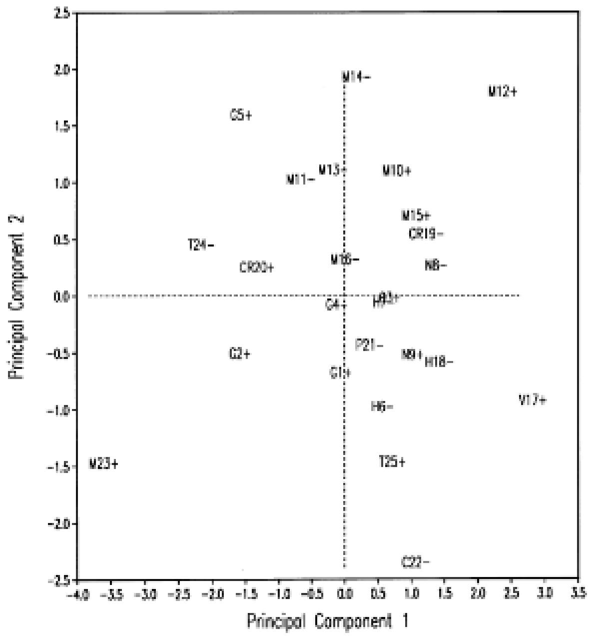


Fig. 4. Plot of the first and second principal components for the 25 different provenances of *Gliricidia* spp. (the sign of the third principal component is given).

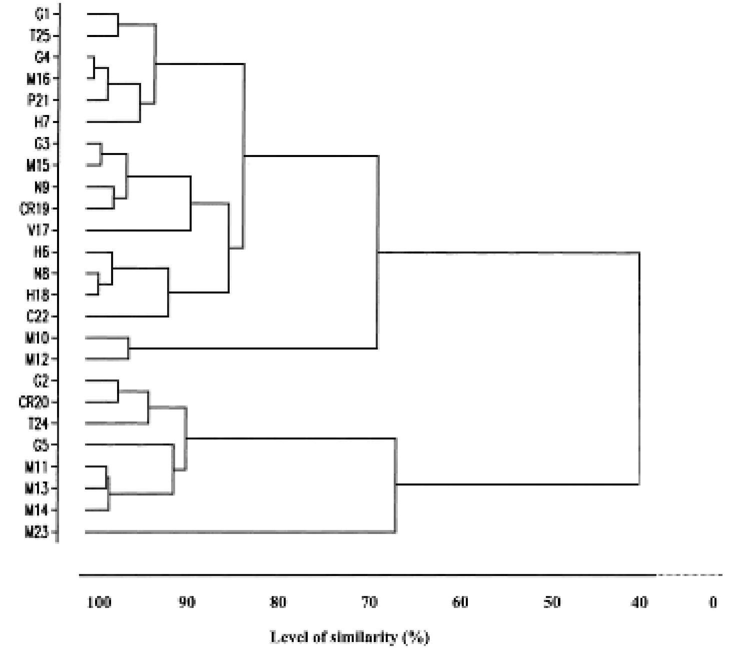


Fig. 6. Dendrogram showing the emerging clusters from hierarchical cluster analysis using a furthest neighbour criterion for the 25 different provenances.

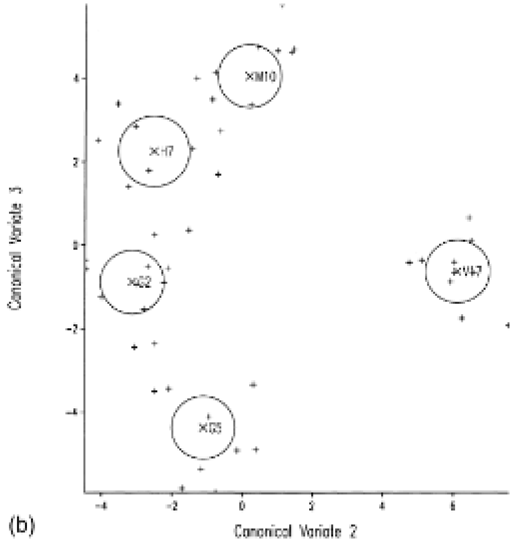


Fig. 7. (a) Plot of the first and second canonical variates showing the relationships between the five provenances G2, G5, H7, M10 and V17 where samples from replicate individual trees were available. (b) Plot of the second and third canonical variates for the five provenances G2, G5, H7, M10 and V17.

Lister et al. 2000. Classification and comparison of Gliricidia provenances using near infrared reflectance spectroscopy. Animal Feed Science and Technology 86: 221-238

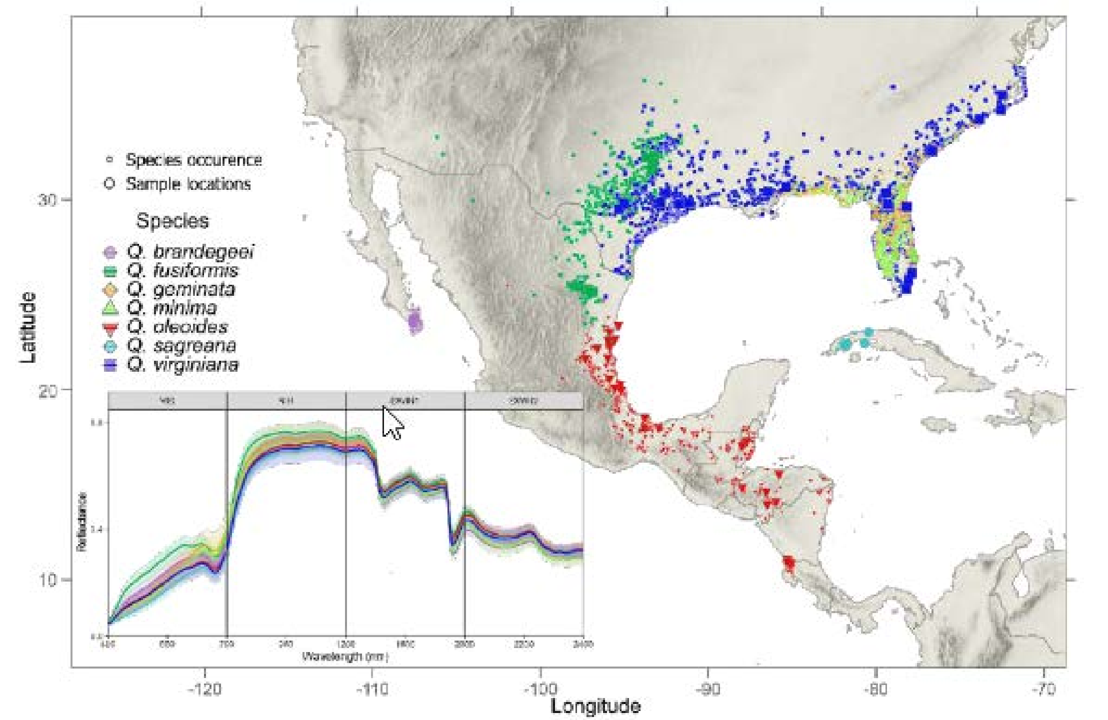
Foliar spectral signatures reveal adaptive divergence in live oaks (Quercus section Virentes) across species and environmental niches

Mariana S Hernández-Leal , J. Antonio Guzmán Q., Antonio González Rodríguez, Jeannine Cavender-Bares

Leaf reflectance spectra were corrected for the splice in bands near 990 and 1900 nm.
Spectra transformed by wavelet transformation (CWT)
This transformation was computed based on a second-order derivative of Gaussian using scales 22, 24, and 26.
Bands at the edge of the spectrometer range (< 400 nm and > 2450 nm) were excluded

Partial least-squares discriminant analysis for species classification

These results demonstrate that **leaf reflectance spectra can be used to capture adaptive differentiation and evolutionary history** across scales, offering a powerful, non-destructive tool for linking phenotype, environment, and evolutionary processes in long-lived plant lineages.



https://doi.org/10.32942/X2BK90

Nir spectroscopy termite species discrimination – spectra on dried and grounded termites

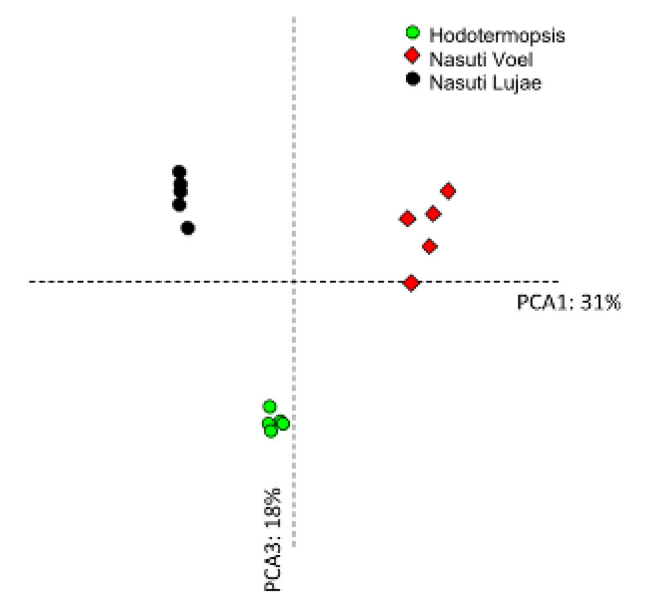


Fig. 1. Principle component analysis of the near infrared reflectance spectra of termite soldiers. Species are *H. sjoestedti*, *N. voeltzkowi* and *N. lujae*.

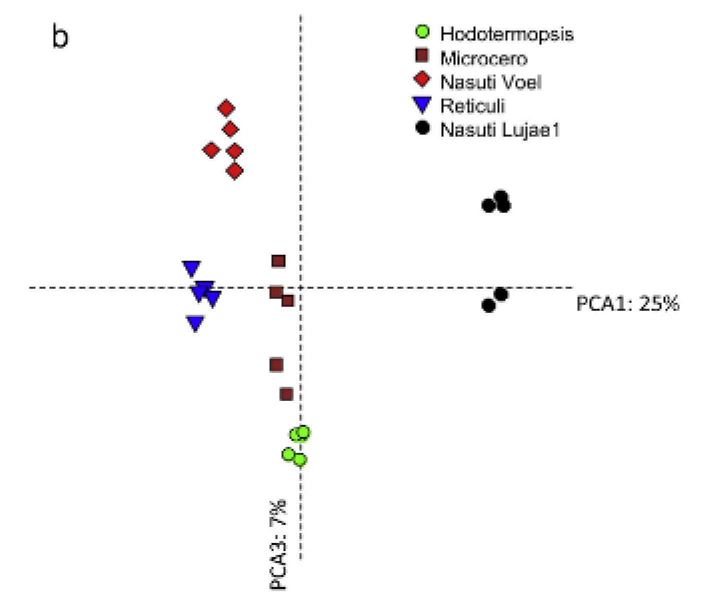


Fig. 2. Principle component analysis of the near infrared reflectance spectra of termite workers. Species are *H. sjoestedti*, *M. parvus*, *N. voeltzkowi*, *R. virginicus* and *N. lujae*. (a) Axis 1 and 2, (b) axis 1 and 3.

Jouquet et al. 2014. Potential of Near Infrared Reflectance Spectroscopy (NIRS) for identifying termite species. European Journal of Soil Biology 60: 49e52

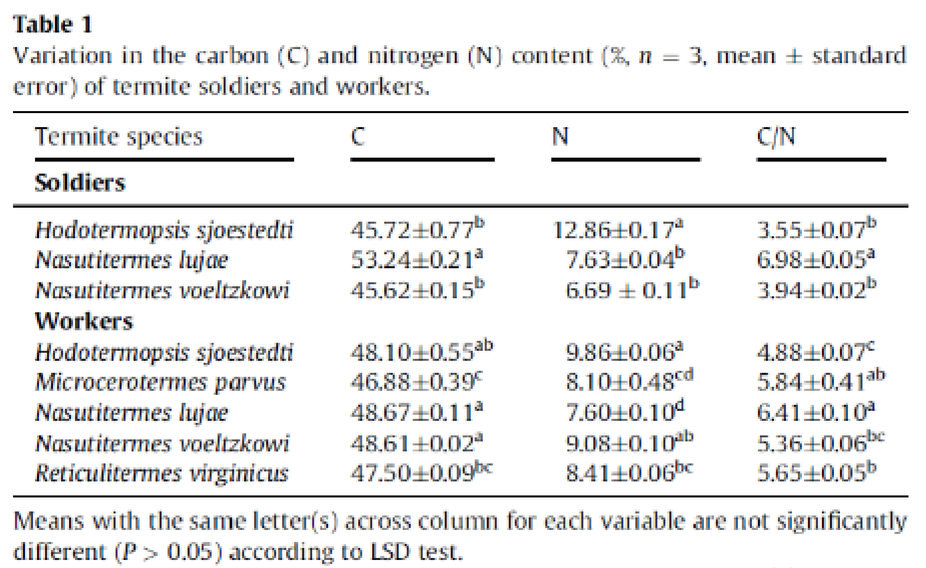


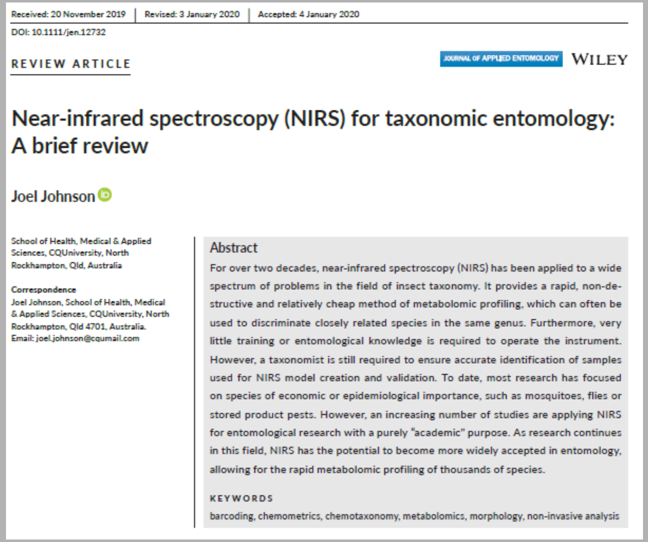
Table 1

Variation in the carbon (C) and nitrogen (N) content (%, $n = 3$, mean ± standard error) of termite soldiers and workers.

Termite species	C	N	C/N
Soldiers			
Hodotermopsis sjoestedti	45.72±0.77^{b}	12.86±0.17^{a}	3.55±0.07^{b}
Nasutitermes lujae	53.24±0.21^{a}	7.63±0.04^{b}	6.98±0.05^{a}
Nasutitermes voeltzkowi	45.62±0.15^{b}	6.69 ± 0.11^{b}	3.94±0.02^{b}
Workers			
Hodotermopsis sjoestedti	48.10±0.55^{ab}	9.86±0.06^{a}	4.88±0.07^{c}
Microcerotermes parvus	46.88±0.39^{c}	8.10±0.48^{cd}	5.84±0.41^{ab}
Nasutitermes lujae	48.67±0.11^{a}	7.60±0.10^{d}	6.41±0.10^{a}
Nasutitermes voeltzkowi	48.61±0.02^{a}	9.08±0.10^{ab}	5.36±0.06^{bc}
Reticulitermes virginicus	47.50±0.09^{bc}	8.41±0.06^{bc}	5.65±0.05^{b}

Means with the same letter(s) across column for each variable are not significantly different ($P > 0.05$) according to LSD test.

