Viability analysis of ForCEEPS for management decision support

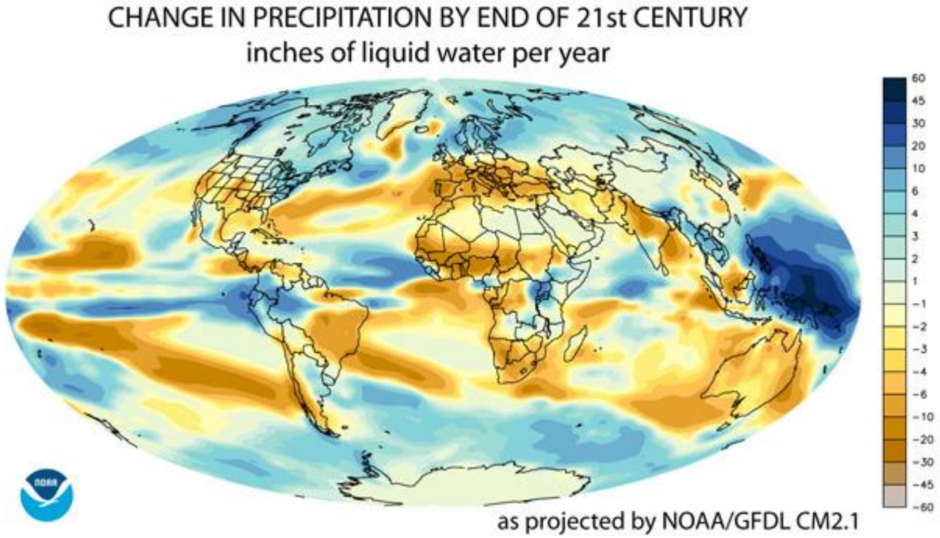
Malara M., Mathias J-D., Pichancourt J-B. and **Jourdan M.**

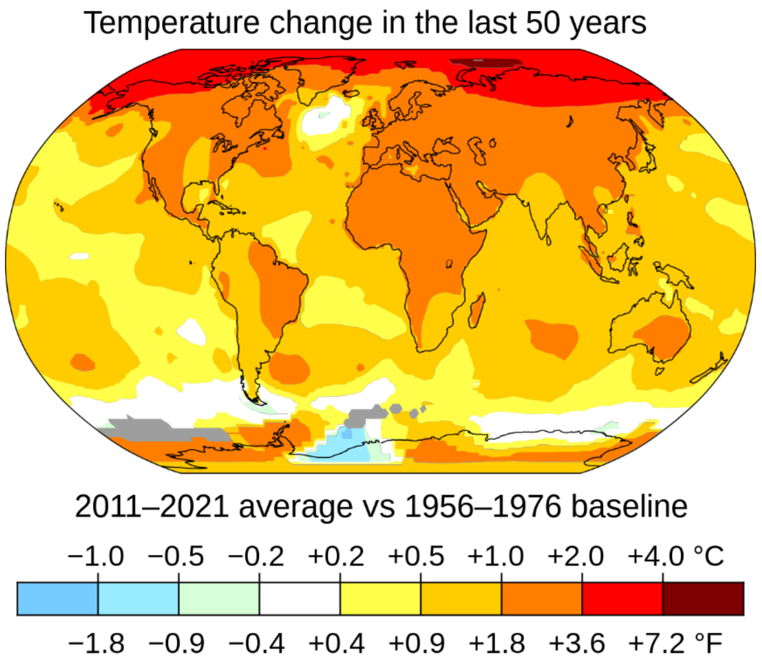
UMR Silva

INRAE

UR LISC

FOREM 2024 – Marion Jourdan


CHANGE IN PRECIPITATION BY END OF 21st CENTURY
inches of liquid water per year
60
45
30
20
10
6
4
3
2
1
−1
−2
−3
−4
−6
−10
−20
−30
−45
−60
as projected by NOAA/GFDL CM2.1


Temperature change in the last 50 years
2011–2021 average vs 1956–1976 baseline
−1.0 −0.5 −0.2 +0.2 +0.5 +1.0 +2.0 +4.0 °C
−1.8 −0.9 −0.4 +0.4 +0.9 +1.8 +3.6 +7.2 °F


© Jan Eifert/dpa/picture-alliance

Context and Aim

Which affect :

- Forest functionning
- Its maintain
- ecosystems services

Context and Aim

Which affect :

- Forest functionning
- Its maintain
- ecosystems services

Can management modulate this effect ?

