EcoPlant: a phytoecological database that allows the prediction of tree species niches and productivity

Christophe Coudun, Jean-Claude J.-C. Gégout, Ingrid Seynave, Christian C. Piedallu

ENGREF: French Institute of Forestry, Agricultural and Environmental Engineering

INRA: French National Institute for Agricultural Research

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EcoPlant

a phytoecological database that allows the prediction of tree species niche and productivity

Christophe COUDUN*,

Jean-Claude GEGOUT, Ingrid SEYNAVE and Christian PIEDALLU

Laboratoire d'Etude des Ressources Forêt-Bois, Equipe Ecologie Forestière, ENGREF, Nancy

*Present address: Centre for Terrestrial Carbon Dynamics, CTCD, UK,
christophe.coudun@forestry.gsi.gov.uk

EcoPlant: why?

There are different **databases** in France to study the different compartments of **ecosystems**

Pedological databases: e.g. DONESOL

Floristic databases: e.g. SOPHY

Ecological databases: e.g. IFN

These databases are **not adapted** to the **quantitative** study of species behaviour to **climate** and physical and chemical **soil parameters**

Forest phytoecological relevés in France

Many forest **phytoecological relevés** (digitalised or in forest catalogues), scattered **all over France**, with:

List of **all species present** on the relevé with **cover/abundance** data

Site-specific environmental description:

physical and chemical **soil** conditions, **climatic** data

EcoPlant was created to **group and structure** all those data in order to **study the response** of forest plant species to the **main climatic and edaphic factors** in a **quantitative** way

Talk divided into three parts

1. Description of EcoPlant

1.1. Structure of EcoPlant

1.2. Description of main variables

2. Main applications of EcoPlant

2.1. Ecological indicator values

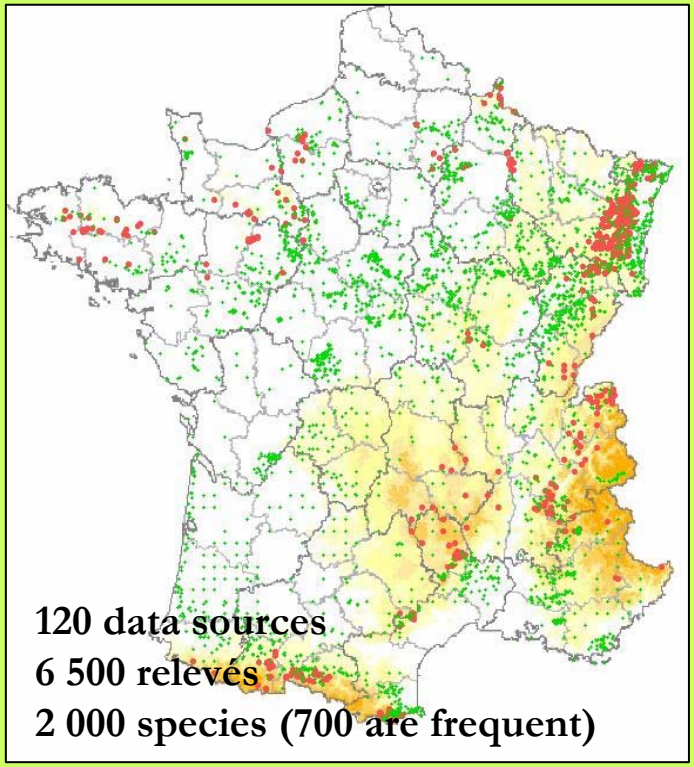
2.2. Ecological niche determination (*Acer campestre*)

2.3. Productivity of forest trees (*Fagus sylvatica*)

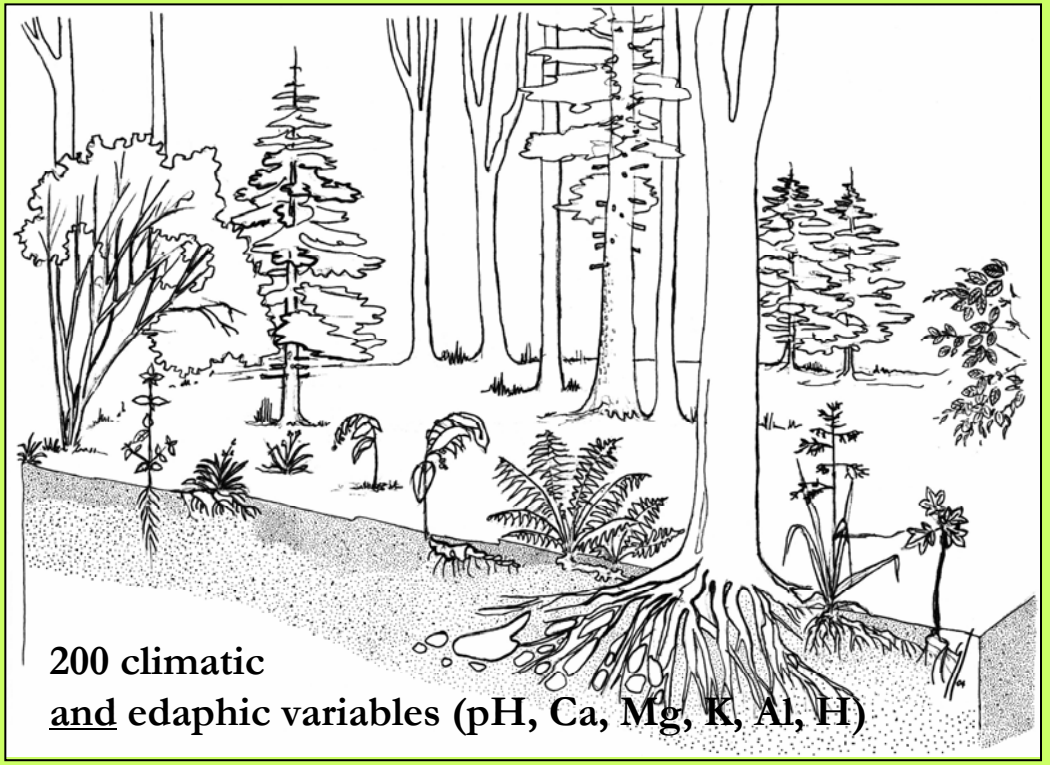
3. Perspectives

1. Description of EcoPlant

Introductory overview

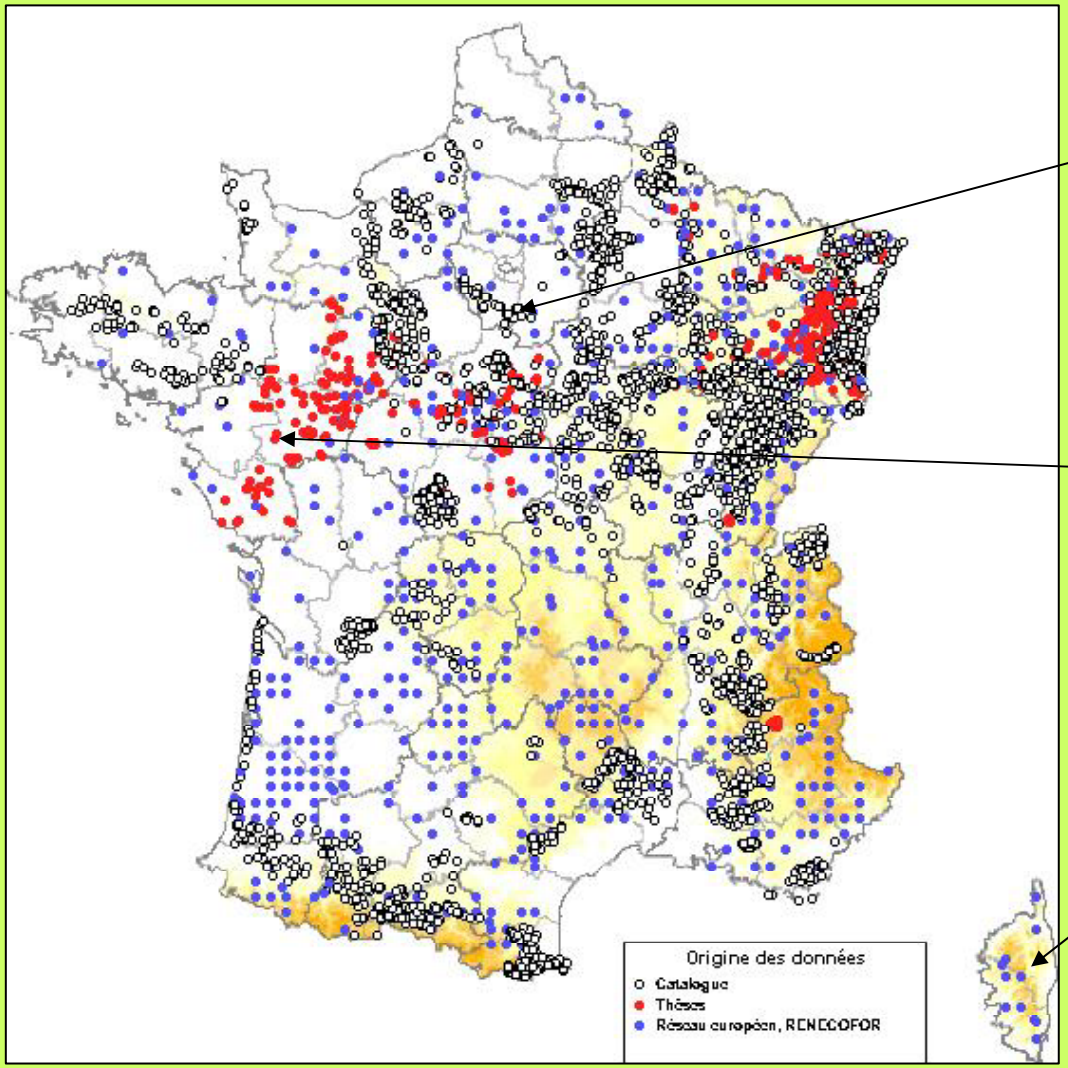


120 data sources
6 500 relevés
2 000 species (700 are frequent)



200 climatic
and edaphic variables (pH, Ca, Mg, K, Al, H)

Three main sources of data



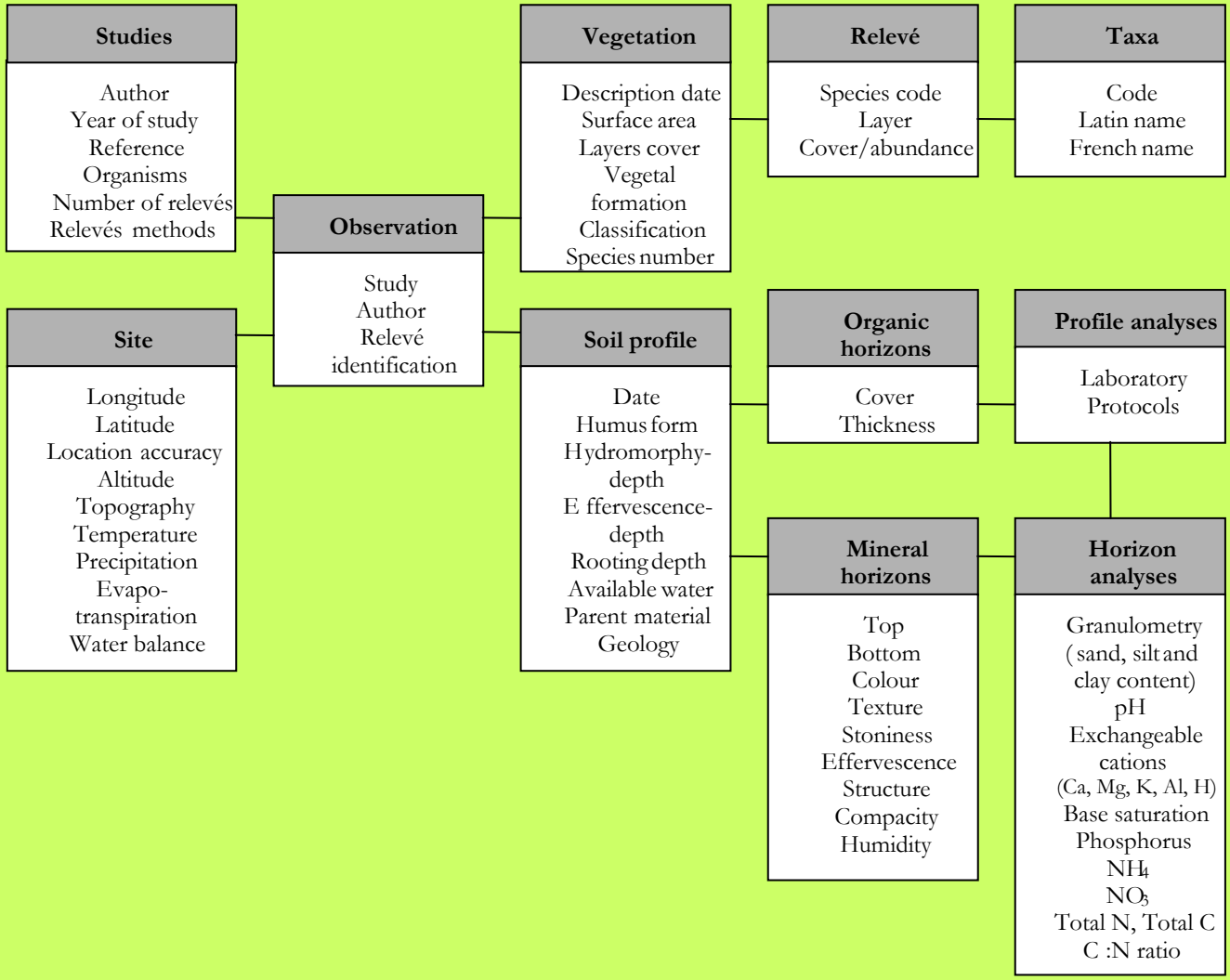
Catalogues of forest sites
(n = 4,282)