Difficultés pour la mesure NIR



Received: 20 November 2019 | Revised: 3 January 2020 | Accepted: 4 January 2020
DOI: 10.1111/jen.12732

REVIEW ARTICLE

JOURNAL OF APPLIED ENTOMOLOGY WILEY

Near-infrared spectroscopy (NIRS) for taxonomic entomology: A brief review

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Email: joel.johnson@cqumail.com

Abstract

For over two decades, near-infrared spectroscopy (NIRS) has been applied to a wide spectrum of problems in the field of insect taxonomy. It provides a rapid, non-destructive and relatively cheap method of metabolomic profiling, which can often be used to discriminate closely related species in the same genus. Furthermore, very little training or entomological knowledge is required to operate the instrument. However, a taxonomist is still required to ensure accurate identification of samples used for NIRS model creation and validation. To date, most research has focused on species of economic or epidemiological importance, such as mosquitoes, flies or stored product pests. However, an increasing number of studies are applying NIRS for entomological research with a purely "academic" purpose. As research continues in this field, NIRS has the potential to become more widely accepted in entomology, allowing for the rapid metabolomic profiling of thousands of species.

KEYWORDS
barcoding, chemometrics, chemotaxonomy, metabolomics, morphology, non-invasive analysis

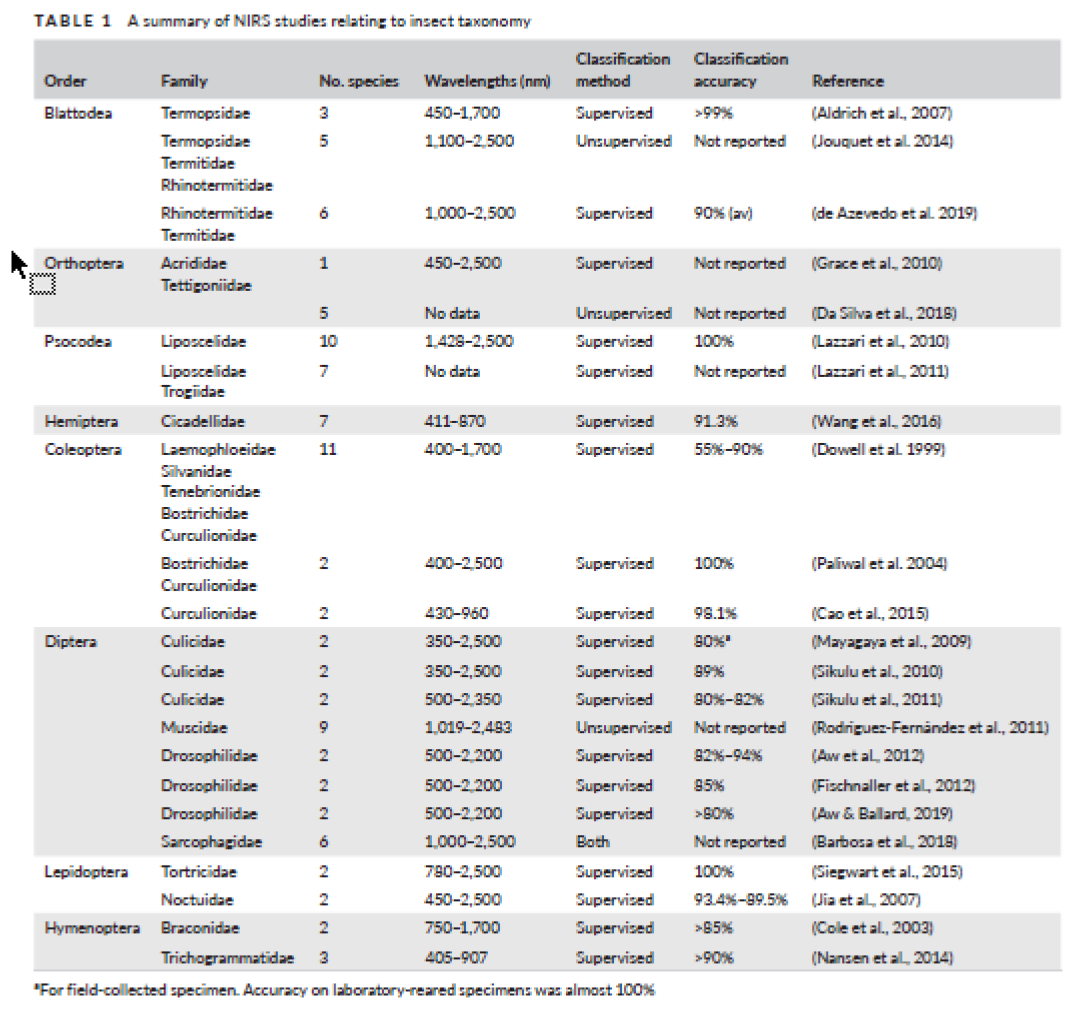
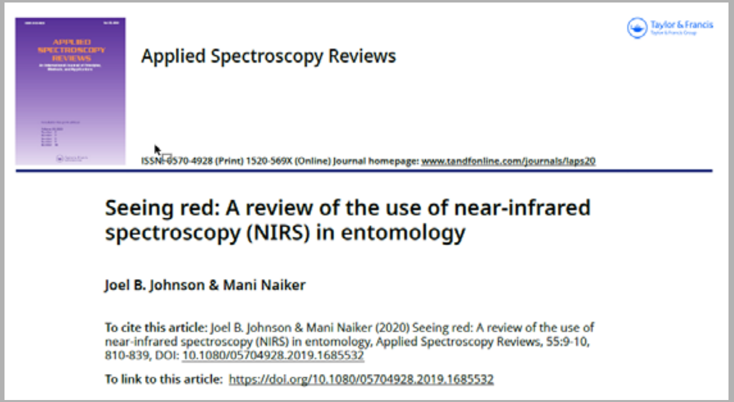


TABLE 1 A summary of NIRS studies relating to insect taxonomy

Order	Family	No. species	Wavelengths (nm)	Classification method	Classification accuracy	Reference
Blattodea	Termopsidae	3	450–1,700	Supervised	>99%	(Aldrich et al., 2007)
	Termopsidae Termitidae Rhinotermitidae	5	1,100–2,500	Unsupervised	Not reported	(Jouquet et al. 2014)
	Rhinotermitidae Termitidae	6	1,000–2,500	Supervised	90% (av)	(de Azevedo et al. 2019)
Orthoptera	Acrididae Tettigoniidae	1	450–2,500	Supervised	Not reported	(Grace et al., 2010)
		5	No data	Unsupervised	Not reported	(Da Silva et al., 2018)
Psocodea	Liposcelidae	10	1,428–2,500	Supervised	100%	(Lazzari et al., 2010)
	Liposcelidae Trogiidae	7	No data	Supervised	Not reported	(Lazzari et al., 2011)
Hemiptera	Cicadellidae	7	411–870	Supervised	91.3%	(Wang et al., 2016)
Coleoptera	Laemophloeidae Silvanidae Tenebrionidae Bostrichidae Curculionidae	11	400–1,700	Supervised	55%–90%	(Dowell et al. 1999)
	Bostrichidae Curculionidae	2	400–2,500	Supervised	100%	(Paliwal et al. 2004)
	Curculionidae	2	430–960	Supervised	98.1%	(Cao et al., 2015)
Diptera	Culicidae	2	350–2,500	Supervised	80%[a]	(Mayagaya et al., 2009)
	Culicidae	2	350–2,500	Supervised	89%	(Sikulu et al., 2010)
	Culicidae	2	500–2,350	Supervised	80%–82%	(Sikulu et al., 2011)
	Muscidae	9	1,019–2,483	Unsupervised	Not reported	(Rodriguez-Fernández et al., 2011)
	Drosophilidae	2	500–2,200	Supervised	82%–94%	(Aw et al., 2012)
	Drosophilidae	2	500–2,200	Supervised	85%	(Fischnaller et al., 2012)
	Drosophilidae	2	500–2,200	Supervised	>80%	(Aw & Ballard, 2019)
	Sarcophagidae	6	1,000–2,500	Both	Not reported	(Barbosa et al., 2018)
Lepidoptera	Tortricidae	2	780–2,500	Supervised	100%	(Siegwart et al., 2015)
	Noctuidae	2	450–2,500	Supervised	93.4%–89.5%	(Jia et al., 2007)
Hymenoptera	Braconidae	2	750–1,700	Supervised	>85%	(Cole et al., 2003)
	Trichogrammatidae	3	405–907	Supervised	>90%	(Nansen et al., 2014)

[a] For field-collected specimen. Accuracy on laboratory-reared specimens was almost 100%



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ISSN: 0570-4928 (Print) 1520-569X (Online) Journal homepage: www.tandfonline.com/journals/laps20

Seeing red: A review of the use of near-infrared spectroscopy (NIRS) in entomology

Joel B. Johnson & Mani Naiker

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To link to this article: https://doi.org/10.1080/05704928.2019.1685532

Nir spectroscopy for hybrid discrimination – spectra on fresh leaves

M. Abasolo et al. / Forest Ecology and Management 304 (2013) 121–131

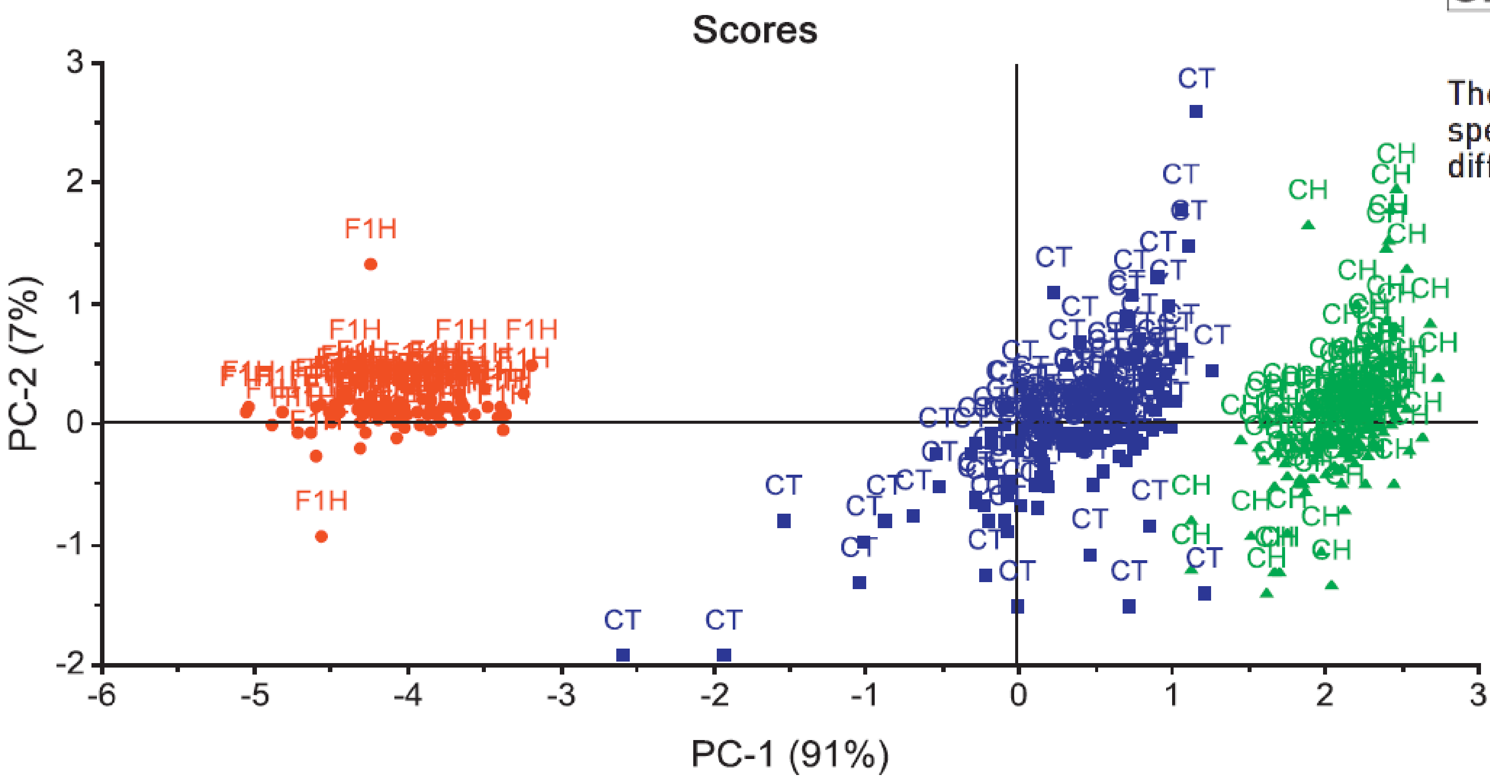


Fig. 3. Scores plot of the first two principal components derived from NIR1 (after Gap-Segment and SNV pre-treatment) using eight-month-old fresh tissue of the CH hybrid group (Blue = *C. torelliana* (*n* = 150), Red = Hybrid (*n* = 78), Green = *C. henryi* (*n* = 127)). (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

J.A. Espinoza, G.R. Hodge and W.S. Dvorak, J. Near Infrared Spectrosc. 18, 437–447 (2012)
Received: 9 February 2012 ■ Revised: 24 May 2012 ■ Accepted: 7 June 2012 ■ Publication: 28 June 2012

JNIRS JOURNAL OF NEAR INFRARED SPECTROSCOPY

The potential use of near infrared spectroscopy to discriminate between different pine species and their hybrids

Nir spectroscopy for genetic analysis – spectra on freeze-dried Eucalyptus leaves

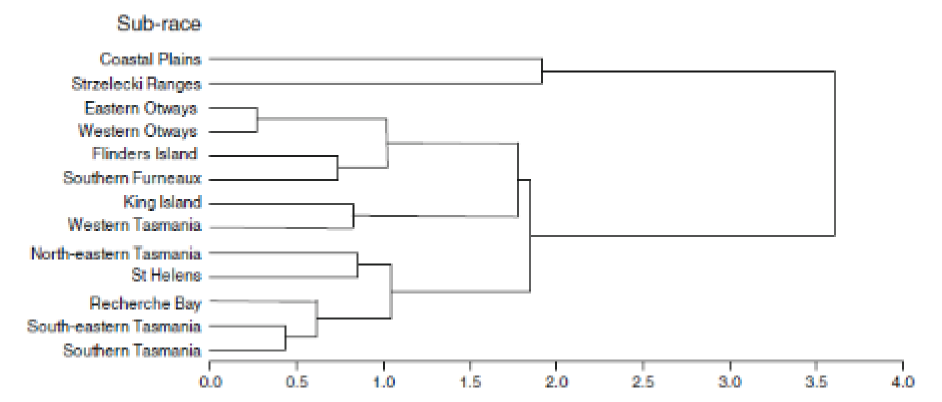
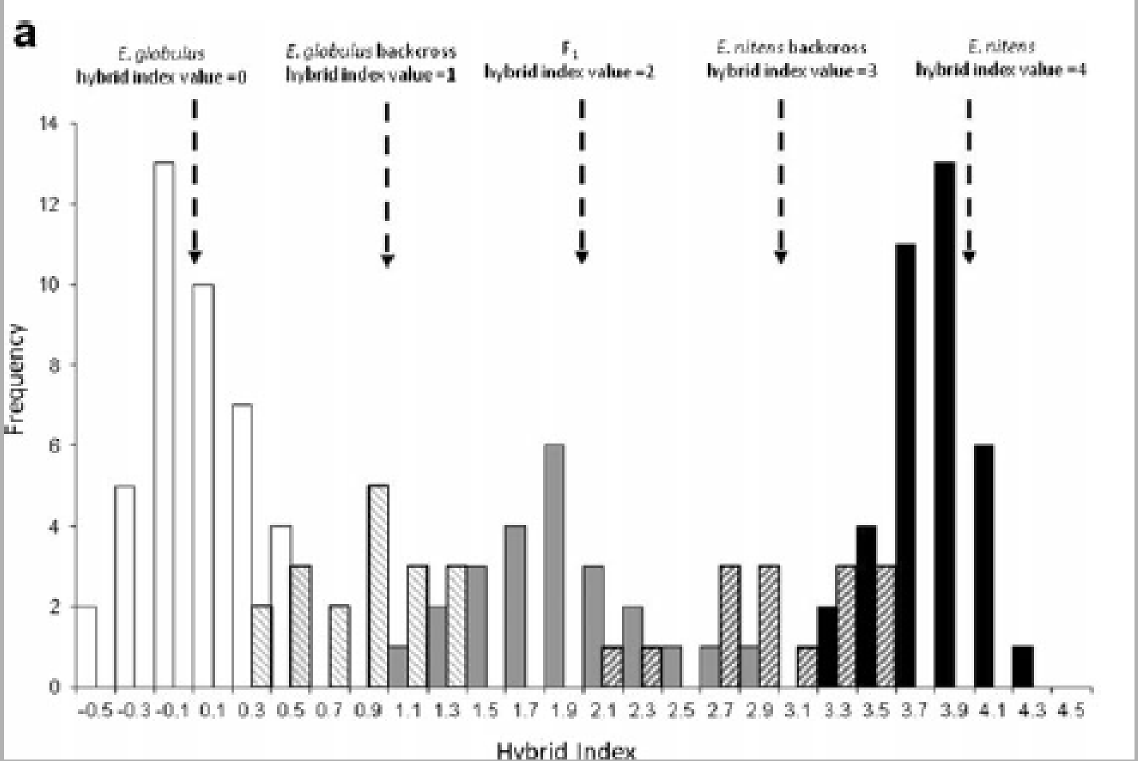


