Adapting the GIS-coop experimental networks to the climate change challenge
- Sessile oak as an example

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1. Introduction: GIS coop

GIS coop founded in 1994: ‘cooperative of data on forest stands growth’

- Members: CPFA, FCBA, IDF-CNPF, AgroParisTech, INRA, Irstea, ONF and supported by the ministry of agriculture and forest

Aims:

- Acquisition and pooling of data on trees and stands growth in order to model growth and productivity of forests stands
- By setting up and monitoring long term experiments covering all environmental and sylvicultural conditions

Studied systems:

- Sessile and pedunculate oaks
- Laricio pine
- Maritime pine
- Douglas
- Mixed forests
1. Introduction: GIS coop

Experimental design:

Sampling design: covering the whole production area
1. Introduction: GIS coop

Experimental design:

Sampling design: covering the whole production area
Site-index based sampling design in each region
1. Introduction: GIS coop

Experimental design:

Sampling design: covering the whole production area

Site-index based sampling design in each region

Long term sylvicultural experiment

Stand densities experiments
Introduction: GIS coop

Experimental design:

- **Sampling design:** covering the whole production area
- **Site-index based sampling design in each region**

**Spatial scales**

- **Tree**
- **Stand**
- **Ressource**

**Long term sylvicultural experiment**

**Stand densities experiments**

**Studying recruitment/growth/mortality processes**

**Studying**

- **htot**
- **htot**

**Experimental design:**

- **Ressource**
- **Stand**
- **Spatial scales**
1. **Introduction: evolution of needs**

**Why do we want to change anything?**
- Environmental changes: how sylvicultural practices can modulate their effects
- Including environmental factors in growth models

**Site index is not enough:**
- Productivity changes: temporal variability of site index
- A single site index may correspond to different environmental conditions

(Bonlemps et al., 2012)
1. Introduction: evolution of needs

→ Changes in aims of the GIS coop: a better consideration of environmental conditions in experimental networks

→ Changes in protocols:
   - Increase the geographical range of networks
   - Improving the description of environmental conditions
   - Modification of the sampling strategy: stratifying networks by environmental factors
Introduction: rethinking the sampling strategy

Today’s talk

Travail initié par Valentine Lafond en 2009
2. Modelisation

Aim: to highlight major environmental factors explaining growth

Comparison of two modelling methods: GAMs and Random Forests

- Improve robustness of results
- Random Forests integrate all candidate variables

Comparison of two growth parameters: basal area increment and site index

- Site index less dependant on sylvicultural practices
- Differences in environmental factors affecting these two parameters?
2. Modelisation: data

NFI data: 167,876 forest plots between 1987 and 2014

- 34,661 stands with sessile oak across France
- 2,350 pure and even-aged stands: basal area increment (BAI)
- 1,514 pure and even-aged stands: site index (SI)
2. Modelisation: data

- Basal area increment: from 0 to 3.2 m²/ha/year
- Site index: from 5 to 40 m at 100 years (Duplat)
- Weak relationship between basal area increment and site index...

Environmental factors included in models:

- Climatic: (seasonnal) mean, min and max temperature, precipitations, climatic water balance and annual radiations
- Soil: soil water capacity, C:N ratio, pH, S:T ratio, permanent and temporary waterlogging
- Stand RDI and dominant height (BAI) or dominant age (SI)
2. Modelisation: basal area increment

GAMs

- Nb. variables: 8
- Expl. dev.: 54 %
- Expl. dev. stand: 43 %
- Expl. dev. enviro: 11 %

RandomForests

- 32 (all)
- 54 %
- 28 %
- 26 %

Stand effect
## 2. Modelisation: basal area increment

### GAMs

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### RandomForests

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**Stand effect**

**Same variable and ‘position’**

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*GAMs Diagram*:

- Explained deviance (%)
- Variables: RDI, c_H0, m, ET_L2, CN, pH, Tmin_1212, RUM_90cm, BHT5_345

*RandomForests Diagram*:

- Explained deviance (%)
- Variables: RDI, c_H0, m, RUM_90cm, ET_L2, CN, pH, BHT5_678
2. Modelisation: basal area increment

- GAMs
  - Nb. variables: 8
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- RandomForests
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**Stand effect**

**Same variable and 'position'**

**Same variable**
2. Modelisation: basal area increment

Concordance between partial response curves
## 2. Modelisation: site index

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**Stand effect**

- Same variable and *position*
- Same variable

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**Variable importance**

- c.Age0_an
- ET_2
- RUM_90cm
- CN_2
- pH_2
- Prec_6190_1212
- Tmin_6190_1212
- Tmax_6190_345
- AONIEB_6190_13
- BHe_6190_345
- Tmin_6190_345
## 2. Modelisation: site index

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### Same variable
- Stand effect
- Same variable and ‘position’
- Same variable
- Different variable but present in the basal area increment model