PhD dissertations
(n = 1,507)

Forest networks
(n = 643)

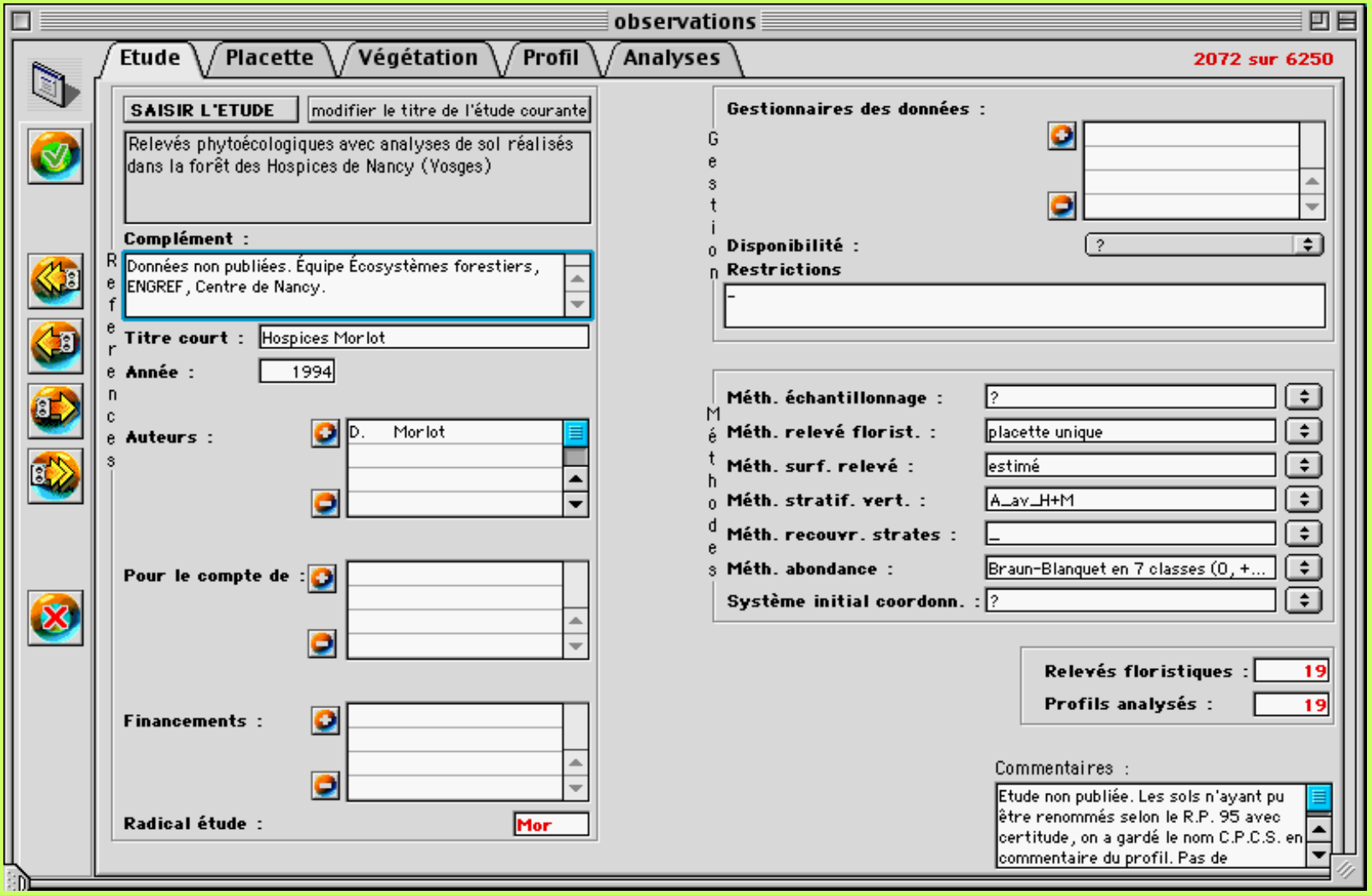
1.1. Structure of EcoPlant

Structure of EcoPlant

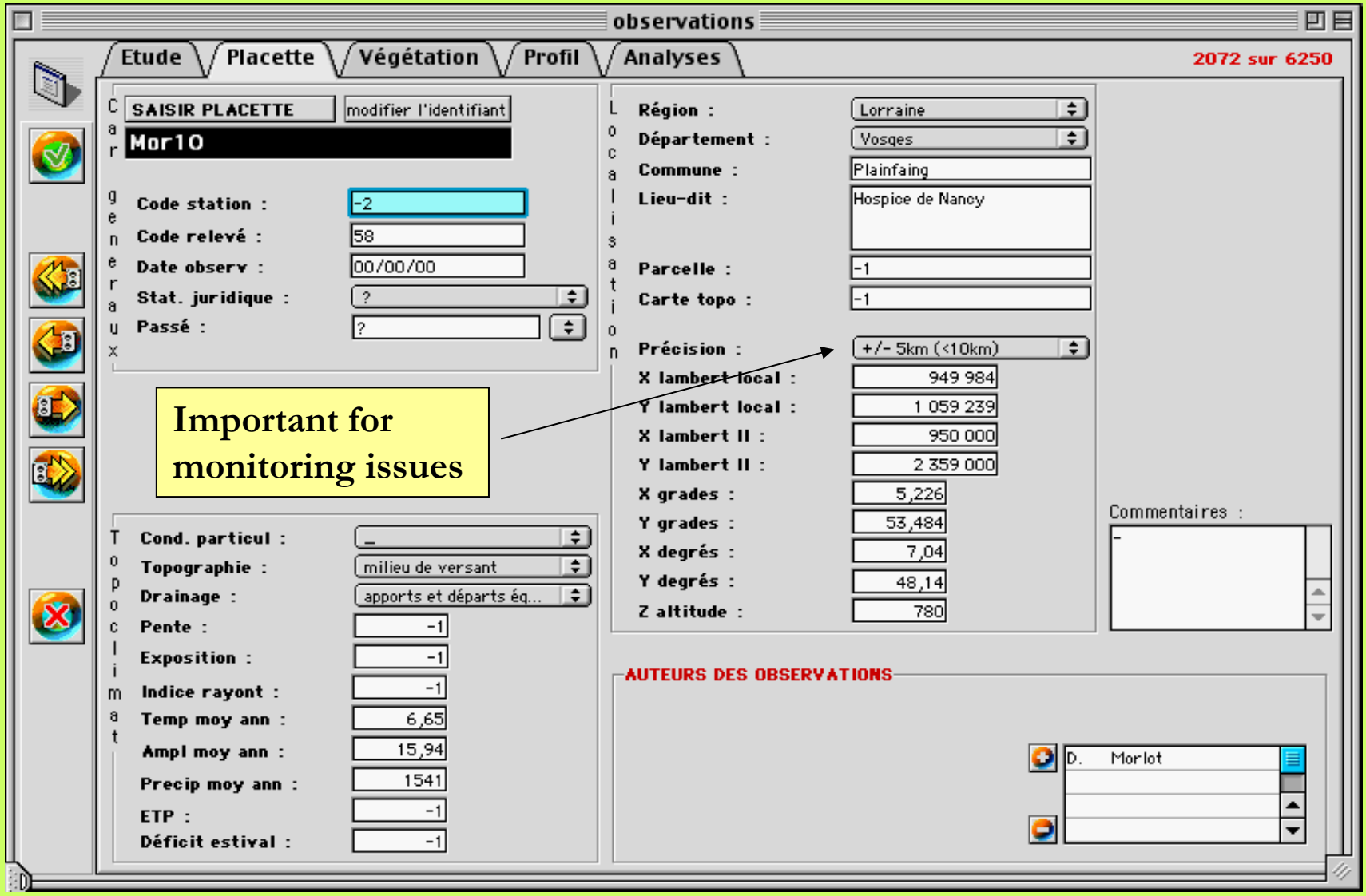


1.2. Description of main variables

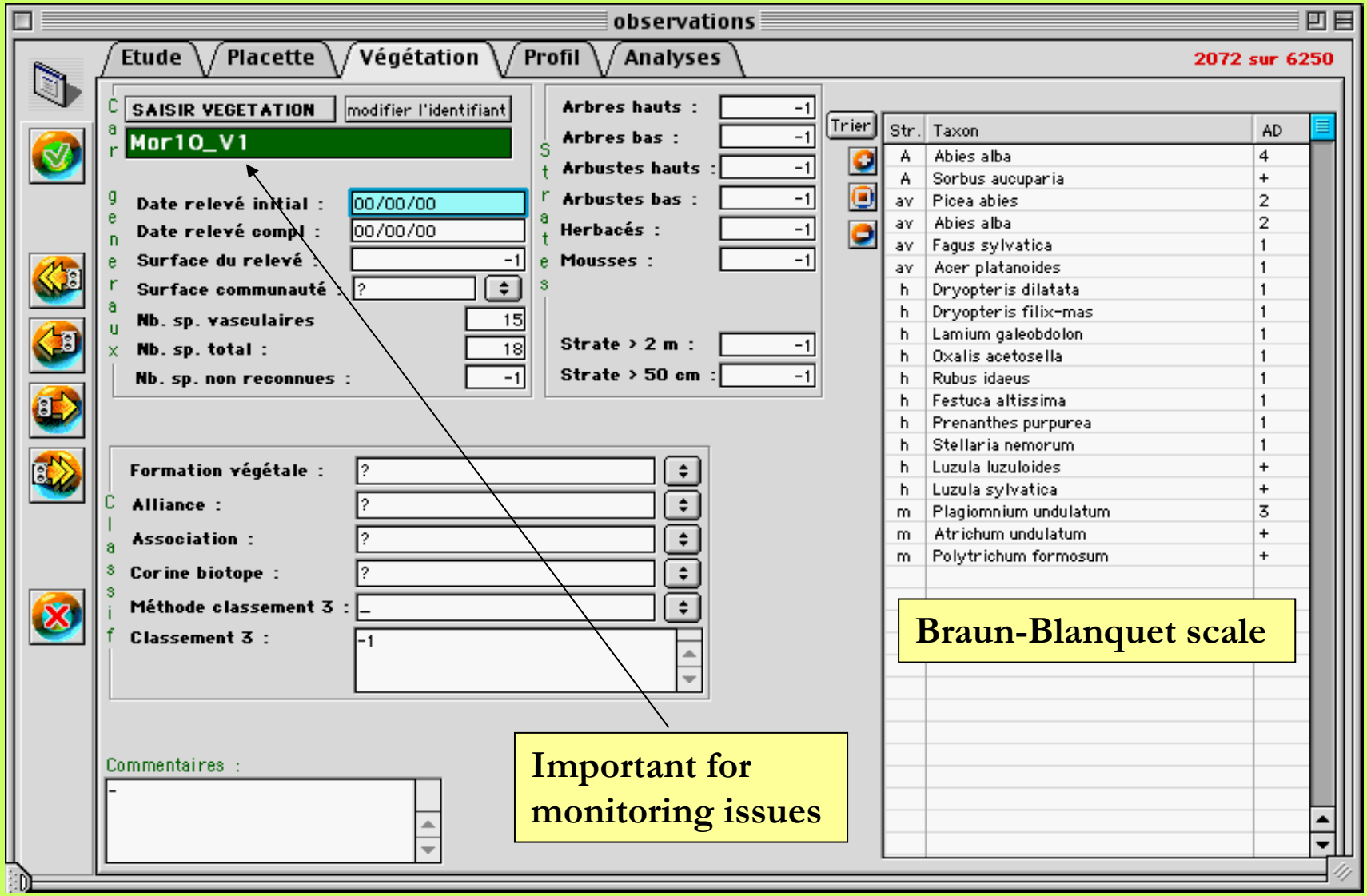
Background data on study



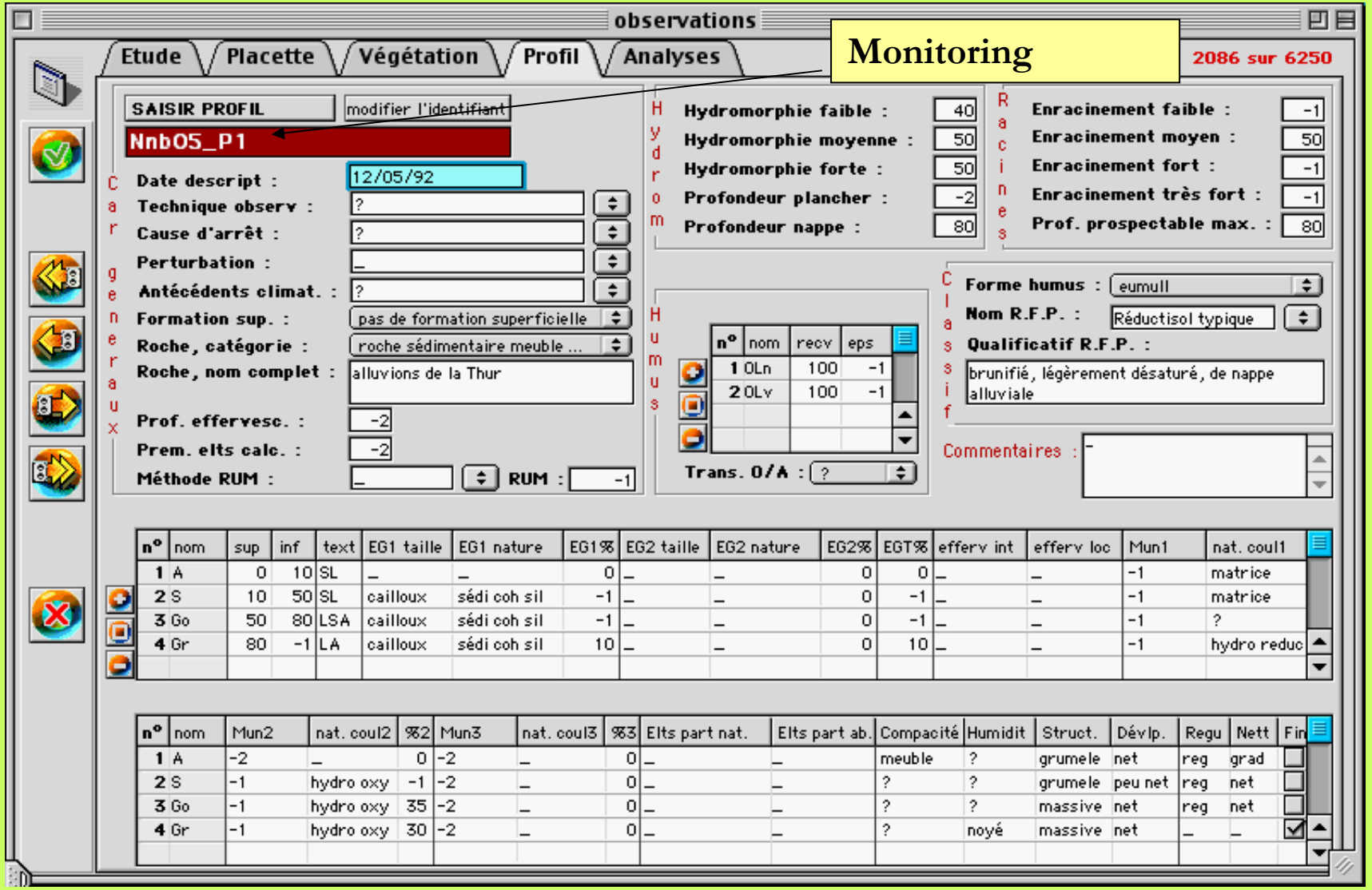
Location and climatic data



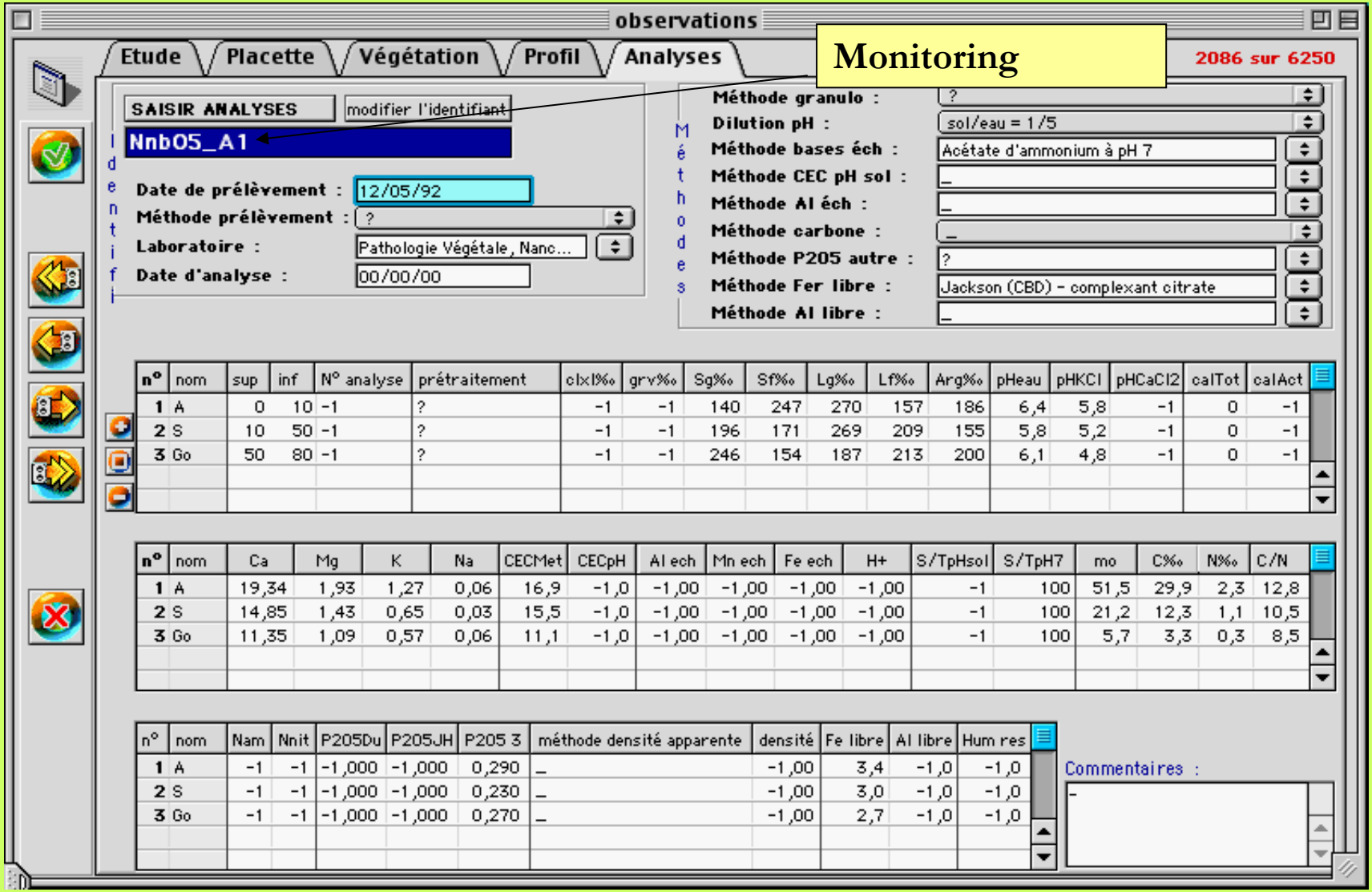
Vegetation and species abundance data



Description of soil profiles and horizons



Physical and chemical analyses of soil horizons

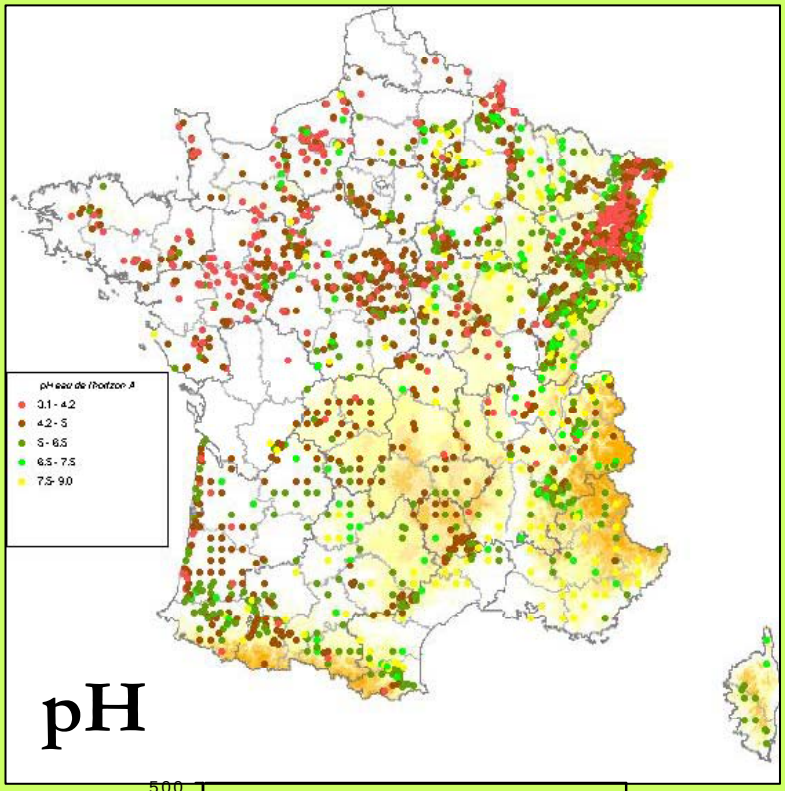


n°	nom	sup	inf	N° analyse	prétraitement	clxl‰	grv‰	Sg‰	Sf‰	Lg‰	Lf‰	Arg‰	pHeau	pHKCl	pHCaCl2	calTot	calAct
1	A	0	10	-1	?	-1	-1	140	247	270	157	186	6,4	5,8	-1	0	-1