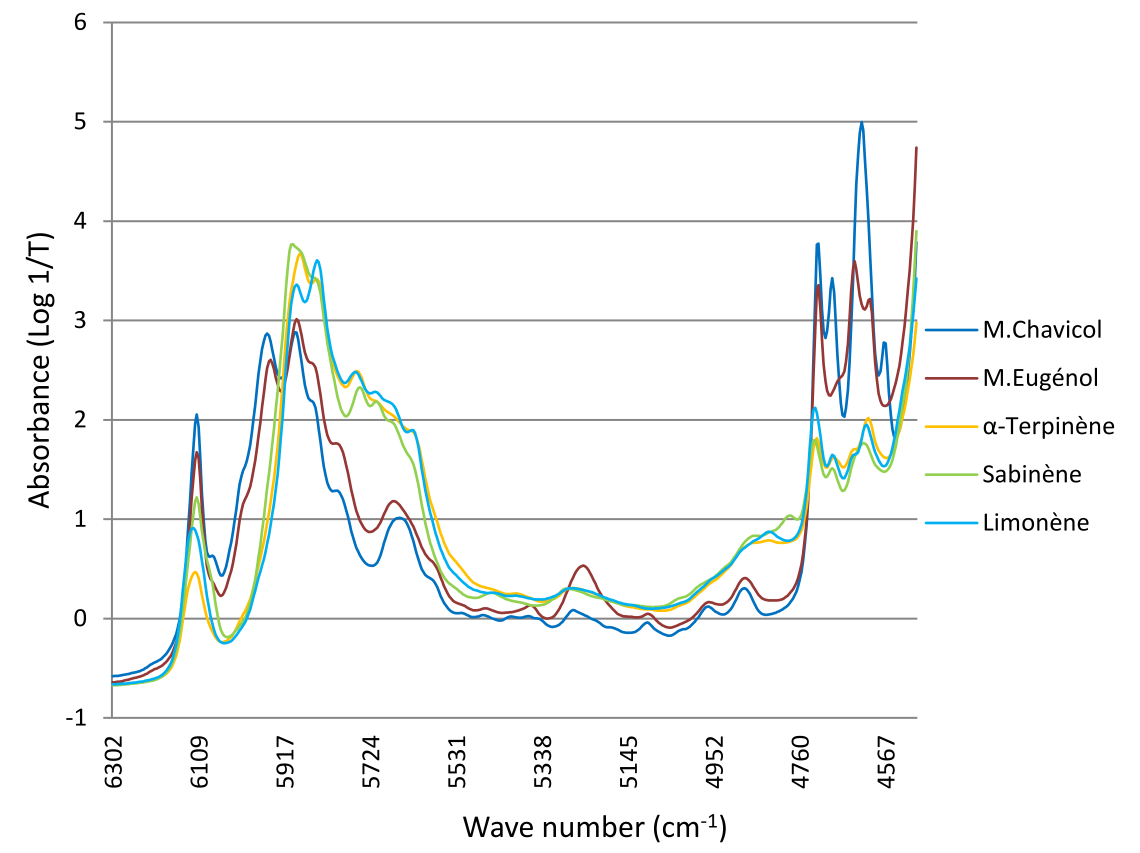
Fig. 4 UPGMA clustering (Mahalanobis distances on the *x*-axis) of 13 sub-races of *E. globulus* summarising the spectral affinities of each sub-race to each other. Discriminant function analyses and UPGMA clustering were based on 20 principal components derived from the NIR spectra. Samples for this analysis were collected from one common garden trial (Salmon River) and included 6–11 families and 17–41 individuals per sub-race



O'Reilly-Wapstra et al. 2013. Genetic analysis of the near-infrared spectral phenome of a global Eucalyptus species. Tree Genetics & Genomes (2013) 9:943–959

NIR spectroscopy for *Ravensara aromatica* essential oil qualities

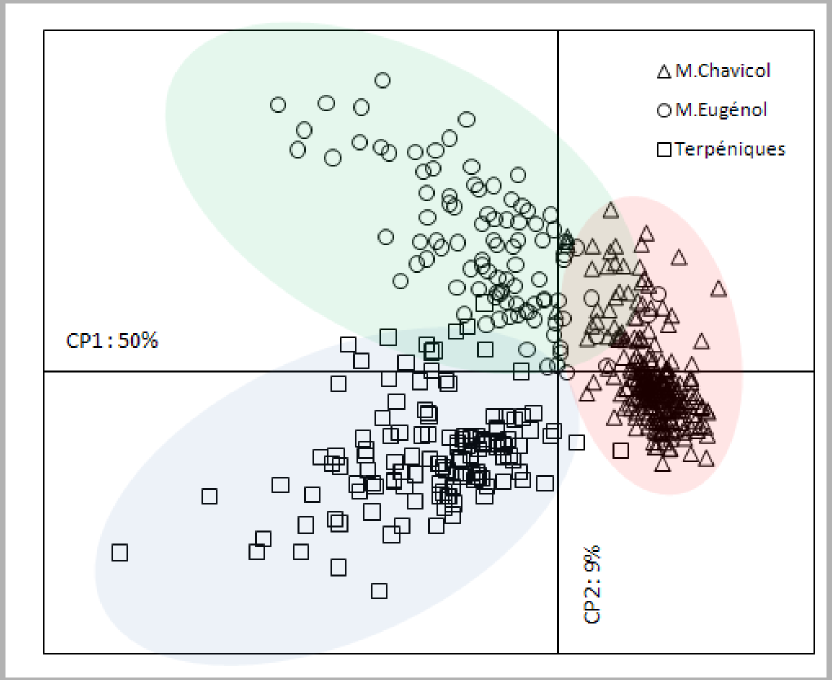
Essential oils extracted from leaves
NIR spectra on grounded leaves and essential oil
5 chemotypes



Hanitra Andrianoelisoa et al. 2013

NIR spectroscopy for *Ravensara aromatica* essential oil qualities

Chemotype identification by HPLC
NIR spectra on **dry leaves**
Methyl chavicol is toxic



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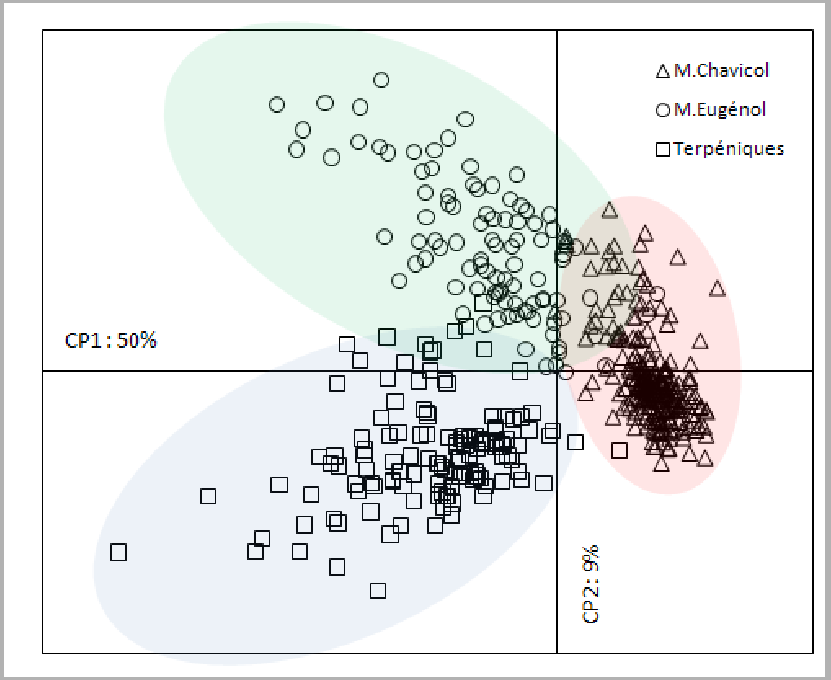


Hanitra Andrianoelisoa et al. 2013

Results of classification by PLS-DA by independent set (55)

		Predicted Groups			
		Methyl Chavicol	Methyl Eugenol	Terpene	Error rate
Determined groups	Methyl chavicol	18	1	0	5 %
	Methyl Eugenol	1	18	0	5 %
	Terpene	-	-	19	0 %

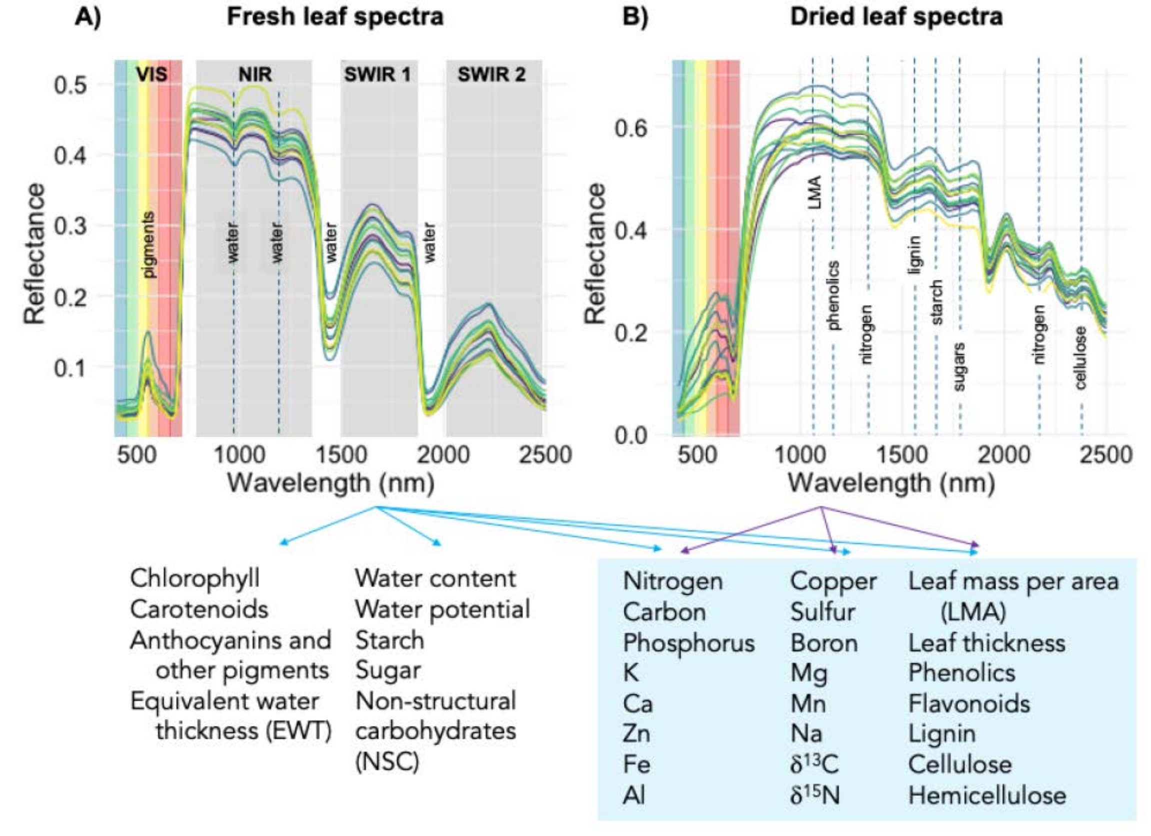
La spectroscopie proche infrarouge et la biodiversité : illustrations pour l'aide à l'identification taxonomique

NextGeneration specimen digitization: The international herbarium community goes spectral!

Cavender-Bares et al. 2025 (under review)

https://doi.org/10.32942/X2V927

In both **fresh and dry leaves**, it may be possible to estimate macronutrients (nitrogen (N), carbon (C), phosphorus (P), potassium (K)) and micronutrients (calcium 220 (Ca), zinc (Zn), iron (Fe), copper (Cu), sulfur (S), boron (B), magnesium (Mg), manganese (Mn), 221 aluminum (Al), sodium (Na)), as well as large stable carbon-based molecules (phenolics, lignin, cellulose or hemicellulose), defense compounds (phenolics, flavonoids) and stable isotopes (∂_{13}C, ∂_{15}N)



Chlorophyll
Carotenoids
Anthocyanins and other pigments
Equivalent water thickness (EWT)

Water content
Water potential
Starch
Sugar
Non-structural carbohydrates (NSC)

Nitrogen
Carbon
Phosphorus
K
Ca
Zn
Fe
Al

Copper
Sulfur
Boron
Mg
Mn
Na
δ^{13}C
δ^{15}N

Leaf mass per area (LMA)
Leaf thickness
Phenolics
Flavonoids
Lignin
Cellulose
Hemicellulose

NextGeneration specimen digitization: The international herbarium community goes spectral!