### Variable importance
- c.Age0_an
- ET_2
- RUM_90cm
- CN_2
- pH_2
- Prec_6190_1212
- Tmax_6190_345
- Tmax_6190_1212
- ADN_6190_345
- PHe_6190_345
- Tmin_6190_345
2. Modelisation: synthesis

GAMs vs. Random Forests
- Concordant results: (almost) same variables and shapes response curves
- GAMs: less variables for an equivalent quality

Basal area increment vs. site index
- Environmental factors more important for site index

Primary environmental factors for growth of sessile oak:
- Soil: temporary waterlogging, soil water capacity, pH, C:N ratio
- Climate (weak influence): spring climatic water balance (RF) and temperature, winter minimal temperature (GAMs)
3. Bibliographic analysis

Aim: to highlight major environmental factors explaining growth

Based on published studies linking growth to environmental factors.
Studying the whole distribution of species.

Questions:

- Do we observe similarities between studies?
- Are environment-growth relationships spatially coherent?
3. Bibliographic analysis: method

Bibliographic database investigated:
- Web of knowledge
- Docpatrimoine (AgroParisTech)

Requests criteria: species, growth, environment
Selection criteria: title, abstract, whole article

Two levels of studies included in the bibliographic database:
- Qualitative analysis → reading notes
- Quantitative analysis → extraction of relationships data: significance, signs of the relationships
3. Bibliographic analysis

References studied: ~ 280

- 50 integrated to the bibliographic database
- 23 with quantitative relationships: 19 radial growth; 2 distribution; 2 height growth

- 1097 variables tested
- 288 variables significant or integrated in models
  \[\rightarrow\] classified by season and climatic factor (hydric/thermic)
3. Bibliographic analysis: global results

Proportion of significant variables

- Thermique
  - Hiver: 69
  - Printemps: 86
  - Été: 123
  - Automne: 81

- Hydrique
  - Hiver: 117
  - Printemps: 156
  - Été: 234
  - Automne: 146
3. Bibliographic analysis: global results

Proportion of significant variables

Signs of the relationships
3. Bibliographic analysis: spatial differentiation

- **Atlantic**
  - United Kingdom
  - West of France
  - North of Spain

- **‘Central’ zone**
  - East of France
  - Germany

- **Continental**
  - Czech Republic
  - Romania
  - Poland
3. Bibliographic analysis: spatial differenciation

Atlantic

‘Central’ zone

Continental

- Spring and summer hydric factors are the most important.
- Thermic factors are more variables:
  - Important in the continental zone
  - Weak in the central zone
  - Depending on seasons in the Atlantic zone
3. Bibliographic analysis: spatial differenciation

- Positive role of hydric factors
- Mostly negative role of summer thermic factors (how to explain positive ones)
- Signs of spring and autumn thermic factors unstables
- Difference in the sign of winter thermic factors between the central and the other zones
3. Bibliographic analysis: synthesis

Precipitation and temperature are the most tested variables: dendrochronological approach

Global scale:
- Spring and summer hydric factors are the most important
- No clear differences between seasons for thermic factors

From atlantic to continental conditions:
- Hydric factors more important in the ‘central’ area
- Inversion of the sign of relationship with the winter thermic factors
- Thermic factors more important for atlantic and continental than central areas
4. Discussion

Agreement between approaches:
- Importance of hydric factors during spring
- Importance of winter thermic factors (GAM models)

Disagreements:
- Importance of soil factors
- Importance of thermic factors during summer and autumn
- Importance of summer hydric conditions
4. Discussion

Are the two approaches comparable?

Winter temperature
Site index analysis
4. Discussion

Are the two approaches comparable?

Winter temperature
Site index analysis

East

West

GAM: Site index 100 years (m)

Winter minimal temperature (°C)
4. Discussion

Are the two approaches comparable?

Winter temperature
Site index analysis

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GAM - Site index 100 years (m) vs Winter minimal temperature (°C)
4. Discussion

Are the two approaches comparable?

Winter temperature
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East and West comparison chart:
- Model: East (+) vs. West (-)
- Bibliography: Both (-)

GAM: Site index 100 years (m)

Winter minimal temperature (°C)
4. Discussion

Comparison of the two approaches:

- Models: spatial response of species along environmental gradients
- Dendrochronology: temporal response of species in a given place

→ Is it possible and how to synthetise this information?
4. Discussion

Comparison of the two approaches:

- Models: spatial response of species along environmental gradients
- Dendrochronology: temporal response of species in a given place

→ Is it possible and how to synthetise this information?

Perspectives:

- Finalising analyses for other species: pedunculate oak, maritime and laricio pine, Douglas and silver fir
- Defining the new sampling design: same for all species?
- Monitoring current and future state of networks according to the new sampling design
Thank you!

Questions?