2	S	10	50	-1	?	-1	-1	196	171	269	209	155	5,8	5,2	-1	0	-1
3	Go	50	80	-1	?	-1	-1	246	154	187	213	200	6,1	4,8	-1	0	-1

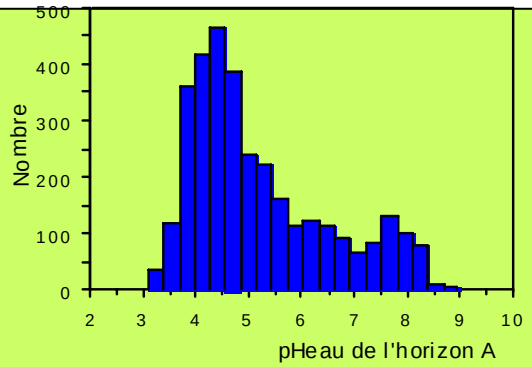
n°	nom	Ca	Mg	K	Na	CECMet	CECpH	Al ech	Mn ech	Fe ech	H+	S/TpHsol	S/TpH7	mo	C‰	N‰	C/N
1	A	19,34	1,93	1,27	0,06	16,9	-1,0	-1,00	-1,00	-1,00	-1,00	-1	100	51,5	29,9	2,3	12,8
2	S	14,85	1,43	0,65	0,03	15,5	-1,0	-1,00	-1,00	-1,00	-1,00	-1	100	21,2	12,3	1,1	10,5
3	Go	11,35	1,09	0,57	0,06	11,1	-1,0	-1,00	-1,00	-1,00	-1,00	-1	100	5,7	3,3	0,3	8,5

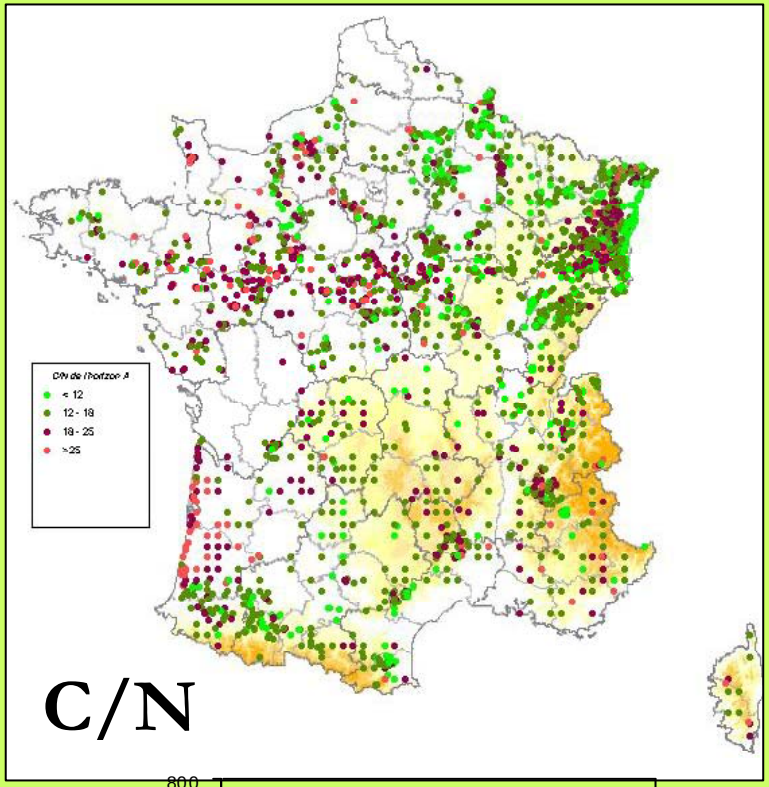
n°	nom	Nam	Nnit	P205Du	P205JH	P205 3	méthode densité apparente	densité	Fe libre	Al libre	Hum res
1	A	-1	-1	-1,000	-1,000	0,290	_	-1,00	3,4	-1,0	-1,0
2	S	-1	-1	-1,000	-1,000	0,230	_	-1,00	3,0	-1,0	-1,0
3	Go	-1	-1	-1,000	-1,000	0,270	_	-1,00	2,7	-1,0	-1,0