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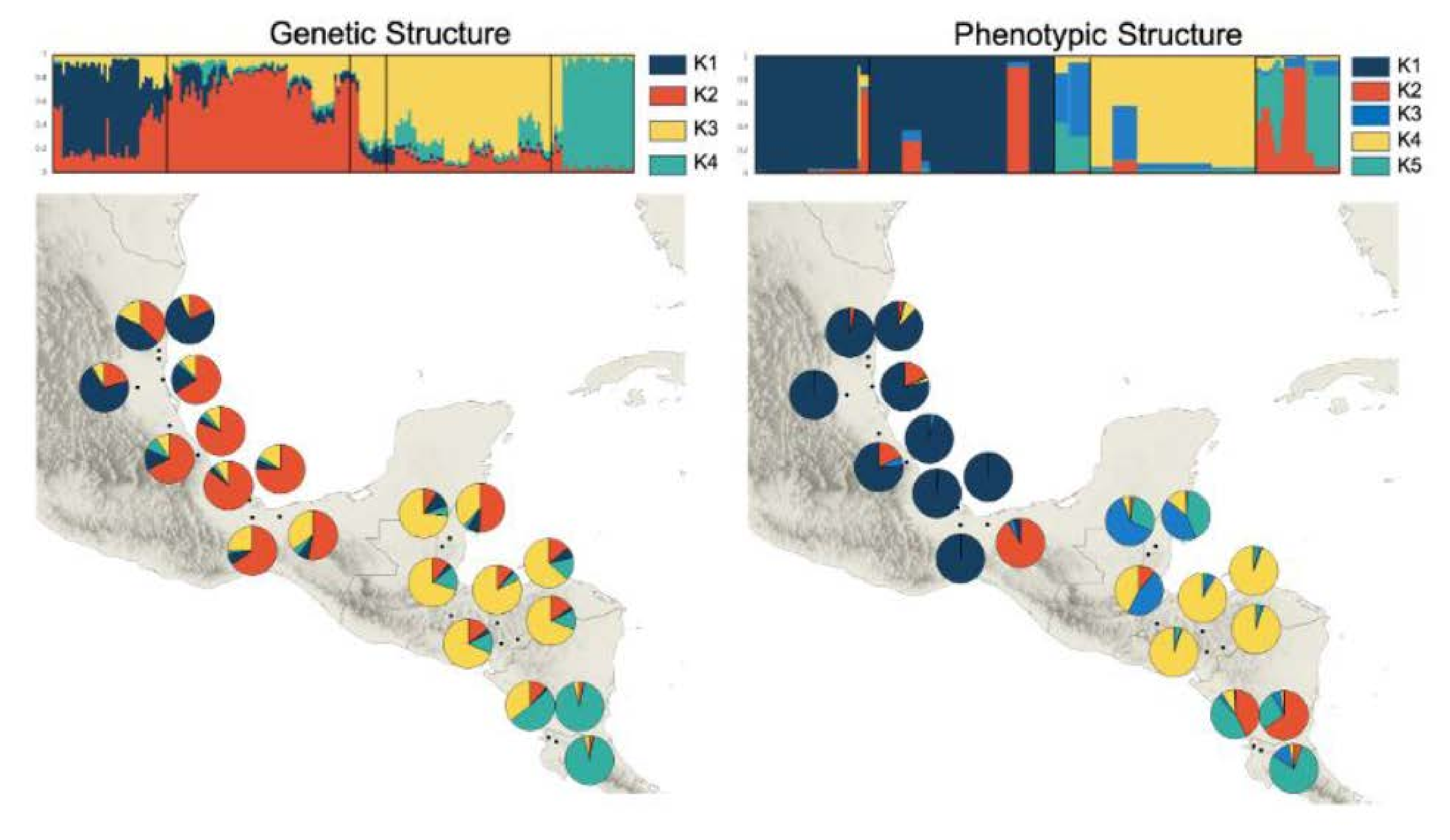
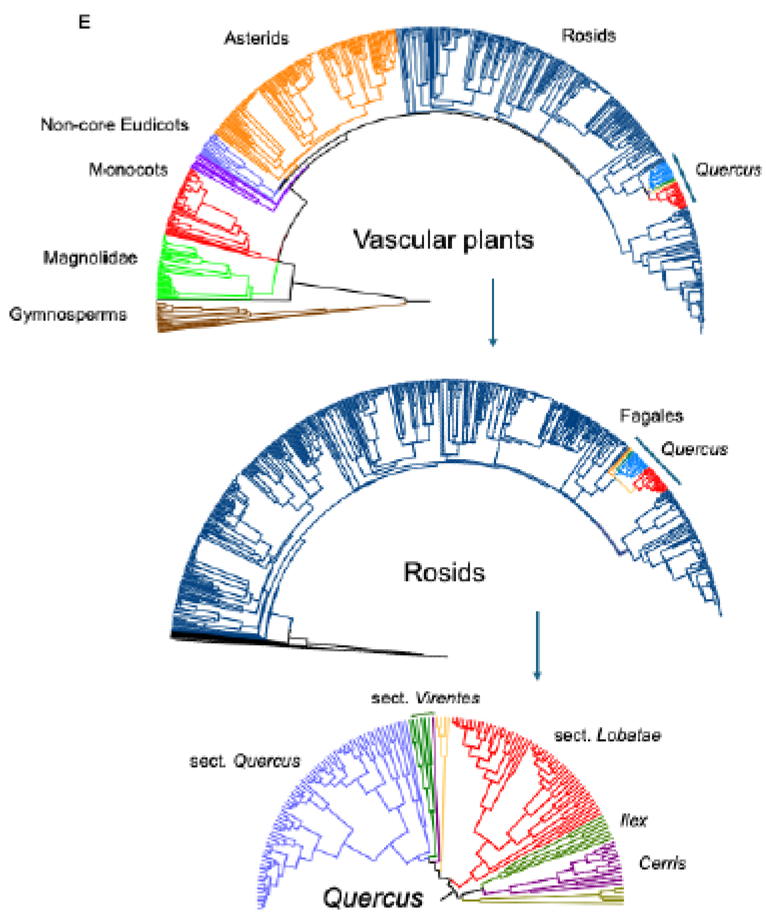


NextGeneration specimen digitization: The international herbarium community goes spectral!

Cavender-Bares et al. 2025 preprint



Stepwise hierarchical approach to taxon classification to place specimens within the plant tree of life.

Classification algorithms, such as partial least squares discriminant analysis (**PLSDA), are limited** by statistical power in the number of entities they can accurately discriminate between.

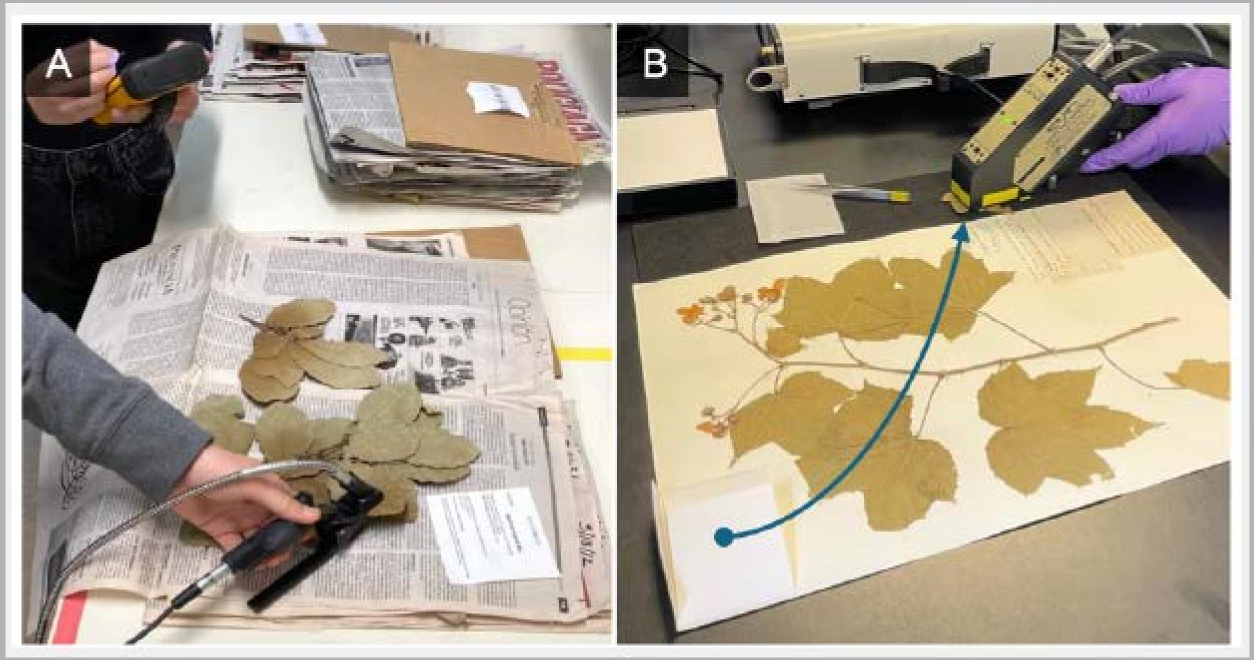
One possible solution is a **nested approach** where spectral signatures are used to **differentiate broad clades** within the vascular plants, and stepwise within increasingly smaller clades, such as orders, families, genera—or increasingly narrow phylogenetic lineages

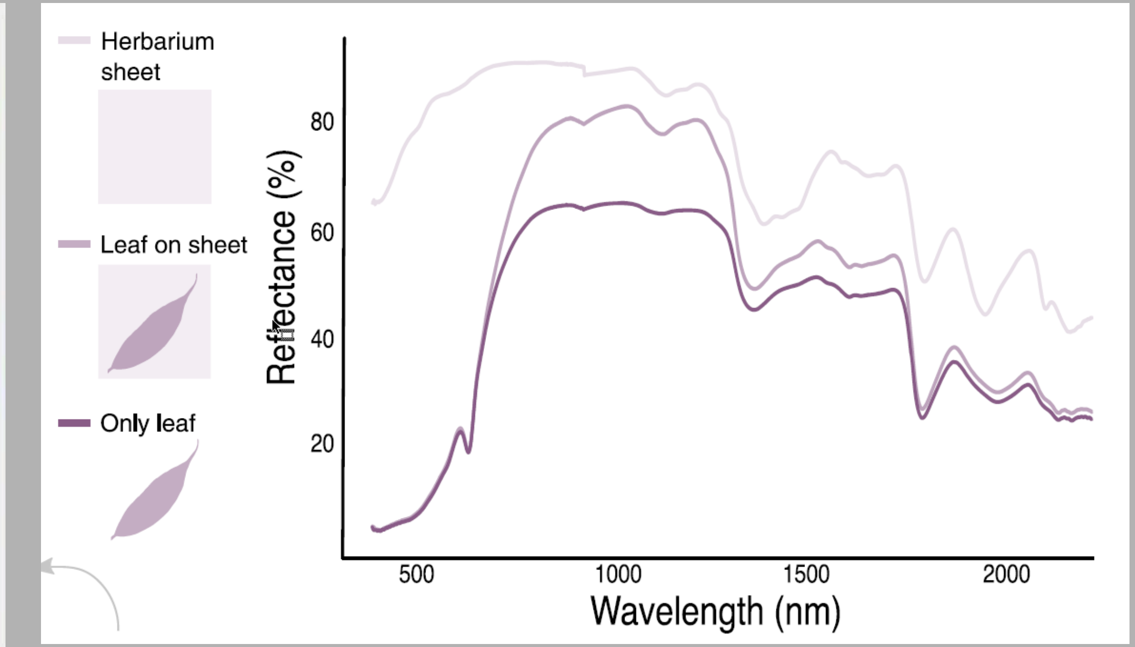
Difficultés pour la mesure NIR

Echantillons collés sur **feuille papier**, en **transmittance**, type de **colle**

Scotchés ou pas

10.1111/nph.70258





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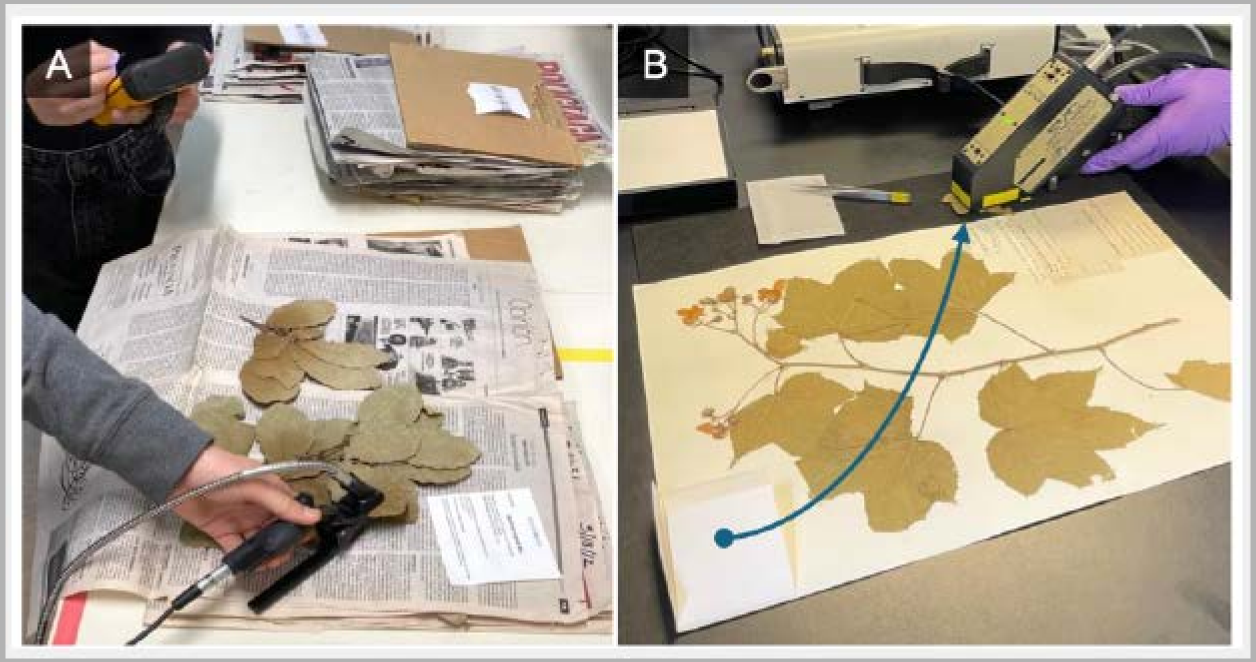
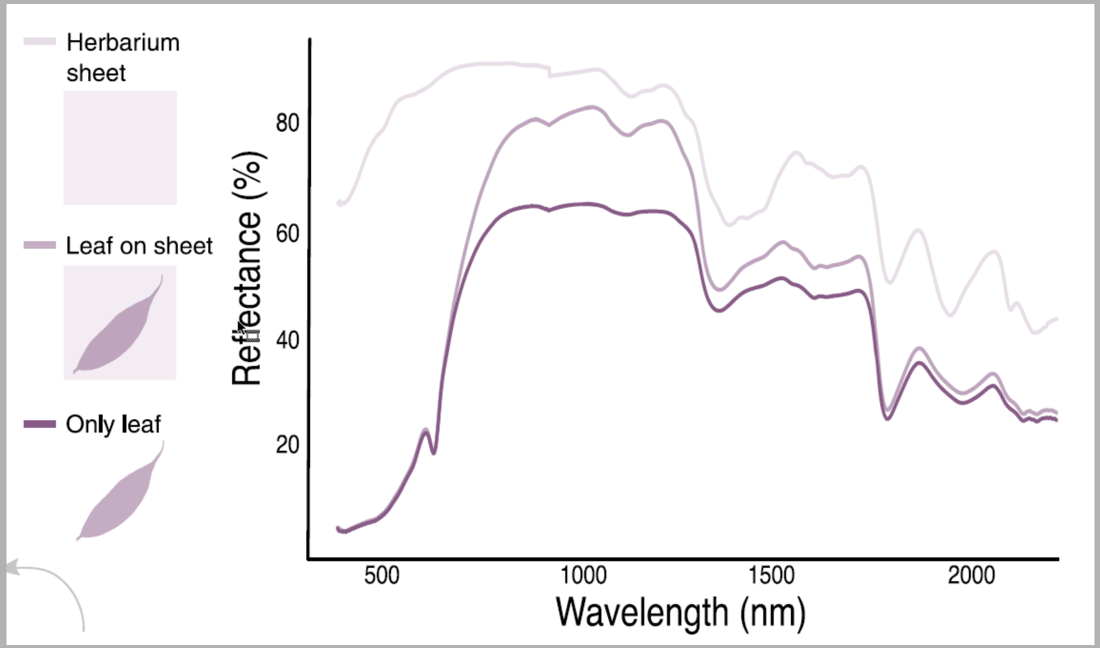




Questionnements :

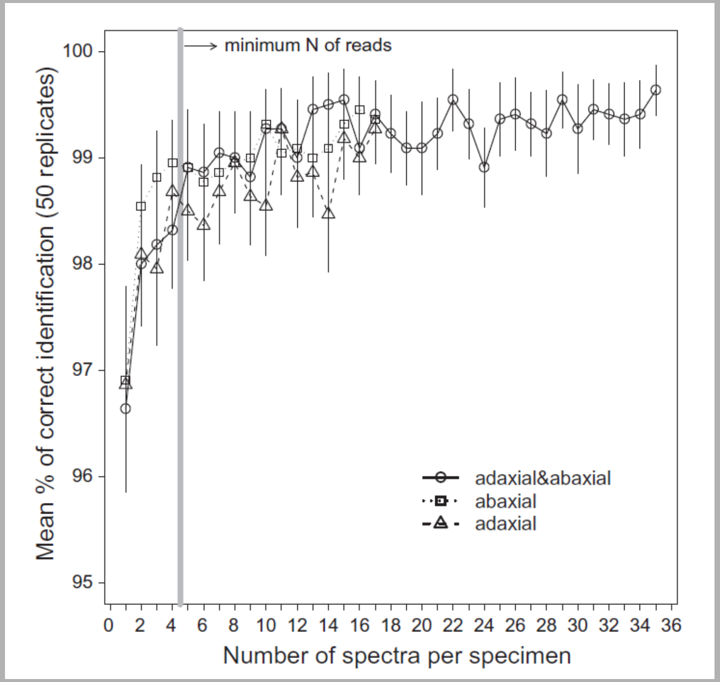
Stade des feuilles à la collecte => jeune, mature, sénescente,
Etat des feuilles => intactes, abimées
Stockage => durée de stockage et conditions
Position dans le houppier (expo soleil/ombre)
Etat de stress

Lang et al. 2015 : We concluded that FT-NIR has a high potential in the identification of species even at **different ontogenetic stage**s, and that **young plants can be identified based on spectra of adults** with **reasonable confidence**.

White et al. 2025 specimen jusqu’à 179 ans

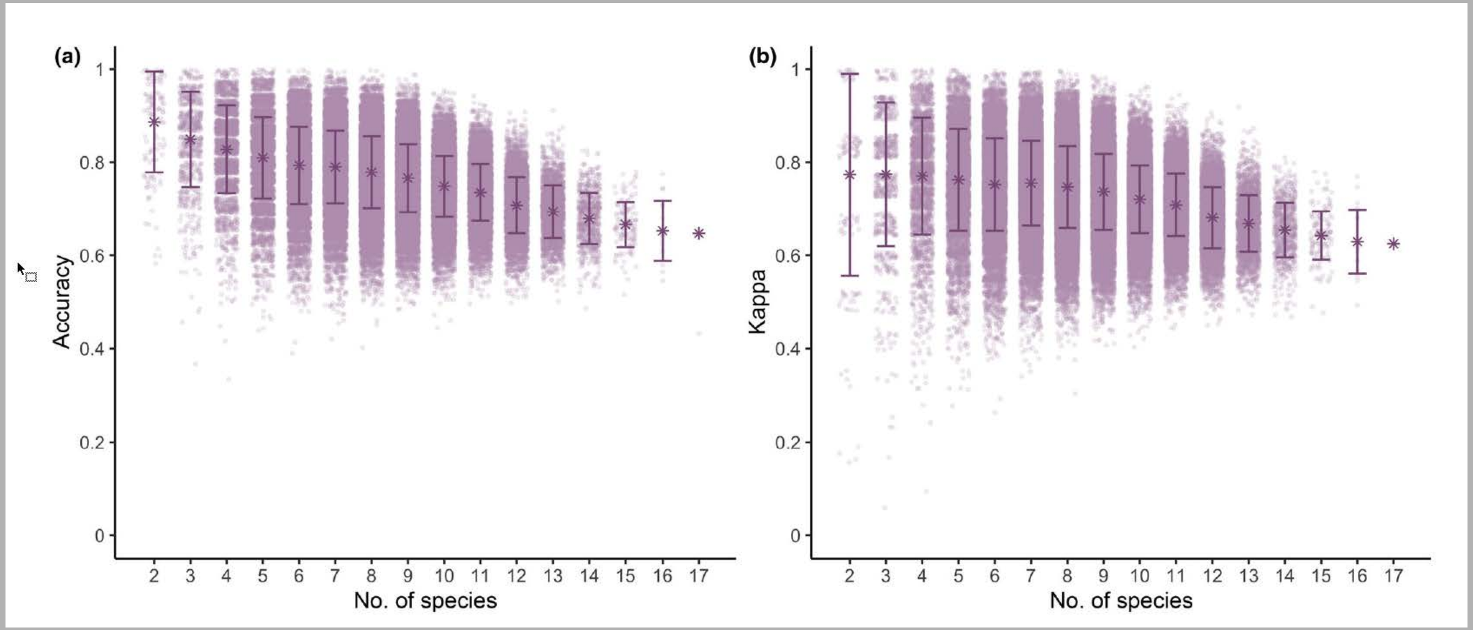
Difficultés pour la mesure NIR

Combien de mesure / échantillon ?



Durgante et al. / Forest Ecology and Management 291 (2013) 240–248

Impact du nombre de classes ?



Plein d’autres questions/contraintes/problèmes

- Etat des feuilles à la collecte => jeune, mature, sénescente, intacte, abimée
- Stockage => durée de stockage et conditions
- Position dans le houppier (expo soleil/ombre)
- Etat de stress des plantes
- Etc.

Pour répondre aux problèmes => on ne reste pas seul·e·s !

Pour répondre aux problèmes => on ne reste pas seul·e·s !

International Herbarium Spectral Digitization (IHerbSpec) Working Group

Date and Time

May 2, 2025

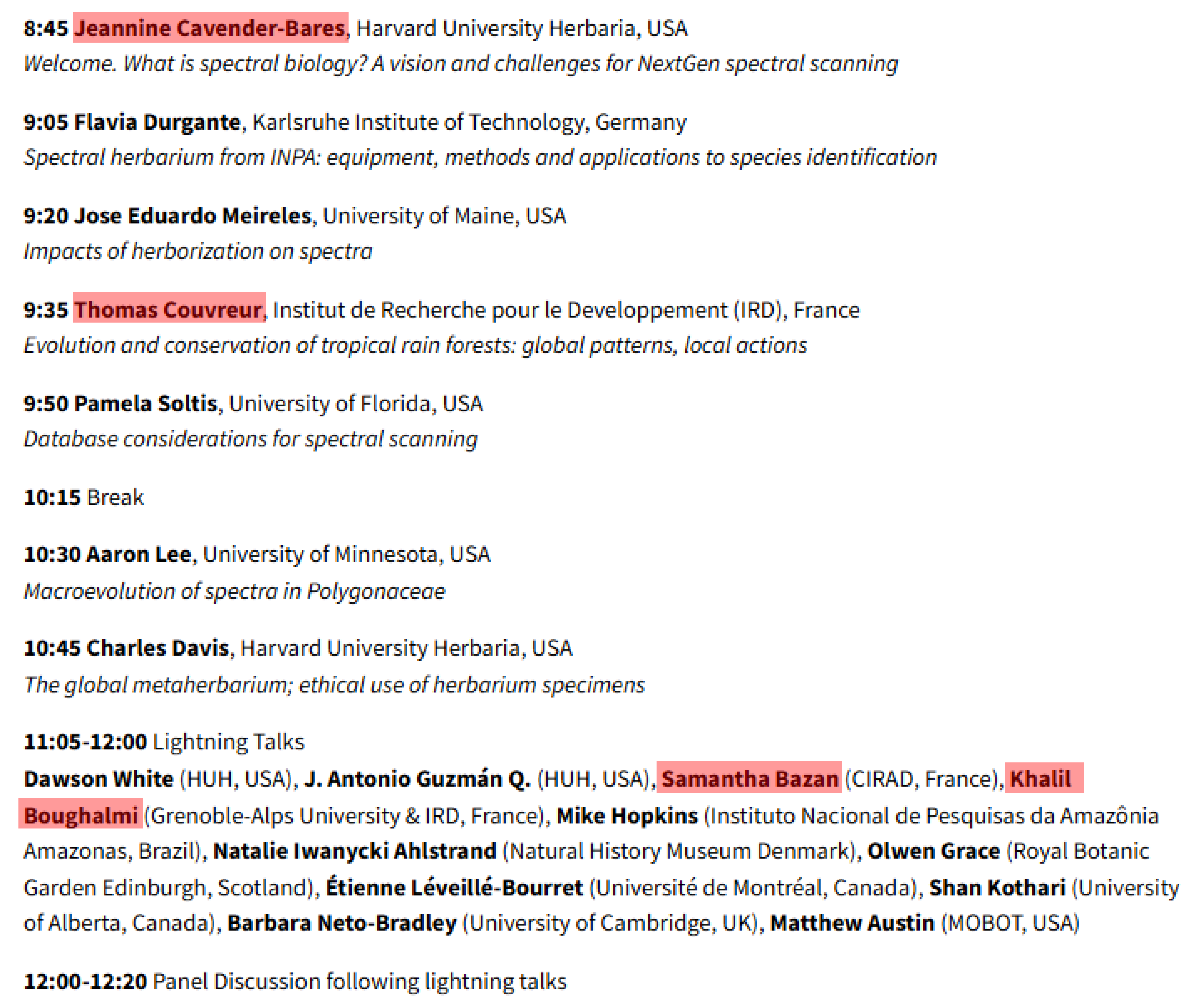
08:45AM - 12:30PM America/New_York

Location

Harvard University Herbaria, Room 125, 22 Divinity Ave.

https://www.youtube.com/live/Zko1-NvlGUE

La spectroscopie proche infrarouge et la biodiversité : illustrations pour l'aide à l'identification taxonomique



8:45 Jeannine Cavender-Bares, Harvard University Herbaria, USA
Welcome. What is spectral biology? A vision and challenges for NextGen spectral scanning

9:05 Flavia Durgante, Karlsruhe Institute of Technology, Germany
Spectral herbarium from INPA: equipment, methods and applications to species identification

9:20 Jose Eduardo Meireles, University of Maine, USA
Impacts of herborization on spectra

9:35 Thomas Couvreur, Institut de Recherche pour le Developpement (IRD), France
Evolution and conservation of tropical rain forests: global patterns, local actions

9:50 Pamela Soltis, University of Florida, USA
Database considerations for spectral scanning

10:15 Break

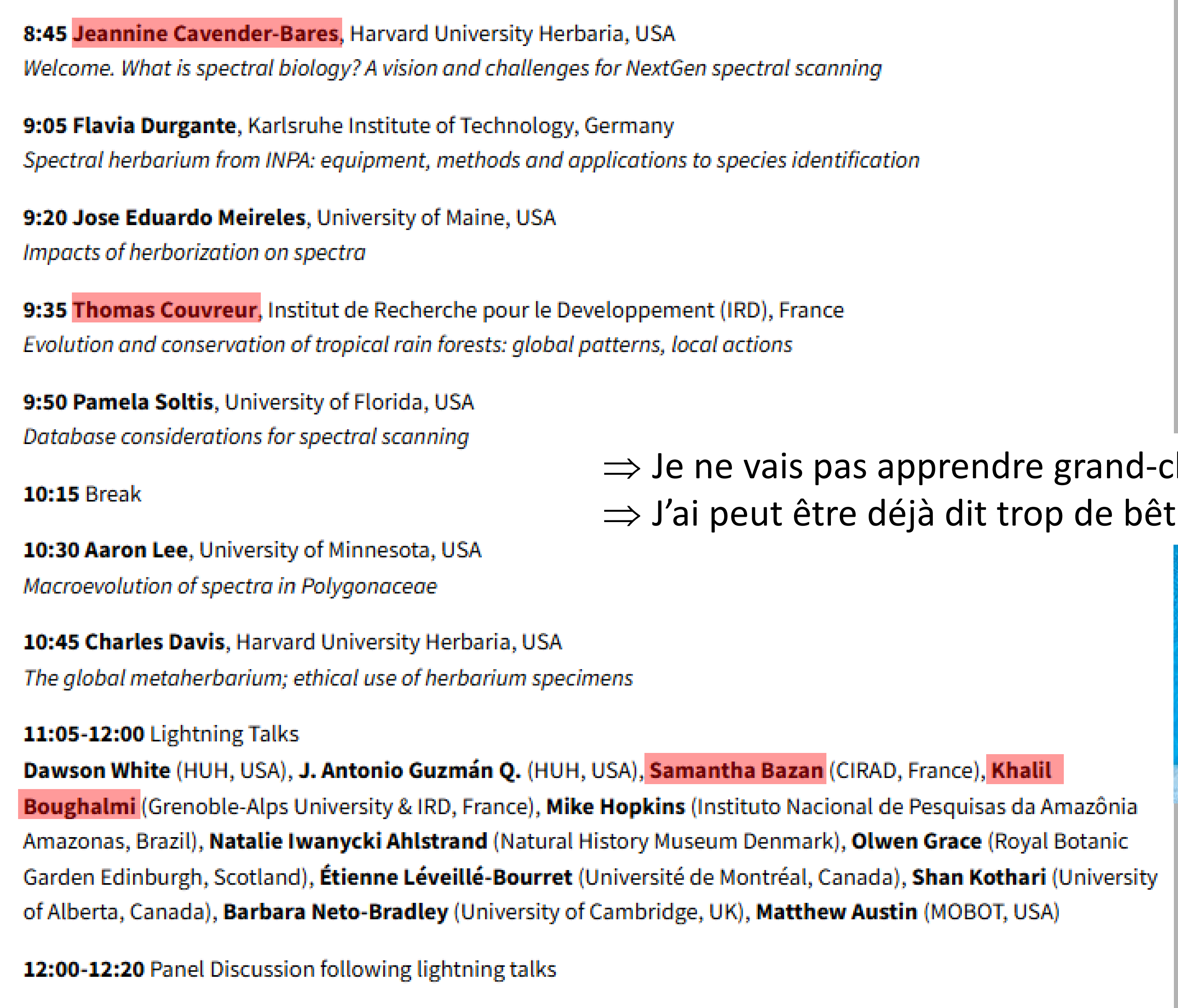
10:30 Aaron Lee, University of Minnesota, USA
Macroevolution of spectra in Polygonaceae

10:45 Charles Davis, Harvard University Herbaria, USA
The global metaherbarium; ethical use of herbarium specimens

11:05-12:00 Lightning Talks
Dawson White (HUH, USA), **J. Antonio Guzmán Q.** (HUH, USA), **Samantha Bazan** (CIRAD, France), **Khalil Boughalmi** (Grenoble-Alps University & IRD, France), **Mike Hopkins** (Instituto Nacional de Pesquisas da Amazônia Amazonas, Brazil), **Natalie Iwanycki Ahlstrand** (Natural History Museum Denmark), **Olwen Grace** (Royal Botanic Garden Edinburgh, Scotland), **Étienne Léveillé-Bourret** (Université de Montréal, Canada), **Shan Kothari** (University of Alberta, Canada), **Barbara Neto-Bradley** (University of Cambridge, UK), **Matthew Austin** (MOBOT, USA)

12:00-12:20 Panel Discussion following lightning talks

La spectroscopie proche infrarouge et la biodiversité : illustrations pour l'aide à l'identification taxonomique



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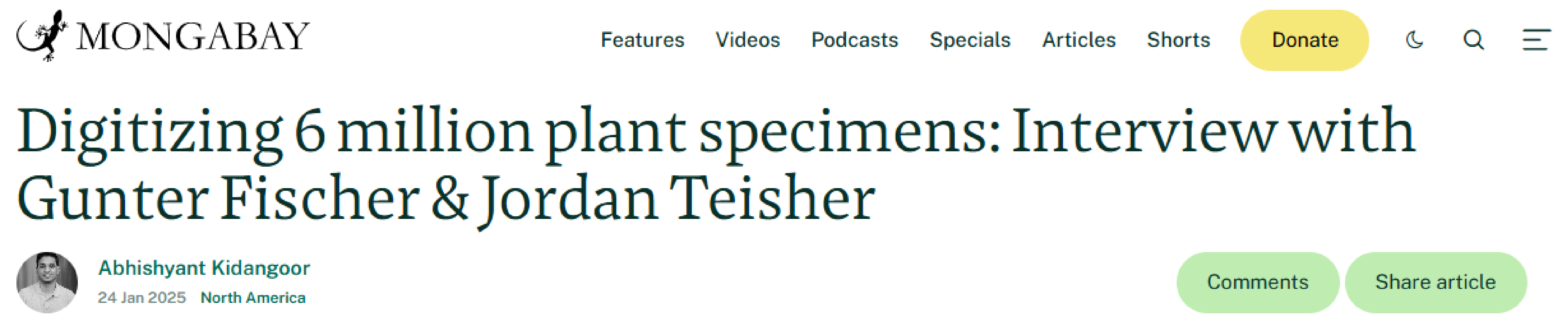
⇒ Je ne vais pas apprendre grand-chose à certain·e·s
⇒ J'ai peut être déjà dit trop de bêtises, et je vais continuer



Digitizing 6 million plant specimens: Interview with Gunter Fischer & Jordan Teisher

Abhishyant Kidangoor
24 Jan 2025 · North America

- *Researchers at Missouri Botanical Garden in the U.S. have launched an initiative to create a digital repository of the 6 million plant specimens stored in the herbarium there.*
- *The six-year Revolutionizing Species Identification initiative aims to combine data obtained from visual and hyperspectral scanning with artificial intelligence to build up a plant repository unlike any before.*

We’re going to be hiring a team of **10 herbarium digitization assistants**, and one of their roles will be reviewing all the transcriptions and making sure that all of that information is accurate.

https://news.mongabay.com/2025/01/digitizing-6-million-plant-specimens-interview-with-gunter-fischer-jordan-teisher/

Questionnements

En plus de ce que j’ai énoncé tout à l’heure
Nombreuses publications de 2025 en évaluation => compétitions ?
Méthode de classification => PLS-DA, LDA, LMA, … et IA
Prétraitement des données spectrales
Sélection de variable (robustesse modèles)

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Résultats sur des validations croisées
Sur de la LOO
« On utilise la LDA parce que ça marche mieux que la PLS-DA »

La spectroscopie proche infrarouge et la biodiversité : illustrations pour l'aide à l'identification taxonomique

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Sur de la LOO
« On utilise la LDA parce que ça marche mieux que la PLS-DA »

Problème d'effectifs ?