National syntheses of ecological variables

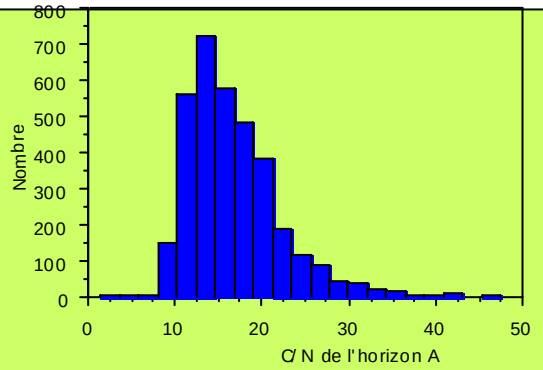


pH

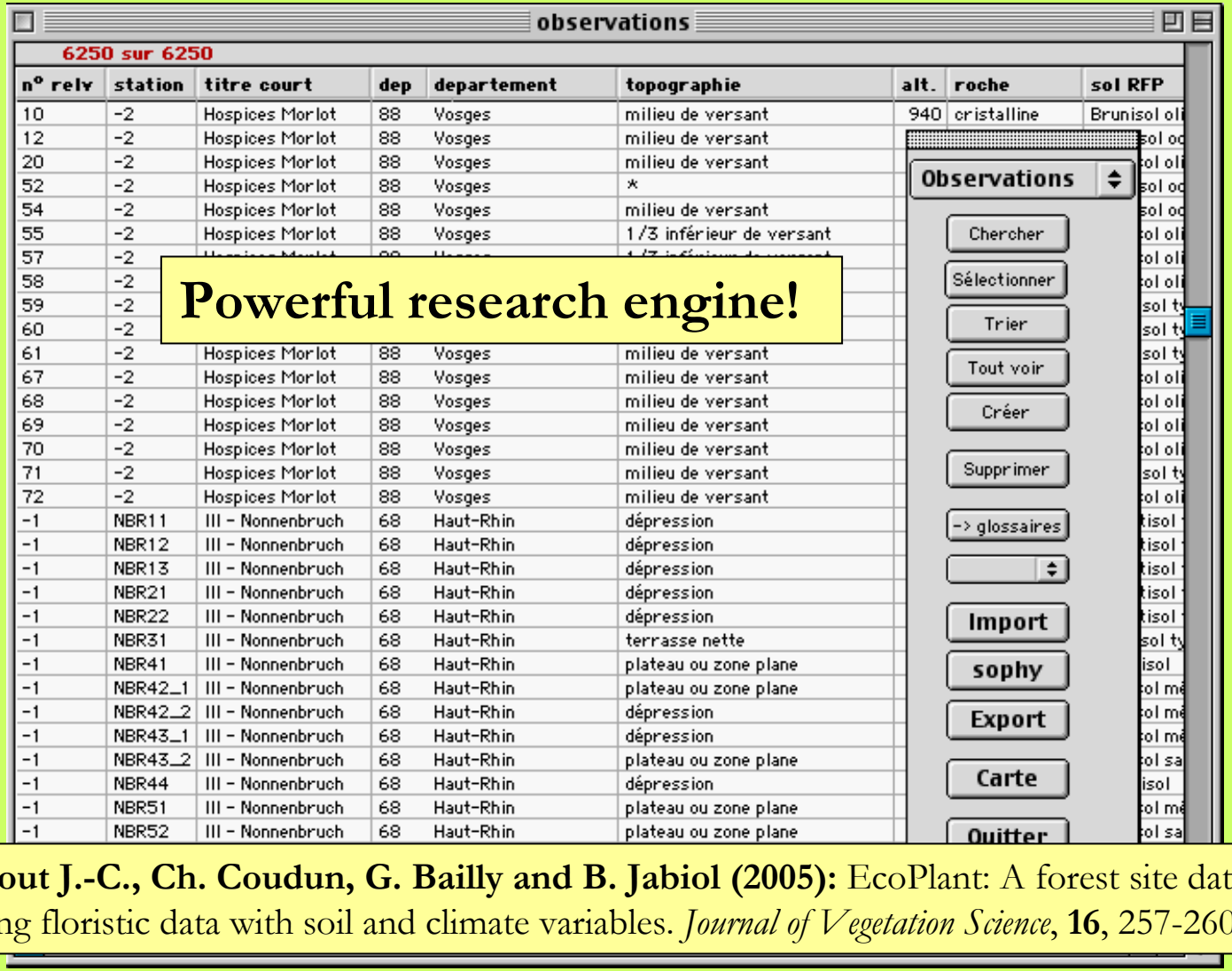




C/N



Summary list of all relevés



n° relv	station	titre court	dep	departement	topographie	alt.	roche	sol RFP
10	-2	Hospices Morlot	88	Vosges	milieu de versant	940	cristalline	Brunisol oli
12	-2	Hospices Morlot	88	Vosges	milieu de versant			sol oc
20	-2	Hospices Morlot	88	Vosges	milieu de versant			col oli
52	-2	Hospices Morlot	88	Vosges	*			sol oc
54	-2	Hospices Morlot	88	Vosges	milieu de versant			sol oc
55	-2	Hospices Morlot	88	Vosges	1/3 inférieur de versant			col oli
57	-2							col oli
58	-2							col oli
59	-2							sol ty
60	-2							sol ty
61	-2	Hospices Morlot	88	Vosges	milieu de versant			sol ty
67	-2	Hospices Morlot	88	Vosges	milieu de versant			col oli
68	-2	Hospices Morlot	88	Vosges	milieu de versant			col oli
69	-2	Hospices Morlot	88	Vosges	milieu de versant			col oli
70	-2	Hospices Morlot	88	Vosges	milieu de versant			col oli
71	-2	Hospices Morlot	88	Vosges	milieu de versant			sol ty
72	-2	Hospices Morlot	88	Vosges	milieu de versant			col oli
-1	NBR11	Ill - Nonnenbruch	68	Haut-Rhin	dépression			isol
-1	NBR12	Ill - Nonnenbruch	68	Haut-Rhin	dépression			isol
-1	NBR13	Ill - Nonnenbruch	68	Haut-Rhin	dépression			isol
-1	NBR21	Ill - Nonnenbruch	68	Haut-Rhin	dépression			isol
-1	NBR22	Ill - Nonnenbruch	68	Haut-Rhin	dépression			isol
-1	NBR31	Ill - Nonnenbruch	68	Haut-Rhin	terrasse nette			sol ty
-1	NBR41	Ill - Nonnenbruch	68	Haut-Rhin	plateau ou zone plane			isol
-1	NBR42_1	Ill - Nonnenbruch	68	Haut-Rhin	plateau ou zone plane			col mé
-1	NBR42_2	Ill - Nonnenbruch	68	Haut-Rhin	dépression			col mé
-1	NBR43_1	Ill - Nonnenbruch	68	Haut-Rhin	dépression			col mé
-1	NBR43_2	Ill - Nonnenbruch	68	Haut-Rhin	plateau ou zone plane			col sa
-1	NBR44	Ill - Nonnenbruch	68	Haut-Rhin	dépression			isol
-1	NBR51	Ill - Nonnenbruch	68	Haut-Rhin	plateau ou zone plane			col mé
-1	NBR52	Ill - Nonnenbruch	68	Haut-Rhin	plateau ou zone plane			col sa

Powerful research engine!

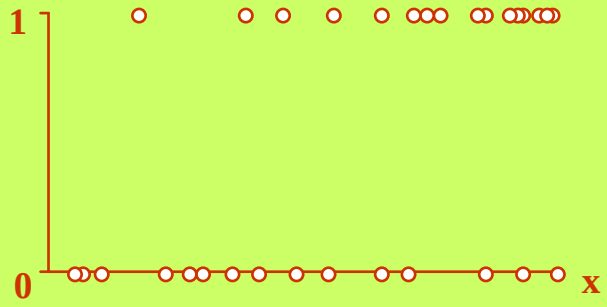
Gégout J.-C., Ch. Coudun, G. Bailly and B. Jabiol (2005): EcoPlant: A forest site database linking floristic data with soil and climate variables. *Journal of Vegetation Science*, **16**, 257-260.

2. Main applications of EcoPlant

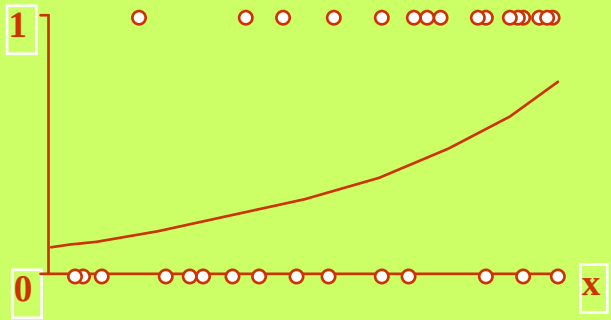
2.1. Ecological indicator values

Ecological response curves along one gradient

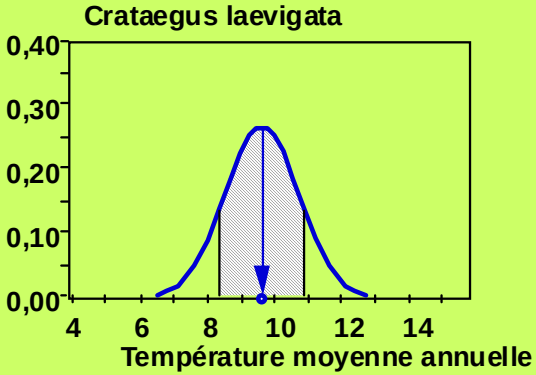
1 - Repartition of observed **presence** (1) and **absence** (0) along an ecological factor (e.g. x = pH)

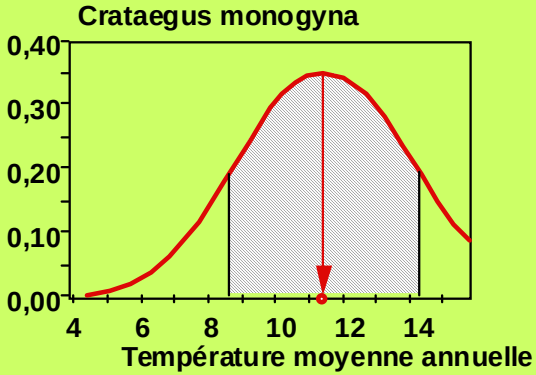


2 - Modelling of species response curve with **logistic regression**



3. Definition of **species indicator values**: optimum and amplitude





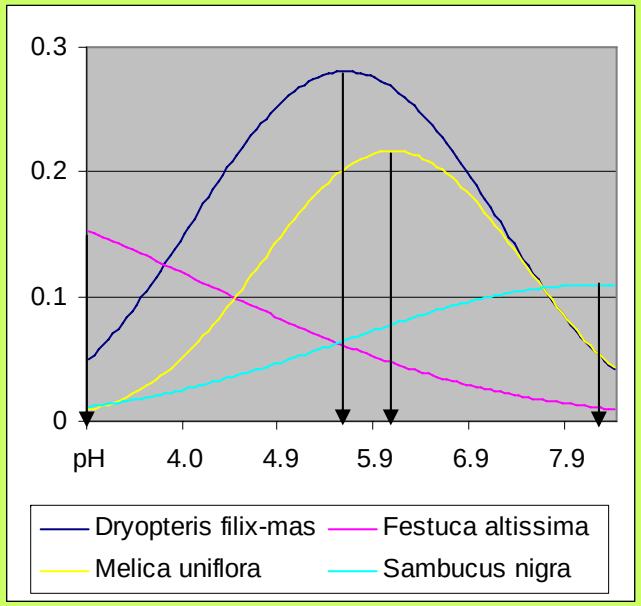
Crataegus laevigata
Optimum : 9.6 °C
Amplitude : 3.2 °C

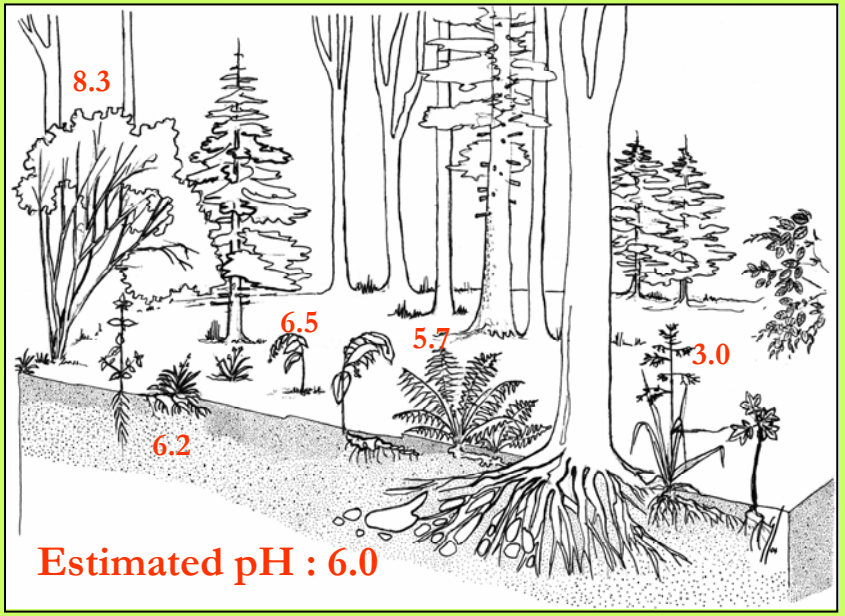
Crataegus monogyna
Optimum : 11.5 °C
Amplitude : 5.5 °C

Species ecological indicator values
based on real measurements

Selection of environmental factors having a « **direct** » physiological influence on plant growth and survival

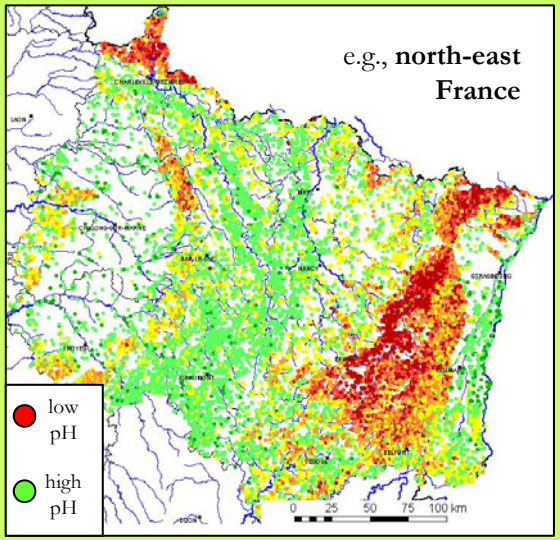
Factor	Measured variable	Ellenberg/Landolt
Acidity	pH, S/T	R
Nitrogen	C/N	N
Temperature	Mean annual T	T
Thermal stress	Mean January T	K
Hydrologic stress	De Marton index	F

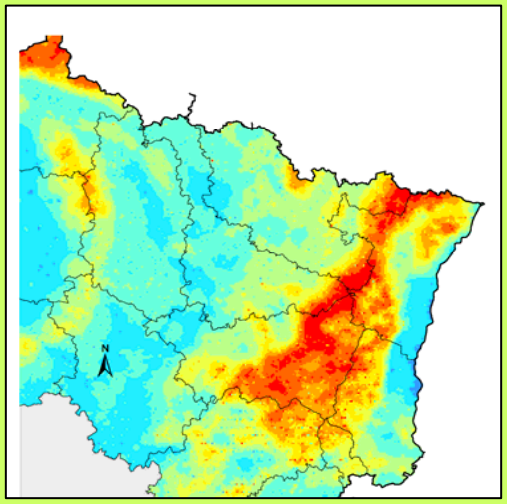


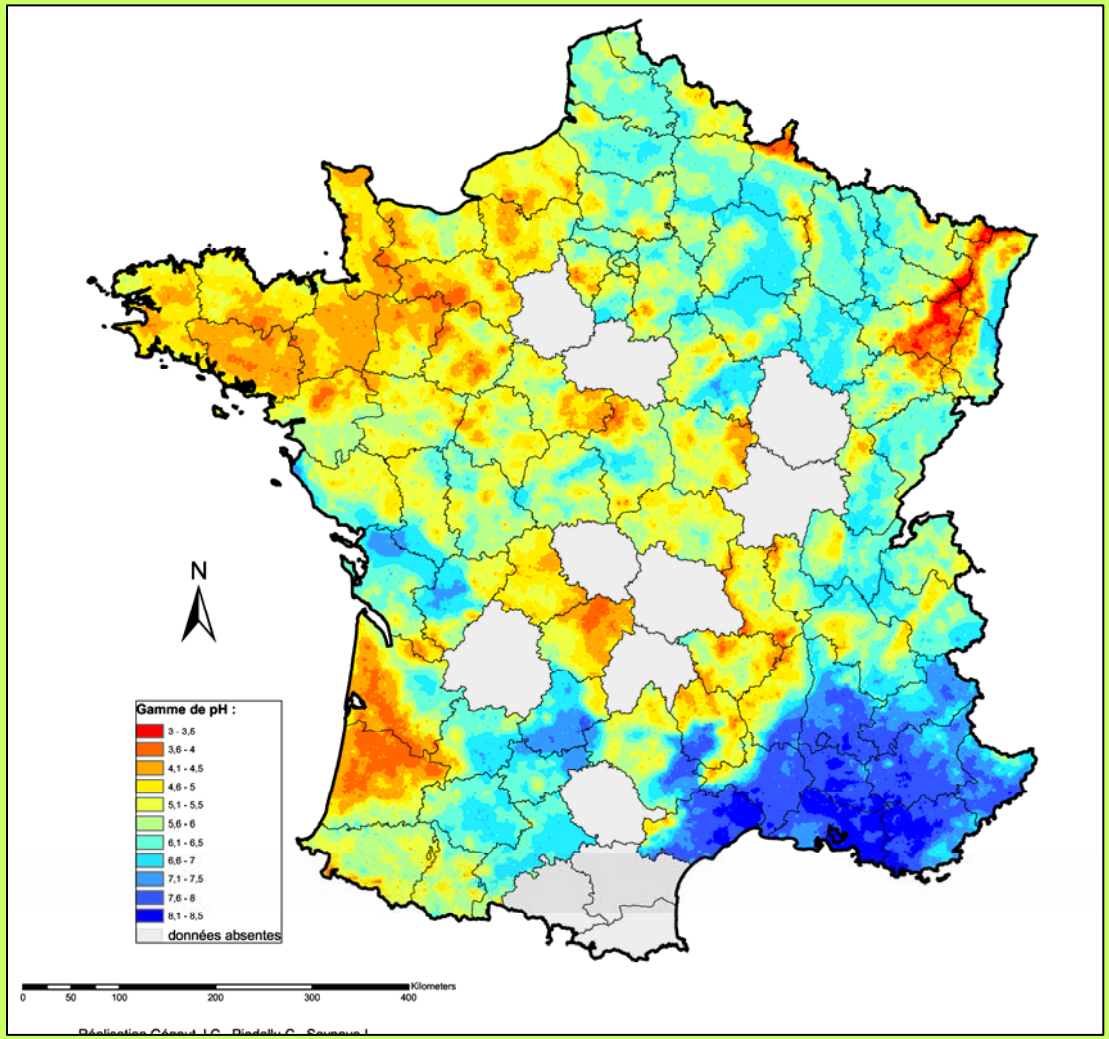


Edaphic maps: e.g. soil pH

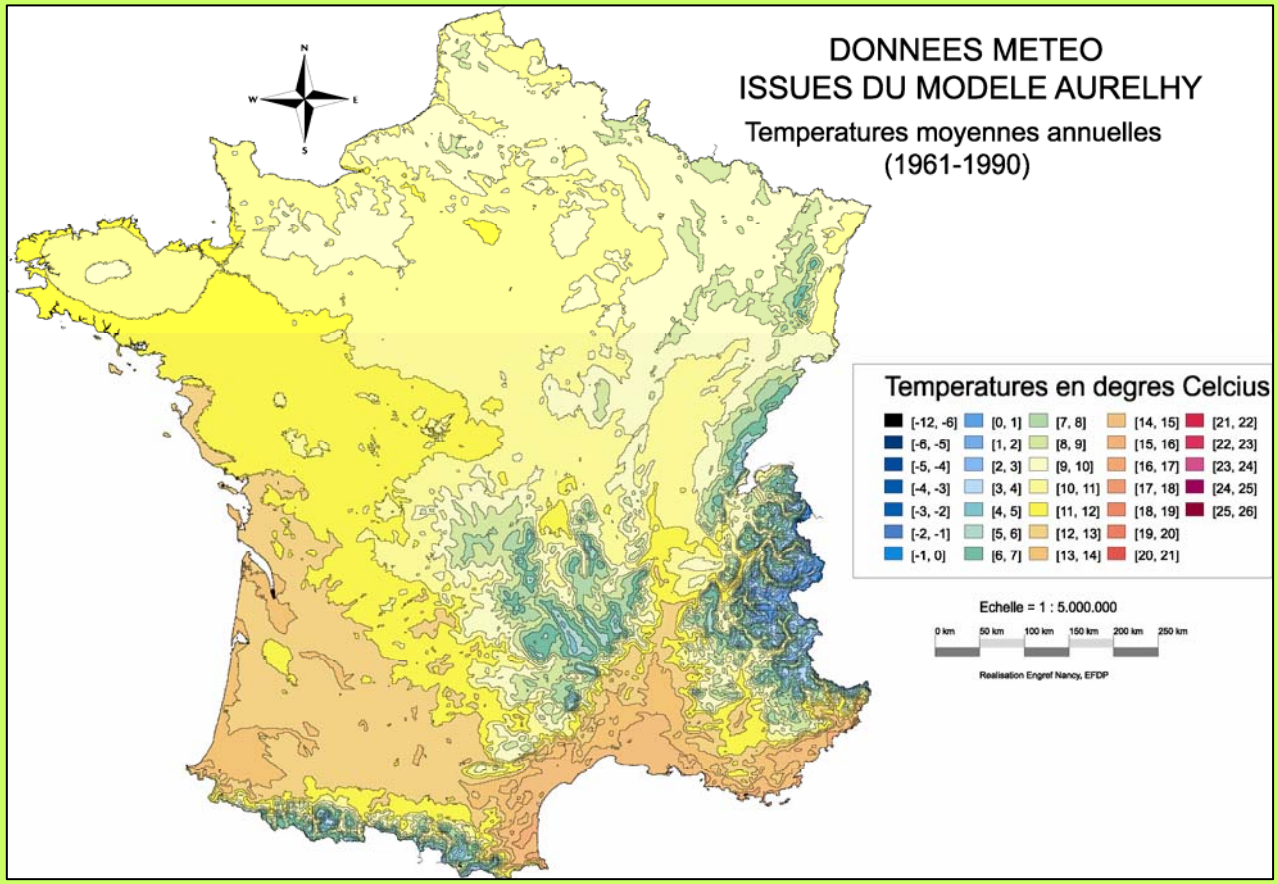
(spatial interpolation of bio-indicated values, from EcoPlant)

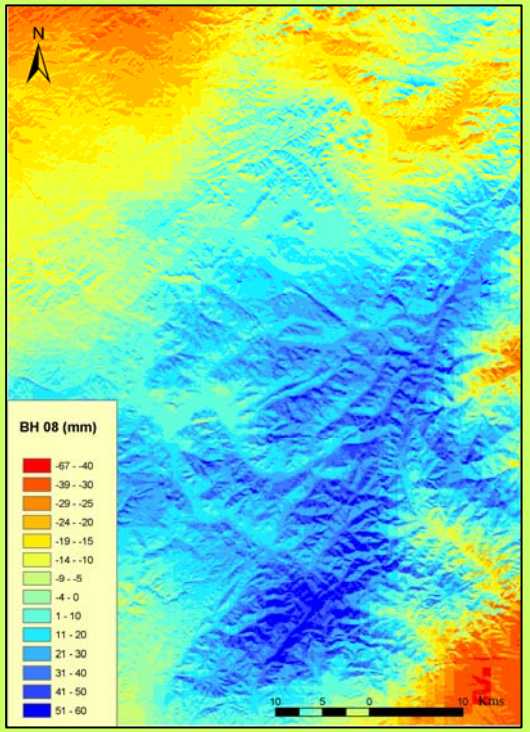






Climatic maps from meteorological data and DEM





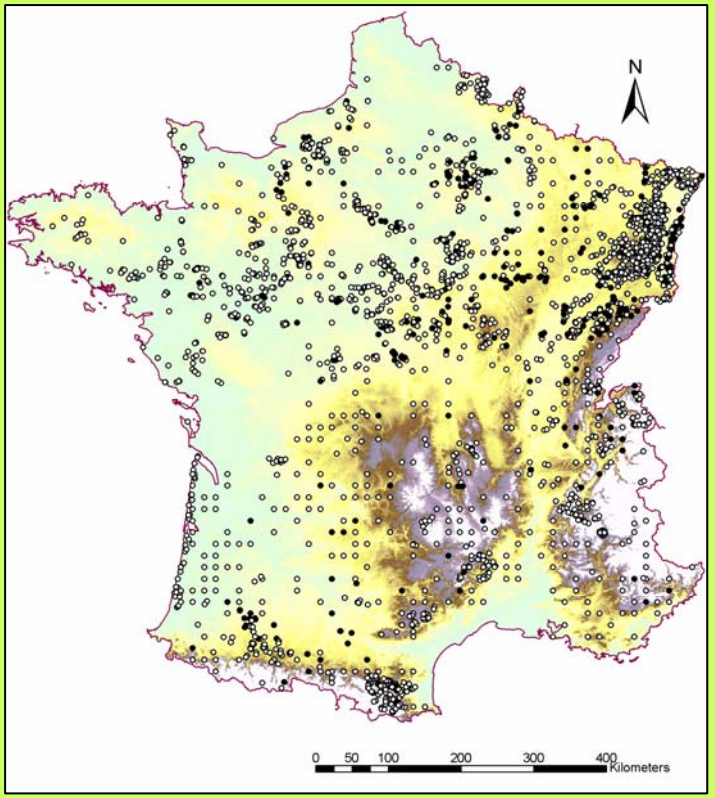
Water balance (P - PET_{Turc}) in the Vosges Mountains