Mufusama Koy Sita et al (under review)

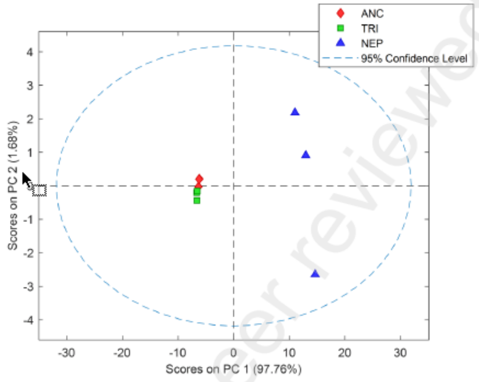
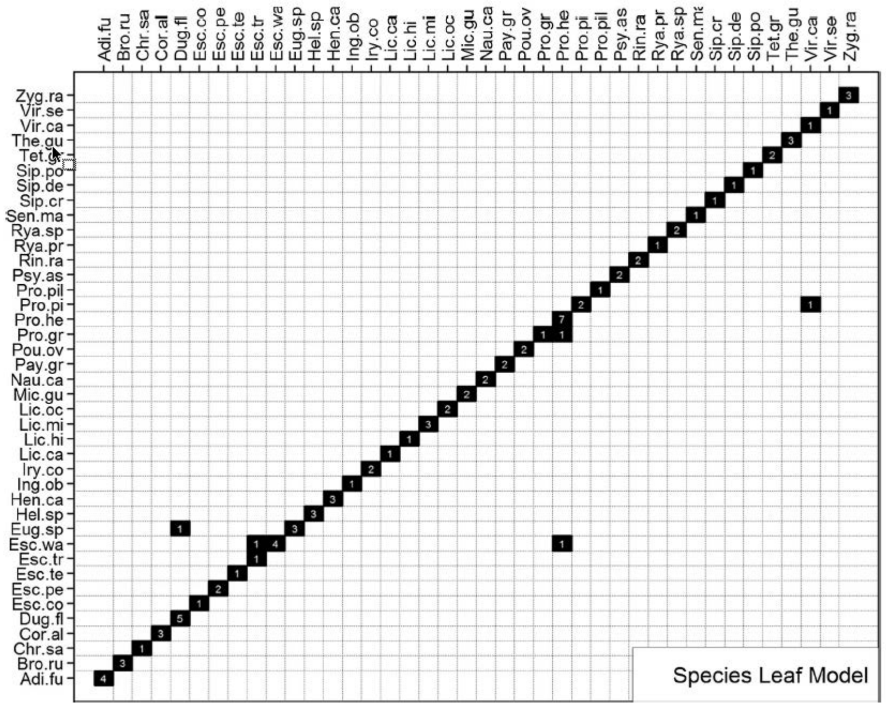


Figure 6. PCA score plots of NIR-A reflection spectra of pure raw materials in the space defined by the first and two principal components; visualization of PCA-2D.

C. Lang et al.

Forest Ecology and Management 406 (201



Rapport de mission

cirad
LA RECHERCHE AGRONOMIQUE
POUR LE DÉVELOPPEMENT

Rapport de Mission

International Herbarium Spectral Scanning (IHerbSpec) Working Group

Harvard University

Boston, 29 avril au 5 mai 2025

Samantha Bazan, Cirad-SELMET- Montpellier

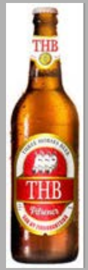
Les prochaines étapes seront :

- poursuite du groupe de travail à travers les réunions régulières
- plusieurs publications communes dont le « Herbarium Reflectance Spectroscopy Base Protocol »
- standardisation des protocoles de prise de spectre et de métadonnées
- partage de données et d'expériences avec plusieurs équipes très avancées

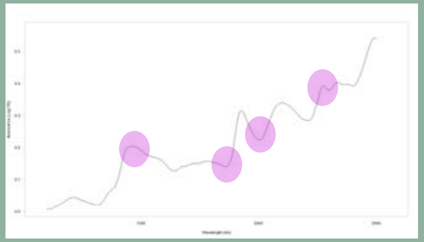
…

Pas de mention / Chimiométrie ? Méthodes et traitements de la donnée ?

Que les communautés se rejoignent
HelioSPIR, ChemHouse x herbiers


THB
THB
Pilsener

Perspectives and message



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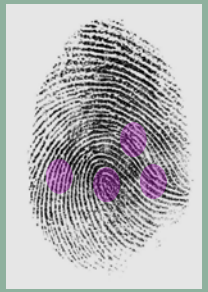
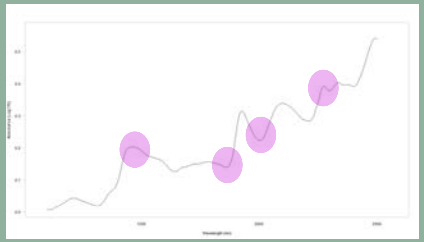


1- NIR spectra = chemical fingerprinting

Could be use to:

- -Trait evaluation (quantitative trait)
- -Discrimination (qualitative trait)

Perspectives and message



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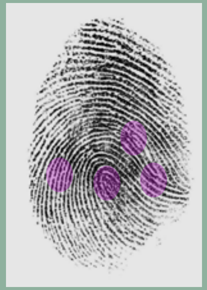

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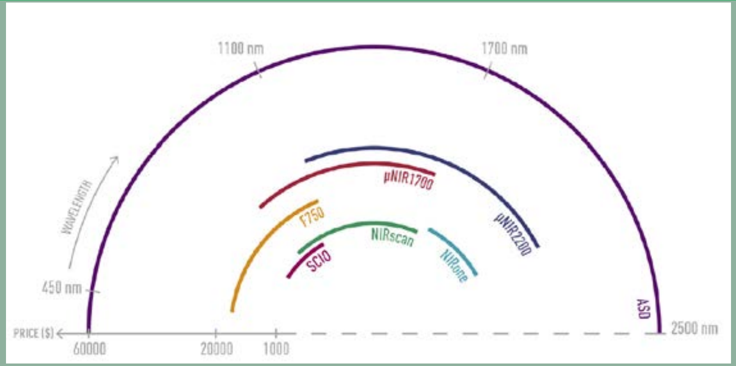
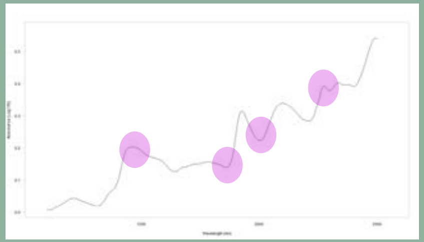


2- Adequate equipment

- -Lab, portable, low-cost, rugged, …
- -Spectral range

Perspectives and message



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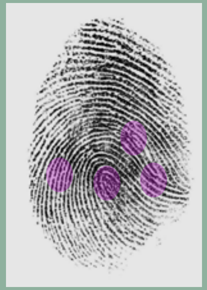

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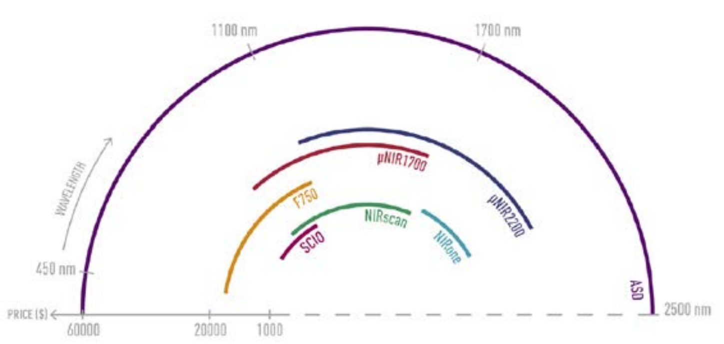

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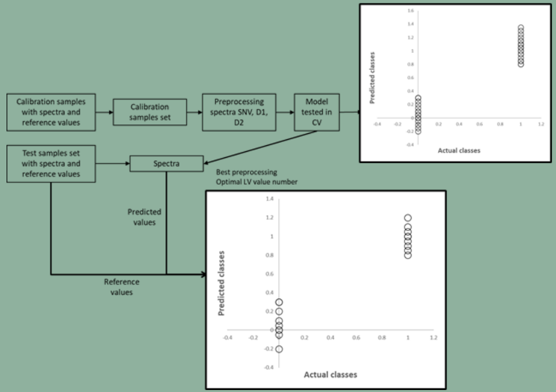


Calibration samples with spectra and reference values

Calibration samples set

Preprocessing spectra SNV, D1, D2

Model tested in CV

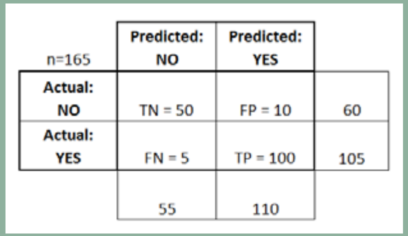
Test samples set with spectra and reference values

Spectra

Best preprocessing
Optimal LV value number

Predicted values

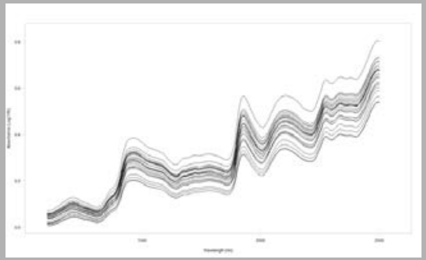
Reference values



n=165	Predicted: NO	Predicted: YES	
Actual: NO	TN = 50	FP = 10	60
Actual: YES	FN = 5	TP = 100	105
	55	110	

3- Calibration and validation processes

- Building human capacity in methodology and chemometrics

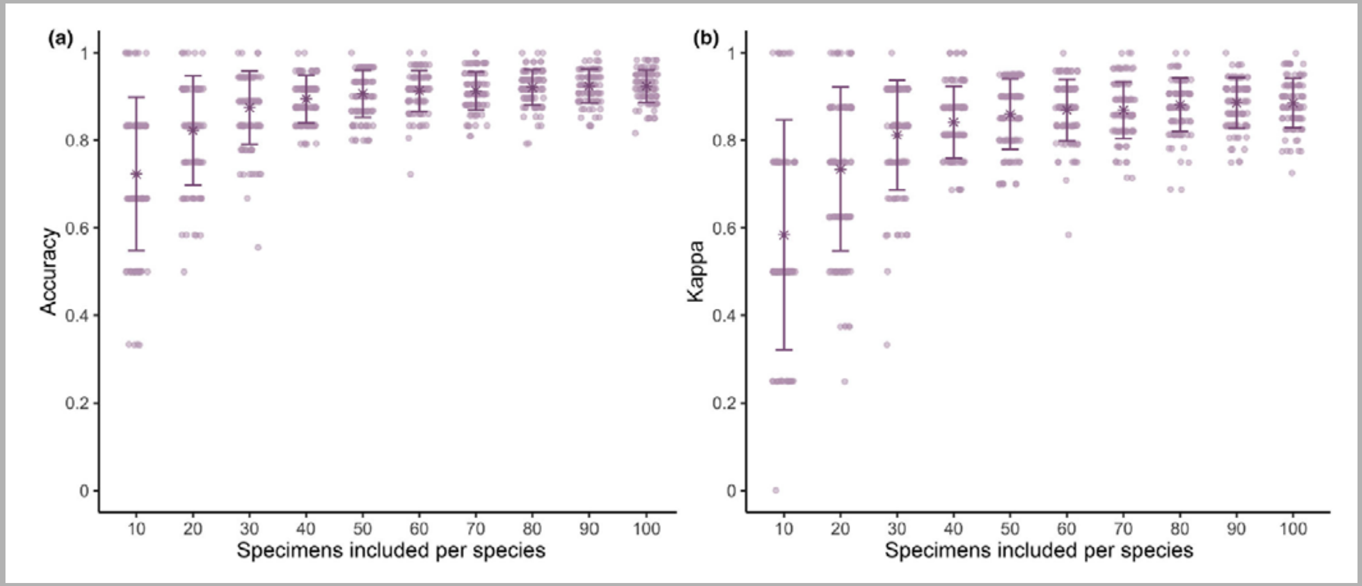


Merci pour votre attention !!!!!

Place aux spécialistes !!!!!

Using reflectance spectra and Pl@ntNet to identify herbarium specimens: a case study with Lithocarpus

10.1111/nph.70258

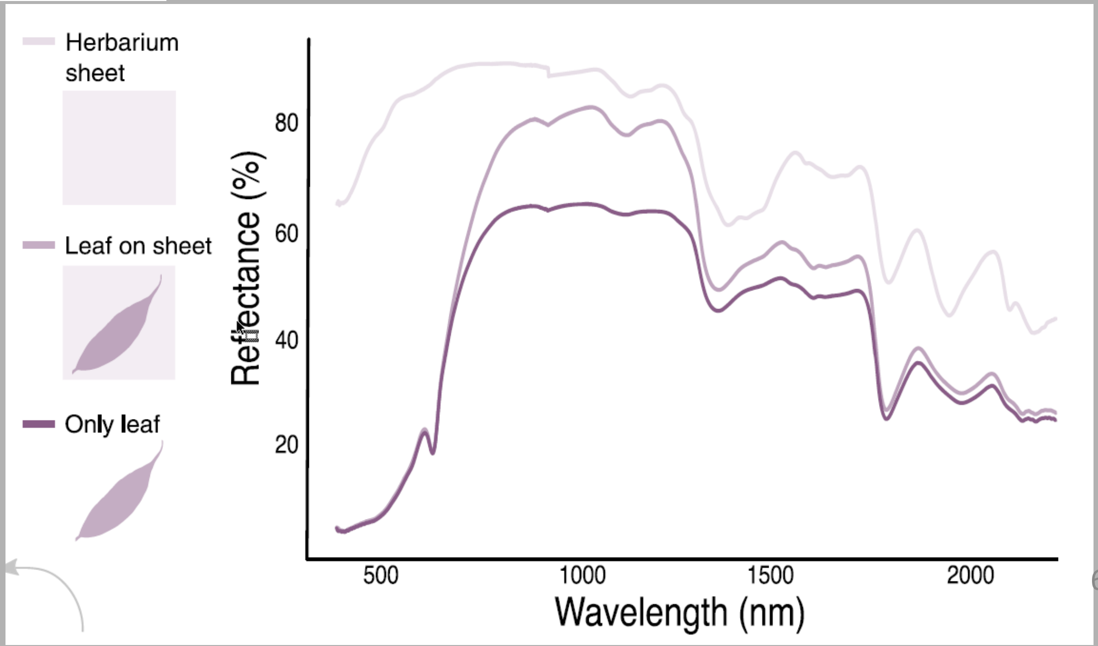


Linear discriminant analysis is an established method used for spectral classification of plant species, from remote sensing to point measurements.