2.2. Ecological niche determination (*Acer campestre*)

Predicting the distibution of *Acer campestre* (L.) in French forests with climatic and edaphic factors

3,286 relevés

460 relevés with presence of *Acer campestre* (**black points**)



156 climatic variables

(T, P, radiation,PET, AET, WB…)

6 edaphic variables

(pH, C/N, S/T, Ca, Mg, K)

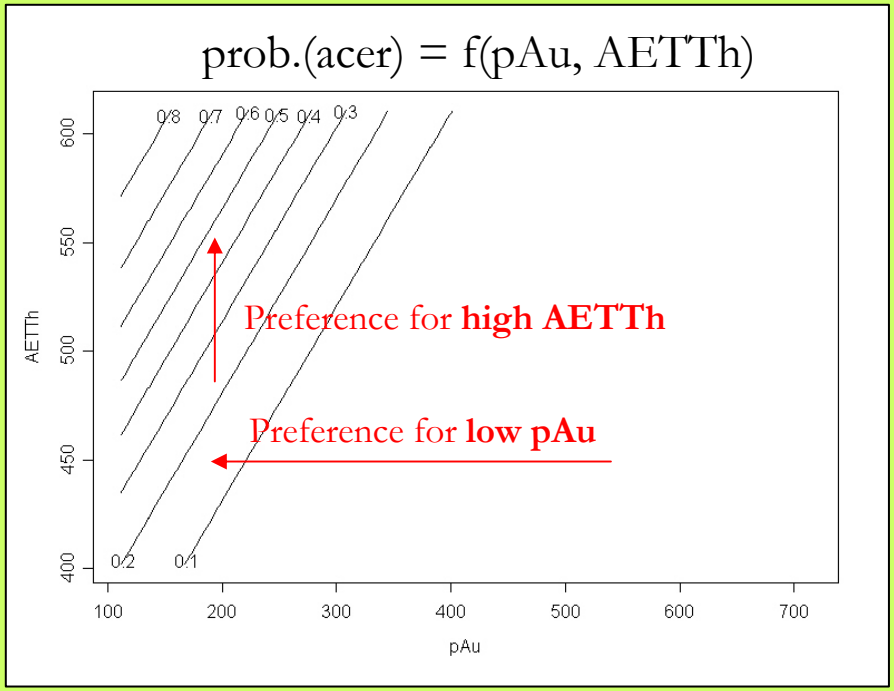
Coudun, Ch., J.-C. Gégout, C. Piedallu and J.-C. Rameau (in press): Soil nutritional factors improve plant species distribution models: an illustration with *Acer campestre* (L.) in France. *Journal of Biogeography*.

Ecological response of *Acer campestre*

(forward stepwise logistic regression)

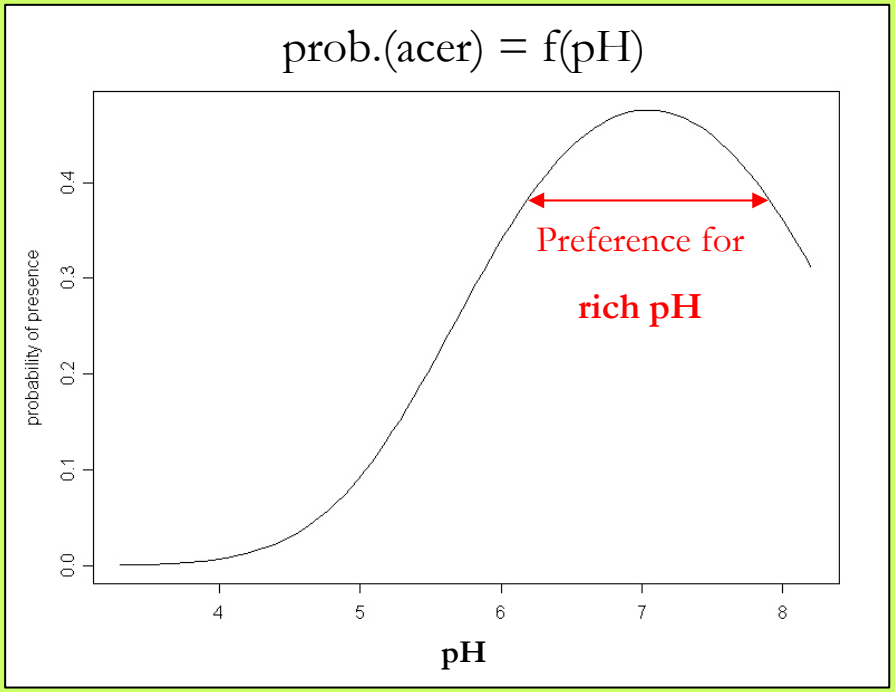
I. Climatic model only

1. **Autumn precipitation** (pAu)
2. **Annual actual evapotranspiration** (AETTh)

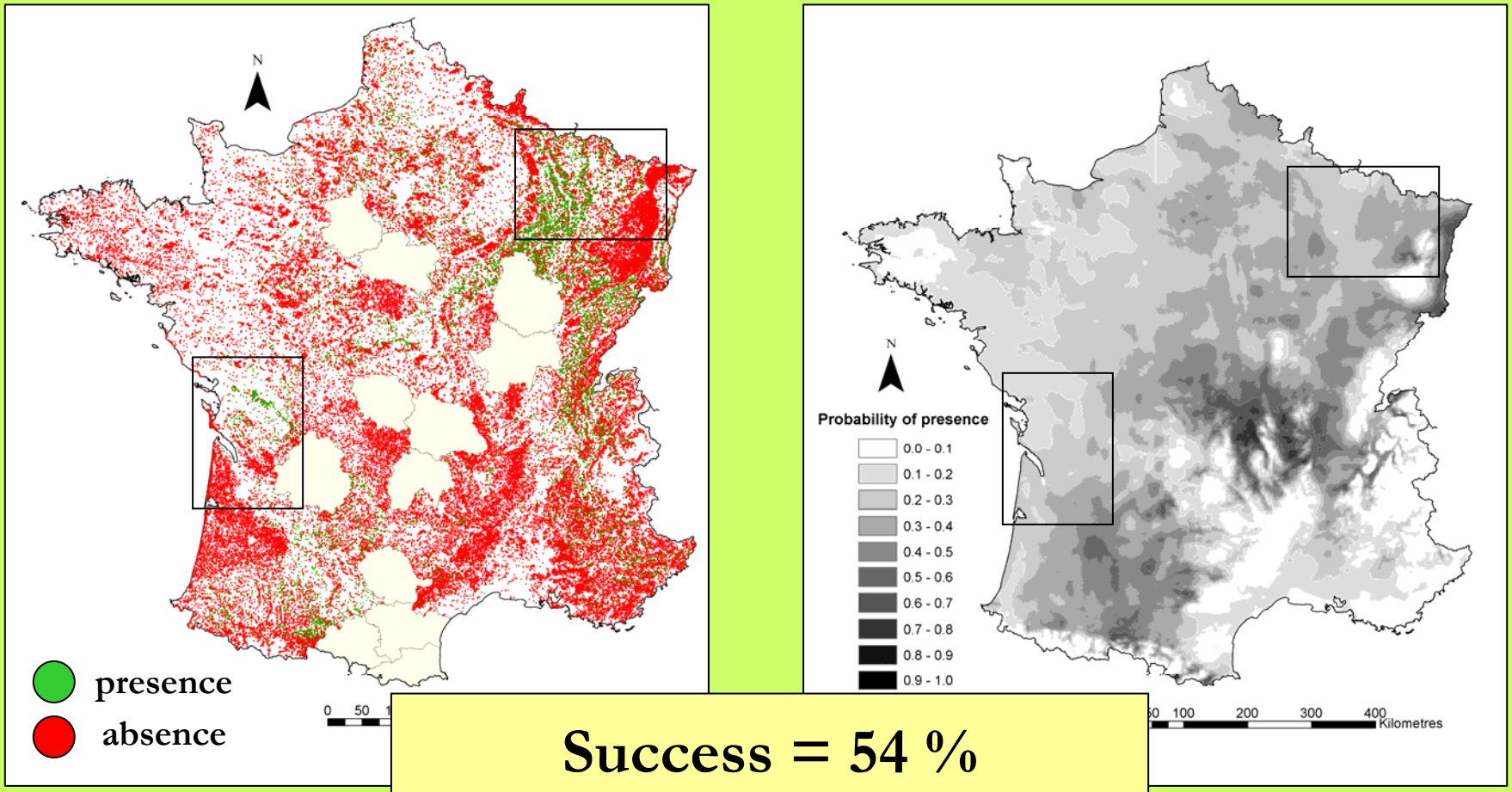


II. Climatic and edaphic model

1. **soil pH** (pH)
2. **Autumn precipitation** (pAu)
3. **Annual actual evapotranspiration** (AETTh)



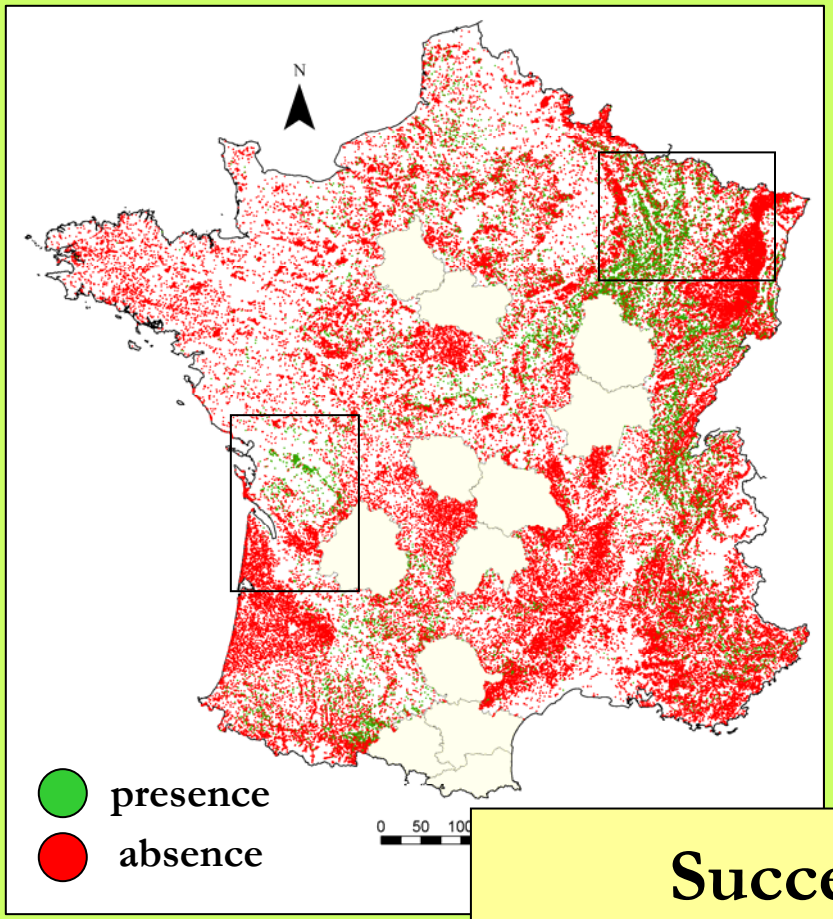
Map 1. Predicting the distribution of *Acer campestre* with climatic factors only (pAu + AETTh)

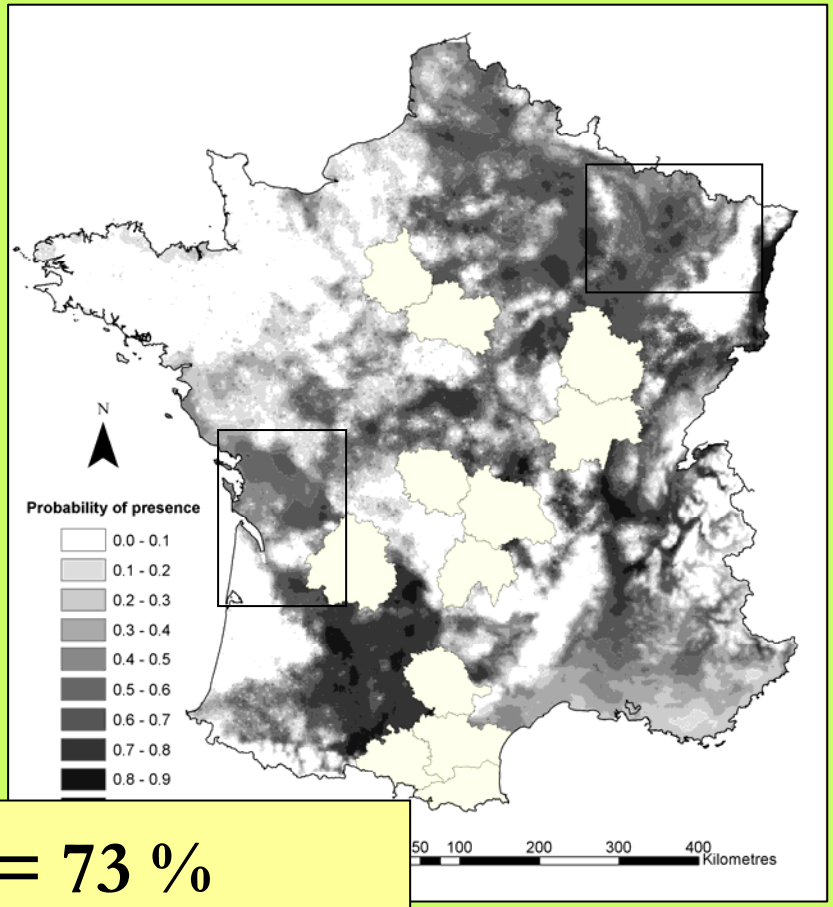


Success = 54 %

73 % presence, 50 % absence

Map 2. Predicting the distribution of *Acer campestre* with climatic and edaphic factors (pH + pAu + AETTh)





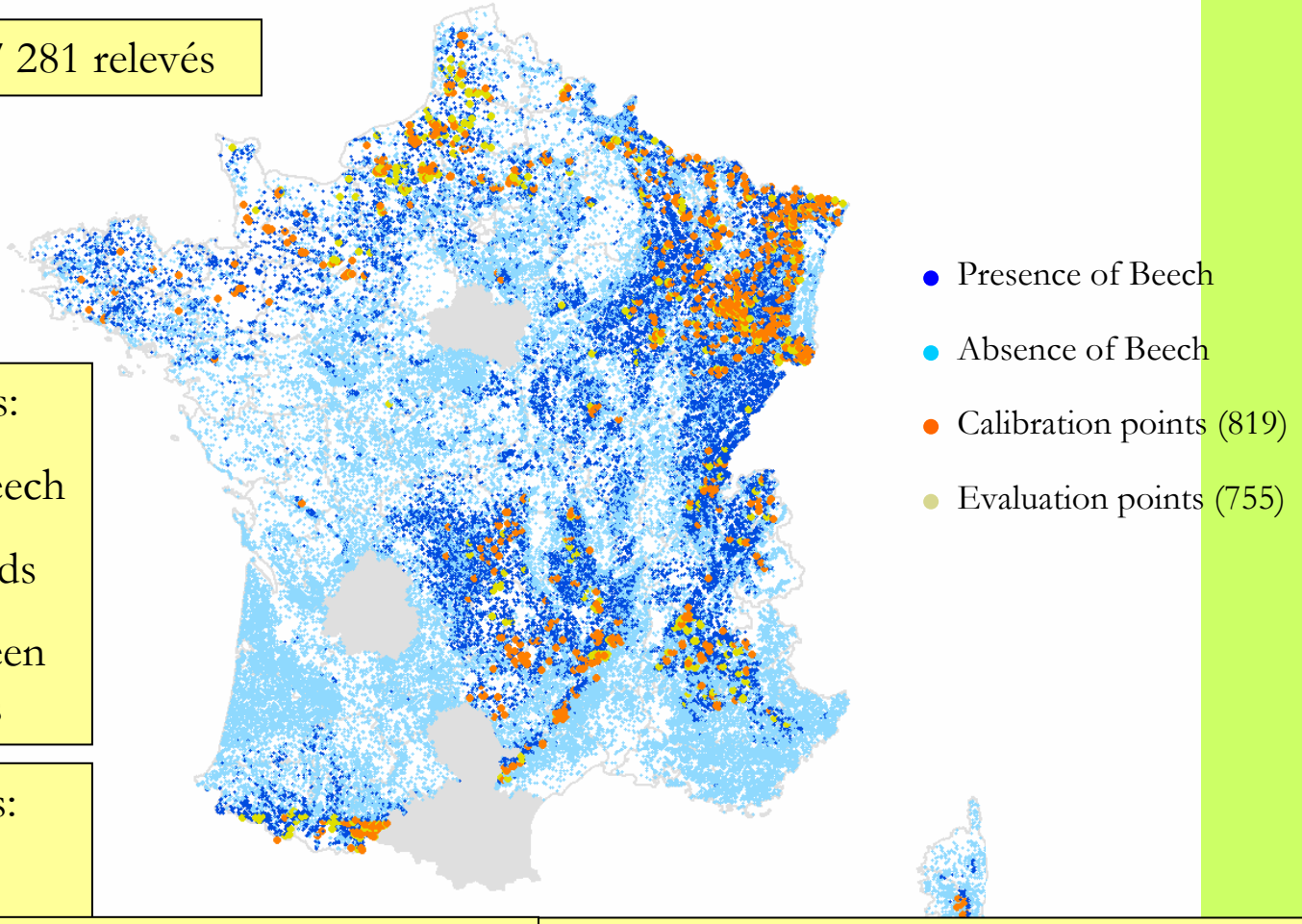
Success = 73 %

86 % presence, 70 % absence

2.2. Productivity of forest trees (*Fagus sylvatica*)

Productivity of *Fagus sylvatica* in French forests

IFN: 97 281 relevés



Calibration points:

(a) dominated by Beech

(b) even-aged stands

(c) stand age between 70 and 100 years

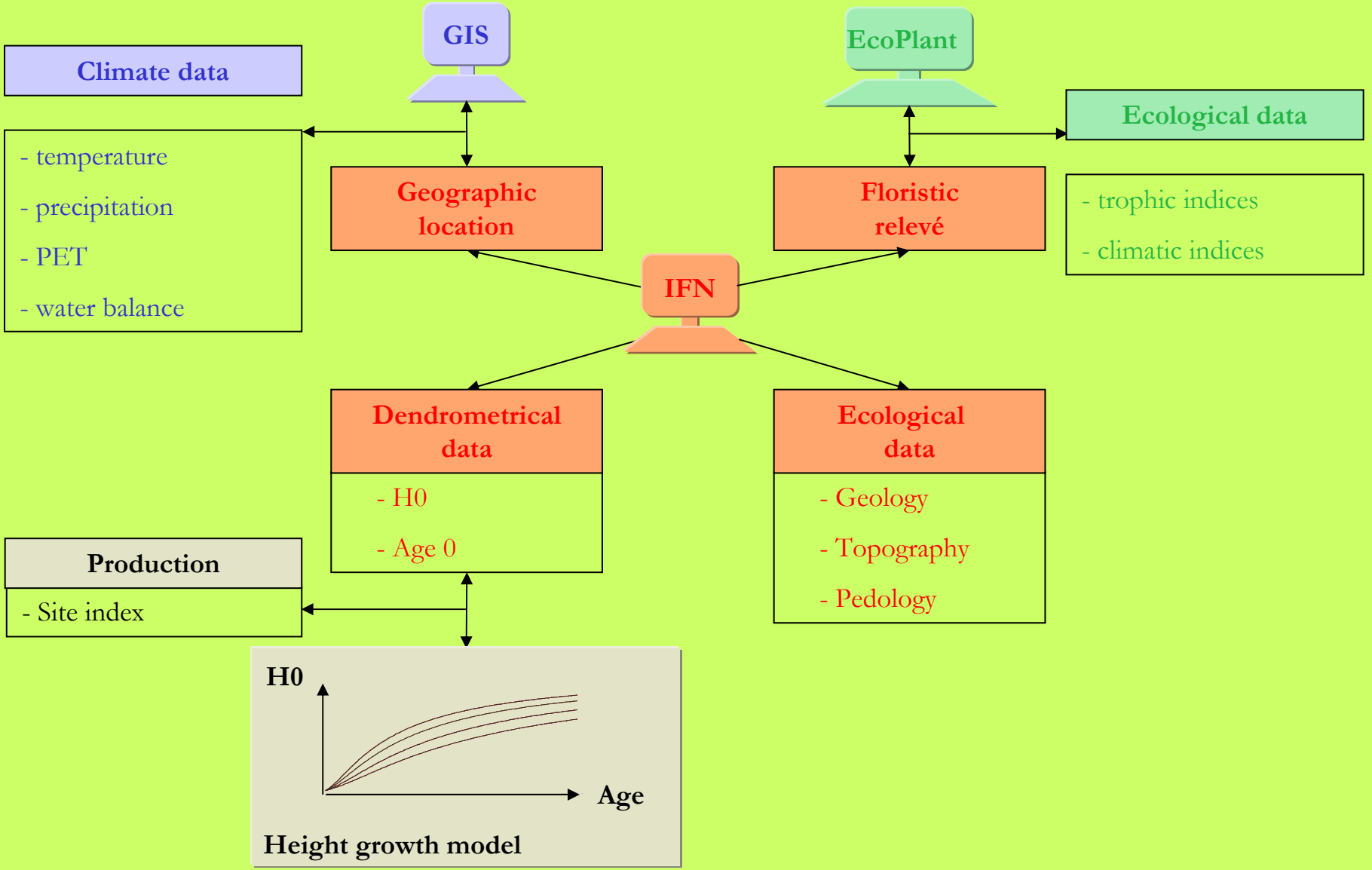
Evaluation points:

same criteria

Measure of productivity: site index (dominant height - in metres - at reference age 100 yr)

Beech in France: SI = 10 to 42 m at 100 years

Beech productivity: coupling databases...



Beech productivity: resulting ecological model

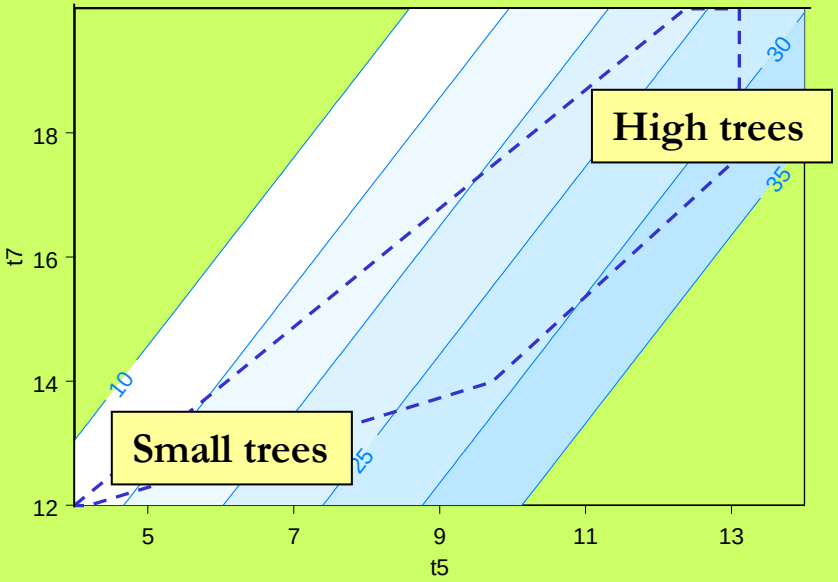
7 environmental variables

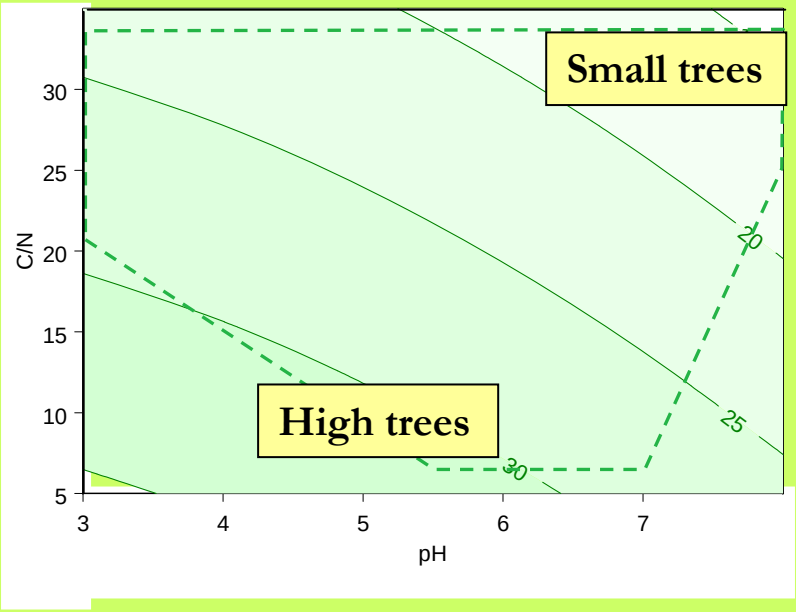
SI = 38.4 + 3.9*t5 - 2.8*t7 - 0.13*$t1^2$ - 0.57 $\cdot 10^{-4}$*$p12^2$