Partial least squares discriminant analysis is another common method for analysing spectral data; however, in preliminary tests, we found LDA to provide higher classification accuracy for these species with smaller training datasets

Depiction of the linear discriminant analysis (LDA) model's accuracy (a) and kappa (b), for discriminating between three species (*Lithocarpus nieuwenhuisii*, *gracilis* and *leptogyne*), across an increasing availability of specimens spectral reflectance data for model construction.

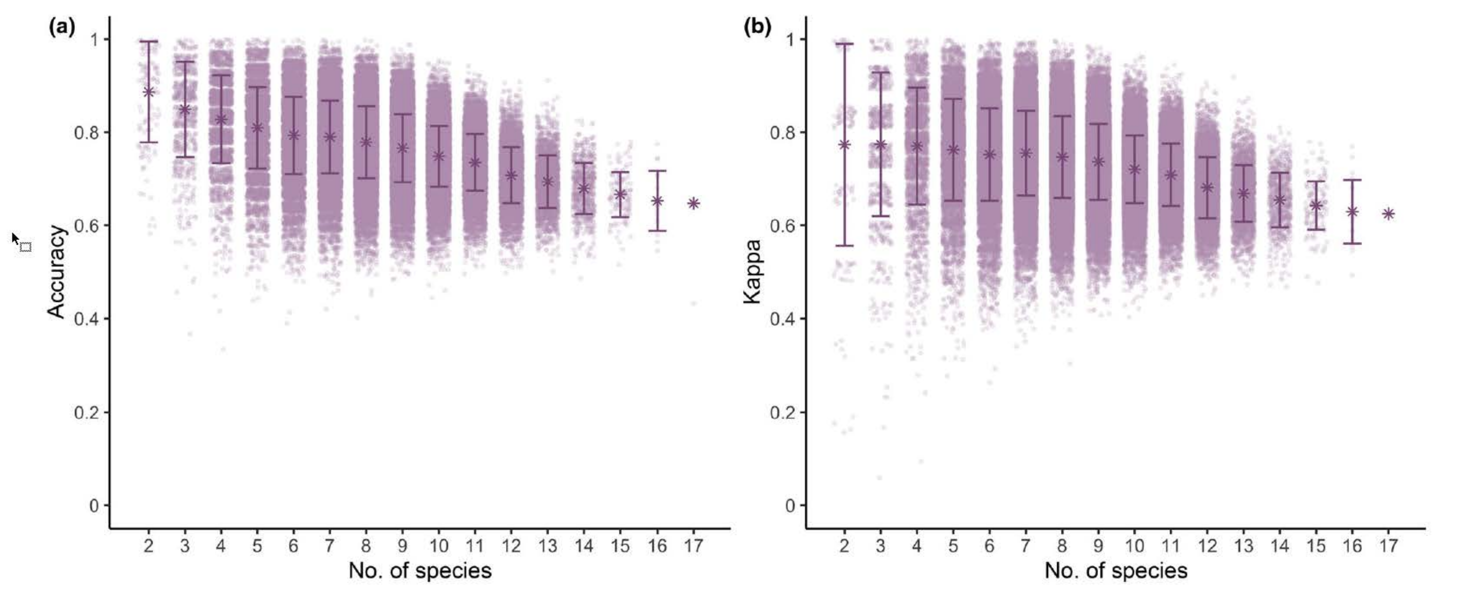
At each level, 80% of the data were used to train an LDA and the remaining 20% were used for validation.



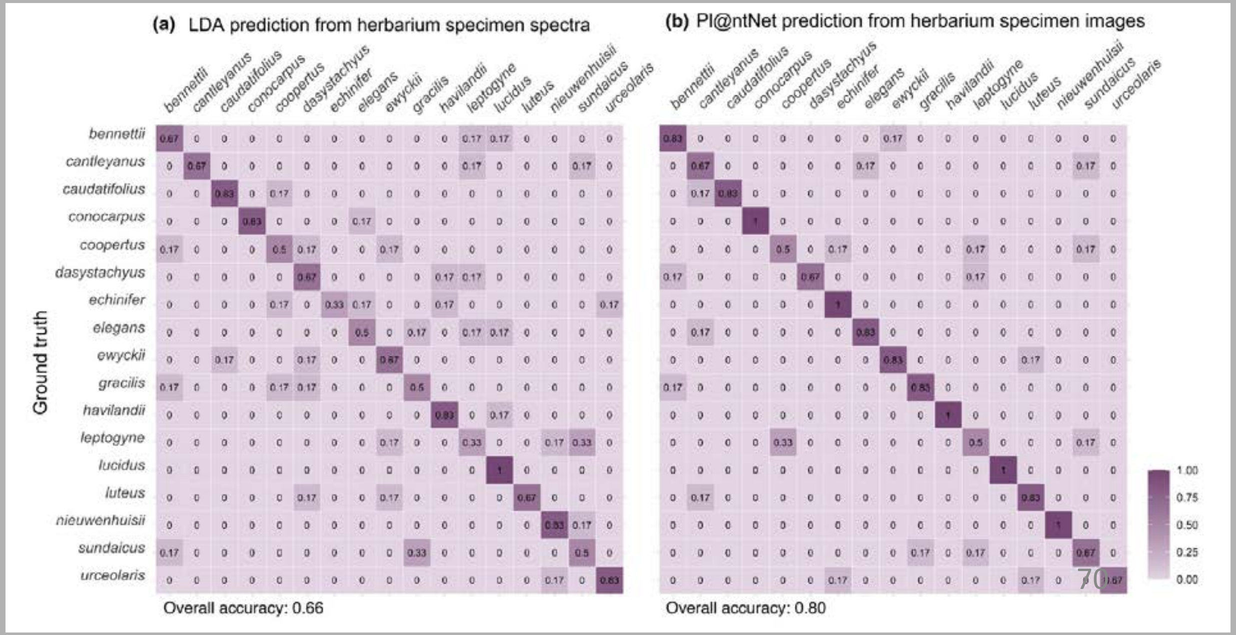
La spectroscopie proche infrarouge et la biodiversité : illustrations pour l'aide à l'identification taxonomique

Depiction of the linear discriminant analysis (LDA)'s accuracy (a) and kappa (b) for discriminating between an increasing number of species, using 30 specimens reflectance spectra per species.

To help capture the variability in model performance, for each number of taxa, all possible combinations within the full set of 17 species were considered.



Confusion matrices for two methods of classifying 17 species of Lithocarpus, using the same set of herbarium specimens to train and validate both models. (a) Confusion matrix for a linear discriminant analysis (LDA) trained on spectral reflectance data from the leaves of herbarium specimens. (b) Confusion matrix for a vision transformer (ViT), implemented through Pl@ntNet, trained on whole images of each herbarium specimen.



(a) LDA prediction from herbarium specimen spectra

	bennettii	*cantleyanus*	*caudatifolius*	*conocarpus*	*coopertus*	*dasystachyus*	*echinifer*	*elegans*	*ewyckii*	*gracilis*	*havilandii*	*leptogyne*	*lucidus*	*luteus*	*nieuwenhuisii*	*sundaicus*	*urceolaris*
bennettii	0.67	0	0	0	0	0	0	0	0	0	0	0.17	0.17	0	0	0	0
cantleyanus	0	0.67	0	0	0	0	0	0	0	0	0	0.17	0	0	0	0.17	0
caudatifolius	0	0	0.83	0	0.17	0	0	0	0	0	0	0	0	0	0	0	0
conocarpus	0	0	0	0.83	0	0	0	0.17	0	0	0	0	0	0	0	0	0
coopertus	0.17	0	0	0	0.5	0.17	0	0	0.17	0	0	0	0	0	0	0	0
dasystachyus	0	0	0	0	0	0.67	0	0	0	0	0.17	0.17	0	0	0	0	0
echinifer	0	0	0	0	0.17	0	0.33	0.17	0	0	0.17	0	0	0	0	0	0.17
elegans	0	0	0	0	0	0	0	0.5	0	0.17	0	0.17	0.17	0	0	0	0
ewyckii	0	0	0.17	0	0	0.17	0	0	0.67	0	0	0	0	0	0	0	0
gracilis	0.17	0	0	0	0.17	0.17	0	0	0	0.5	0	0	0	0	0	0	0
havilandii	0	0	0	0	0	0	0	0	0	0	0.83	0	0.17	0	0	0	0
leptogyne	0	0	0	0	0	0	0	0	0.17	0	0	0.33	0	0	0.17	0.33	0
lucidus	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
luteus	0	0	0	0	0	0.17	0	0	0.17	0	0	0	0	0.67	0	0	0
nieuwenhuisii	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.83	0.17	0
sundaicus	0.17	0	0	0	0	0	0	0	0	0.33	0	0	0	0	0	0.5	0
urceolaris	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.17	0	0.83

Overall accuracy: 0.66

(b) Pl@ntNet prediction from herbarium specimen images

	bennettii	*cantleyanus*	*caudatifolius*	*conocarpus*	*coopertus*	*dasystachyus*	*echinifer*	*elegans*	*ewyckii*	*gracilis*	*havilandii*	*leptogyne*	*lucidus*	*luteus*	*nieuwenhuisii*	*sundaicus*	*urceolaris*
bennettii	0.83	0	0	0	0	0	0	0	0.17	0	0	0	0	0	0	0	0
cantleyanus	0	0.67	0	0	0	0	0	0.17	0	0	0	0	0	0	0	0.17	0
caudatifolius	0	0.17	0.83	0	0	0	0	0	0	0	0	0	0	0	0	0	0
conocarpus	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
coopertus	0	0	0	0	0.5	0	0.17	0	0	0	0	0.17	0	0	0	0.17	0
dasystachyus	0.17	0	0	0	0	0.67	0	0	0	0	0	0.17	0	0	0	0	0
echinifer	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
elegans	0	0.17	0	0	0	0	0	0.83	0	0	0	0	0	0	0	0	0
ewyckii	0	0	0	0	0	0	0	0	0.83	0	0	0	0	0.17	0	0	0
gracilis	0.17	0	0	0	0	0	0	0	0	0.83	0	0	0	0	0	0	0
havilandii	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
leptogyne	0	0	0	0	0.33	0	0	0	0	0	0	0.5	0	0	0	0.17	0
lucidus	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
luteus	0	0.17	0	0	0	0	0	0	0	0	0	0	0	0.83	0	0	0
nieuwenhuisii	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
sundaicus	0	0	0	0	0	0	0	0	0	0.17	0	0.17	0	0	0	0.67	0
urceolaris	0	0	0	0	0	0	0.17	0	0	0	0	0	0	0.17	0	0	0.67

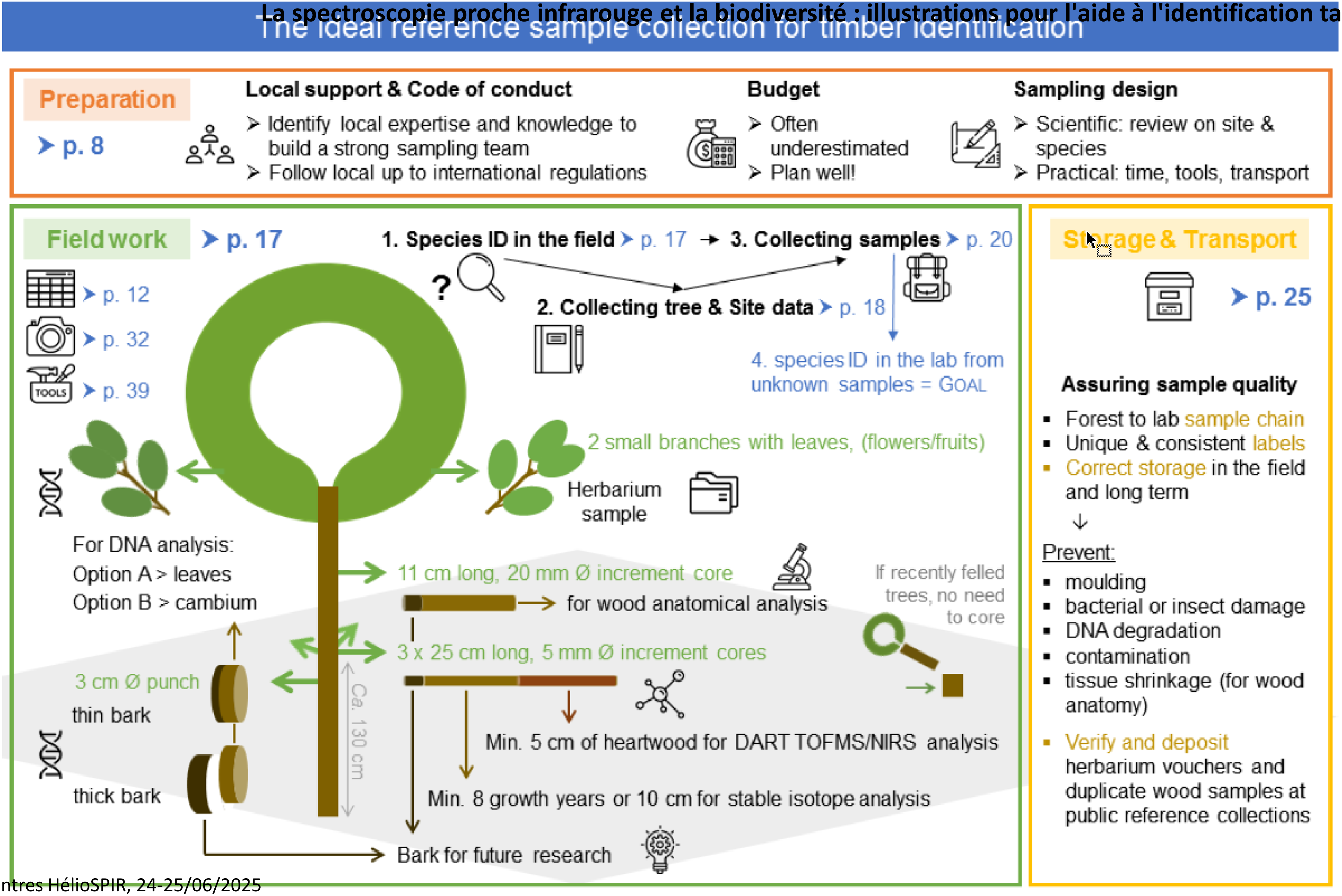
Overall accuracy: 0.80

White et al. 2025 (under review) Seeing herbaria in a new light: leaf reflectance spectroscopy unlocks trait and classification modeling in plant biodiversity collections

Reflectance spectroscopy applied to herbarium collections offers a transformative method to generate phenomic data across the plant tree of life. Despite specimen preservation challenges, we demonstrate spectra from herbarium specimens can reliably predict traits and distinguish species across specimens up to 179 years old. These findings justify the integration of spectral data into the Global Metaherbarium.