+ 0.35*prof

- 0.37*C/N - 0.16*pH^2

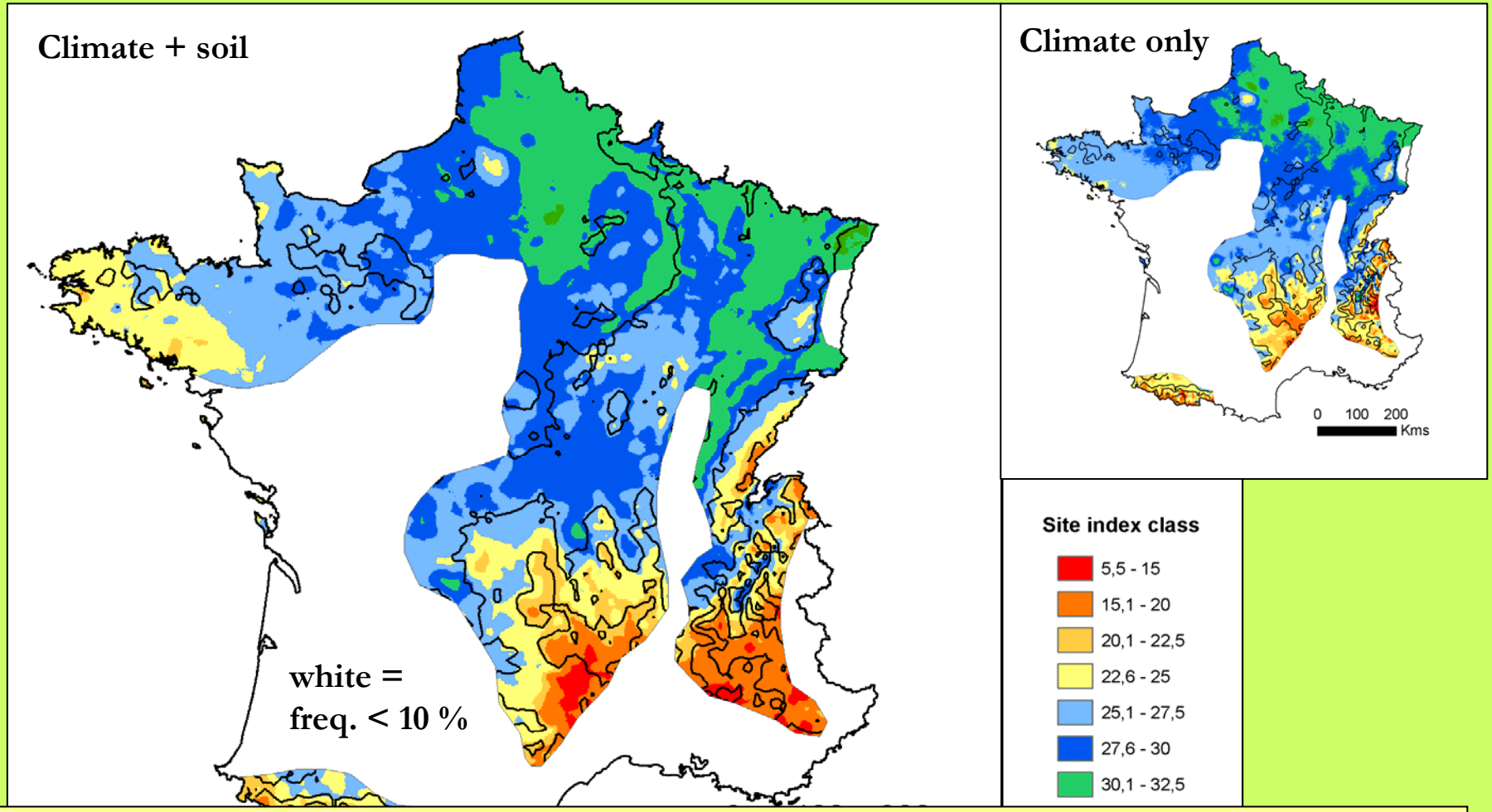
- Climate - GIS
- IFN
- EcoPlant VI





R2 = 0.59; **RMSE** = 3.8 m

Beech productivity: prediction maps



Seynave, I., J.-C. Gégout, J.-C. Hervé and J.-F. Dhôte (in review): How do climate and soil control the spatial distribution of *Fagus sylvatica* productivity? *Global Ecology & Biogeography*.

3. Perspectives

Perspectives for EcoPlant

Integration of phytoecological relevés contained in **PhD dissertations**

Realisation of **new relevés** and **collaborations** to get a better knowledge in poorly represented regions

Integration of **open environments** into EcoPlant to investigate the behaviour of **all species** of French flora

Geographic extension of EcoPlant at the European scale to study the ecological of certains species in the **totality** of their distribution range

Coupling of EcoPlant with species traits databases (e.g. LEDA)

Translation of EcoPlant into English (software, dictionary of data, technical reports, etc.).

Other research perspectives

Characterisation of **geographical variation** of species ecological niche (e.g. two regions in Coudun & Gégout 2005)

Use of EcoPlant edaphic indicator values to produce fine-grain **maps** of France of **mineral nutrition conditions**

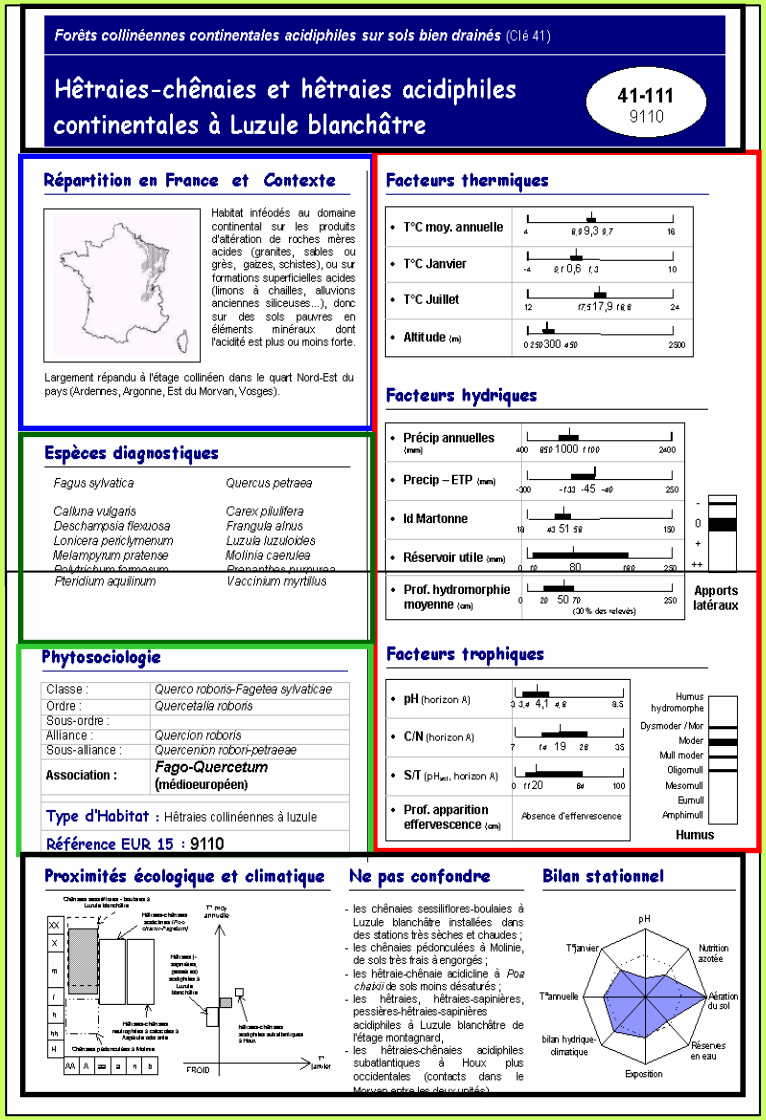
Use of bio-indicated trophic variables to investigate further the **productivity** of forest trees (e.g. already *Abies alba*, *Picea abies*, *Fagus sylvatica*)

Classification and ecology of French forest ecosystems (all relevés in north-east France are already classified), especially those with particular **patrimonial** or **conservation** interest

Quantitative characterisation of response of forest plant species/communities to **global change**

Many thanks/Vielen Dank !

Use of EcoPlant to characterise forest habitats



Forêts collinéennes continentales acidiphiles sur sols bien drainés (Clé 41)

Hêtraies-chênaies et hêtraies acidiphiles continentales à Luzule blanchâtre

41-111
9110

Répartition en France et Contexte

Habitat inféodés au domaine continental sur les produits d'altération de roches mères acides (granites, sables ou grès, gaizes, schistes), ou sur formations superficielles acides (limons à chailles, alluvions anciennes siliceuses...), donc sur des sols pauvres en éléments minéraux dont l'acidité est plus ou moins forte.

Largement répandu à l'étage collinéen dans le quart Nord-Est du pays (Ardennes, Argonne, Est du Morvan, Vosges).

Espèces diagnostiques

Fagus sylvatica	*Quercus petraea*
Calluna vulgaris	*Carex pilulifera*
Deschampsia flexuosa	*Frangula alnus*
Lonicera periclymenum	*Luzula luzuloides*
Melampyrum pratense	*Molinia caerulea*
Polytrichum formosum	*Rhaponticum pulchrum*
Pteridium aquilinum	*Vaccinium myrtillus*

Phytosociologie

Classe :	*Querco roboris-Fagetea sylvaticae*
Ordre :	*Quercetalia roboris*
Sous-ordre :	
Alliance :	*Quercion roboris*
Sous-alliance :	*Quercenion robori-petraeae*
Association :	***Fago-Quercetum*** **(médioeuropéen)**

Type d'Habitat : Hêtraies collinéennes à luzule

Référence EUR 15 : 9110

Facteurs thermiques

- T°C moy. annuelle
- T°C Janvier
- T°C Juillet
- Altitude (m)

Facteurs hydriques

- Précip annuelles (mm)
- Precip – ETP (mm)
- Id Martonne
- Réservoir utile (mm)
- Prof. hydromorphie moyenne (cm) (30 % des relevés)

Apports latéraux

Facteurs trophiques

- pH (horizon A)
- C/N (horizon A)
- S/T (pH_{act}, horizon A)
- Prof. apparition effervescence (cm) Absence d'effervescence

Humus hydromorphe, Dysmoder / Mor, Moder, Mull moder, Oligomull, Mesomull, Eumull, Amphimull

Humus

Proximités écologique et climatique

FROID

Ne pas confondre

- les chênaies sessiliflores-boulaies à Luzule blanchâtre installées dans des stations très sèches et chaudes ;
- les chênaies pédonculées à Molinie, de sols très frais à engorgés ;
- les hêtraie-chênaie acidicline à *Poa chaixii* de sols moins désaturés ;
- les hêtraies, hêtraies-sapinières, pessières-hêtraies-sapinières acidiphiles à Luzule blanchâtre de l'étage montagnard,
- les hêtraies-chênaies acidiphiles subatlantiques à Houx plus occidentales (contacts dans le Morvan entre les deux unités)

Bilan stationnel

pH, Nutrition azotée, Aération du sol, Réserves en eau, Exposition, bilan hydrique-climatique, T°annuelle, T°janvier

For each habitat

Habitat distribution

Ecology

Diagnostic species

Phytosociological classification

Summary diagrams

+ floristic composition within habitat

Neutroclines		
Hedera helix	**86**	**1,9**
Carpinus betulus	**83**	**2,4**
Corylus avellana	62	1,1
Viola reichenbachiana	54	2,2
Rosa arvensis	49	2,1
Polygonatum multiflorum	44	1,6
Carex sylvatica	43	1,2
Crataegus laevigata	40	1,6
Eurhynchium striatum	40	1,3
Lamium galeobdolon	40	1,1
Vicia sepium	40	2,8
Euphorbia amygdaloides	38	2,0
Prunus avium	33	1,8

Frequency index

Diagnostic index

Relative abundance