Questionnements

Nombreuses publications de 2025 en évaluation ?
Méthode de classification => PLS-DA, LDA, LMA, … et IA
Prétraitement des données spectrales
Sélection de variable (robustesse modèles)



The ideal reference sample collection for timber identification

Preparation

➤ p. 8

Local support & Code of conduct

- ➤ Identify local expertise and knowledge to build a strong sampling team
- ➤ Follow local up to international regulations

Budget

- ➤ Often underestimated
- ➤ Plan well!

Sampling design

- ➤ Scientific: review on site & species
- ➤ Practical: time, tools, transport

Field work

➤ p. 17

➤ p. 12

➤ p. 32

➤ p. 39

1. Species ID in the field ➤ p. 17 → 3. Collecting samples ➤ p. 20

2. Collecting tree & Site data ➤ p. 18

4. species ID in the lab from unknown samples = GOAL

2 small branches with leaves, (flowers/fruits)

Herbarium sample

For DNA analysis:
Option A > leaves
Option B > cambium

11 cm long, 20 mm Ø increment core

for wood anatomical analysis

If recently felled trees, no need to core

3 x 25 cm long, 5 mm Ø increment cores

3 cm Ø punch

thin bark

thick bark

Ca. 130 cm

Min. 5 cm of heartwood for DART TOFMS/NIRS analysis

Min. 8 growth years or 10 cm for stable isotope analysis

Bark for future research

Storage & Transport

➤ p. 25

Assuring sample quality

- Forest to lab sample chain
- Unique & consistent labels
- Correct storage in the field and long term

↓

Prevent:

- moulding
- bacterial or insect damage
- DNA degradation
- contamination
- tissue shrinkage (for wood anatomy)

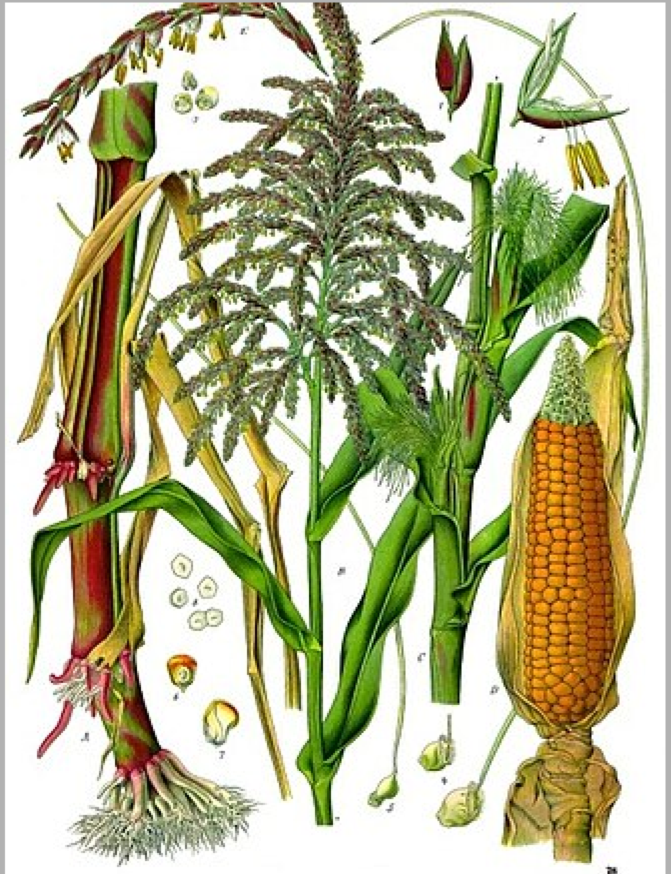
- Verify and deposit herbarium vouchers and duplicate wood samples at public reference collections

LES SPÉCIMENS "TYPE" ET LE RÔLE DES COLLECTIONS NATURALISTES

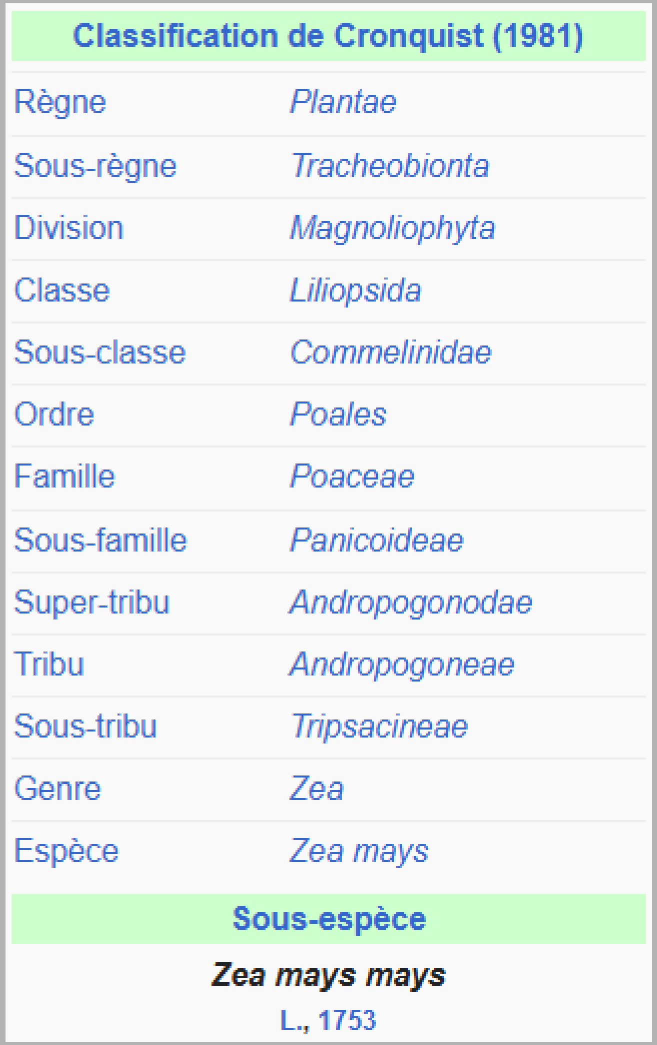
Un **spécimen "type"** est un spécimen sélectionné qui sert de **point de référence** lorsqu'une espèce, animale ou végétale, est **décrite** et **nommée** pour la première fois. conserver ces spécimens de référence qui permettent d'avoir un outil de connaissance stable (Muséum national d'Histoire naturelle)

Un spécimen est un matériel de référence : une plante réelle (ou une ou plusieurs parties d'une plante ou un ensemble de petites plantes), morte et conservée dans un herbier (ou son équivalent pour les champignons : carpophore/sporophore sec ou conservé dans un milieu idoine, une culture mycélienne etc..).

⇒ Herbiers
⇒ Xylothèque



Maïs. Dessin d'Eugen Köhler, 1897.



Classification de Cronquist (1981)

Règne	*Plantae*
Sous-règne	*Tracheobionta*
Division	*Magnoliophyta*
Classe	*Liliopsida*
Sous-classe	*Commelinidae*
Ordre	*Poales*
Famille	*Poaceae*
Sous-famille	*Panicoideae*
Super-tribu	*Andropogonodae*
Tribu	*Andropogoneae*
Sous-tribu	*Tripsacineae*
Genre	*Zea*
Espèce	*Zea mays*

Sous-espèce

Zea mays mays

L., 1753

https://fr.wikipedia.org/wiki/Ma%C3%AFs#:~:text=Elle%20appartient%20%C3%A0%20la%20famille,sous%2Dfamille%20des%20Pooideae).

76

Merci !
Misaotra !

Is NIR widely used?

Bovine meat

Wood

Beer (water, corn, hops, …)

Rice

Coconut milk

Cassava

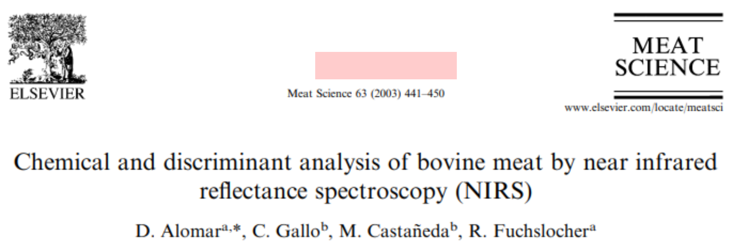
Pork meat

77

Merci !
Misaotra !

Is NIR widely used? => YES!!!

Bovine meat



ELSEVIER

Meat Science 63 (2003) 441–450

MEAT SCIENCE

www.elsevier.com/locate/meatsci

Chemical and discriminant analysis of bovine meat by near infrared reflectance spectroscopy (NIRS)

D. Alomar[a],*, C. Gallo[b], M. Castañeda[b], R. Fuchslocher[a]

Wood

JNIRS JOURNAL OF NEAR INFRARED SPECTROSCOPY

Special Issue on Wood and Wood Products

A review of band assignments in near infrared spectra of wood and wood components

Manfred Schwanninger[a,*] José Carlos Rodrigues[b] and Karin Fackler[c]

Talanta Open 7 (2023) 100180

Contents lists available at ScienceDirect

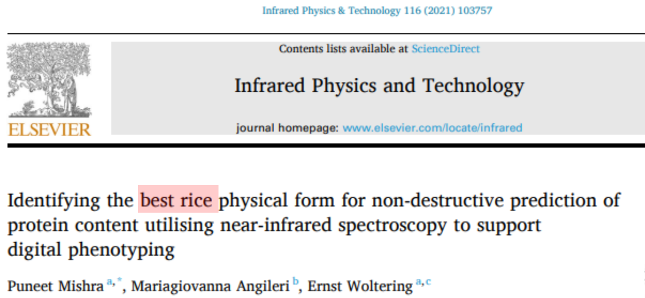
Talanta Open

journal homepage: www.sciencedirect.com/journal/talanta-open

ELSEVIER

Combining portable NIR spectroscopy and multivariate calibration for the determination of ethanol in fermented alcoholic beverages by a multi-product model

Ana Carolina da Costa Fulgêncio[a], Glaucimar Alex Passos Resende[a], Marden Claret Fontoura Teixeira[a], Bruno Gonçalves Botelho[a], Marcelo Martins Sena[a,b,*]



Infrared Physics & Technology 116 (2021) 103757

Contents lists available at ScienceDirect

Infrared Physics and Technology

journal homepage: www.elsevier.com/locate/infrared

ELSEVIER

Identifying the best rice physical form for non-destructive prediction of protein content utilising near-infrared spectroscopy to support digital phenotyping

Puneet Mishra[a,*], Mariagiovanna Angileri[b], Ernst Woltering[a,c]

Rice

Journal of Food Composition and Analysis 128 (2024) 106009

Contents lists available at ScienceDirect

Journal of Food Composition and Analysis

journal homepage: www.elsevier.com/locate/jfca

ELSEVIER

Rapid, non-destructive prediction of coconut composition for sustainable UHT milk production via near-infrared spectroscopy

Patcharanun Suksangpanomrung, Pitiporn Ritthiruangdej[*], Arisara Hiriotappa, Nantawan Therdthai

Coconut milk

Pork meat

foods

MDPI

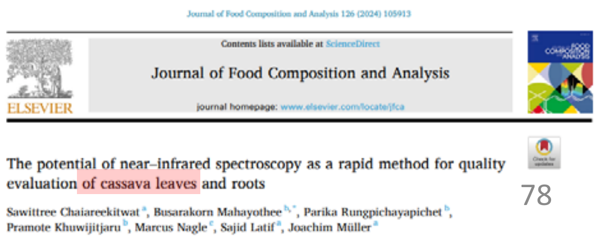
Communication

Determination of Pork Meat Storage Time Using Near-Infrared Spectroscopy Combined with Fuzzy Clustering Algorithms

Qiulin Li[1], Xiaohong Wu[2,3], Jun Zheng[4,*], Bin Wu[5], Hao Jian[6], Changzhi Sun[1] and Yibiao Tang[1]

Beer (water, corn, hops, …)

Cassava



Journal of Food Composition and Analysis 126 (2024) 105913

Contents lists available at ScienceDirect

Journal of Food Composition and Analysis

journal homepage: www.elsevier.com/locate/jfca

ELSEVIER

The potential of near–infrared spectroscopy as a rapid method for quality evaluation of cassava leaves and roots

Sawittree Chaiareekitwat[a], Busarakorn Mahayothee[b,*], Parika Rungpichayapichet[b], Pramote Khuwijitjaru[b], Marcus Nagle[c], Sajid Latif[a], Joachim Müller[a]

Many thanks to

Madagascar
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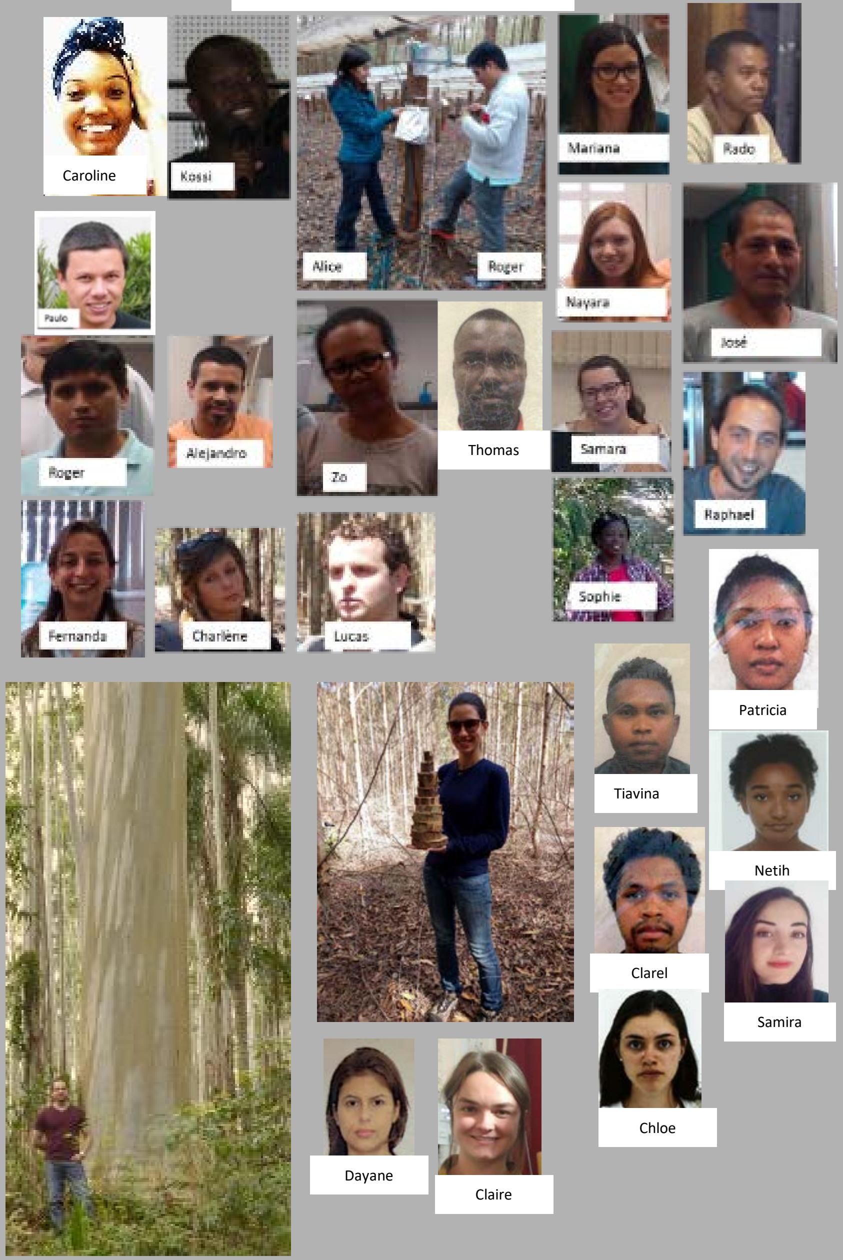
Ivory Cost
Congo
Peru
Indonesia
Costa Rica

Students



Colleagues