Context and Aim

Which affect :

- Forest functionning
- Its maintain
- ecosystems services

Can management modulate this effect ?

Which management for the future?

Which tools to help the decision?

Context and Aim

- **Forestry decision** support tool in a context of **multiple risks**

Context and Aim

- **Forestry decision** support tool in a context of **multiple risks**

- Crucial points :
  - **Forest dynamic** model with **management**

Context and Aim

- **Forestry decision** support tool in a context of **multiple risks**

- Crucial points :
  - **Forest dynamic** model with **management**
  - **Decision-making method**

    → satisfactory silvicultural itinerary

Context and Aim

- **Forestry decision** support tool in a context of **multiple risks**

- Crucial points :
  - **Forest dynamic** model with **management**
  - **Decision-making method**
    → satisfactory silvicultural itinerary
  - Analysis **method**

Context and Aim

- **Forestry decision** support tool in a context of **multiple risks**

- Crucial points :
  - **Forest dynamic** model with **management**
  - **Decision-making method**
    - → satisfactory silvicultural itinerary
  - Analysis **method**

- Solutions :
  - **Multi-agent mechanistic** model
  - **Control** theory
    - **+ genetic algorithm**
  - **Multivariate analysis** and **classification**

Method

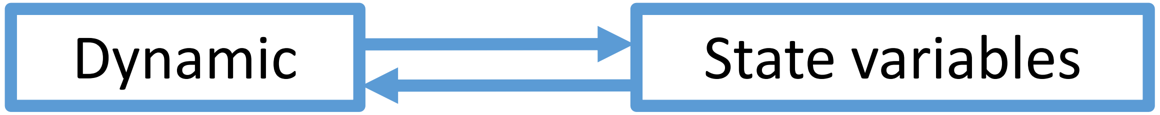
Define the control problem

Manage forest affected by climate change achieving objectives

Define the control problem

Manage forest affected by climate change achieving objectives

1) System, state variables x and its dynamic f

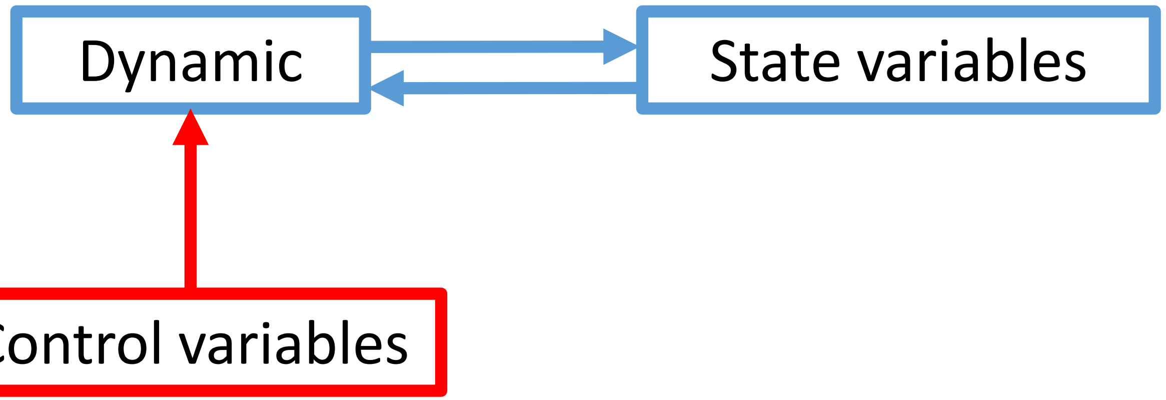


Define the control problem

Manage forest affected by climate change achieving objectives

1) System, state variables x and its dynamic f

2) Control u and its effect on the dynamic



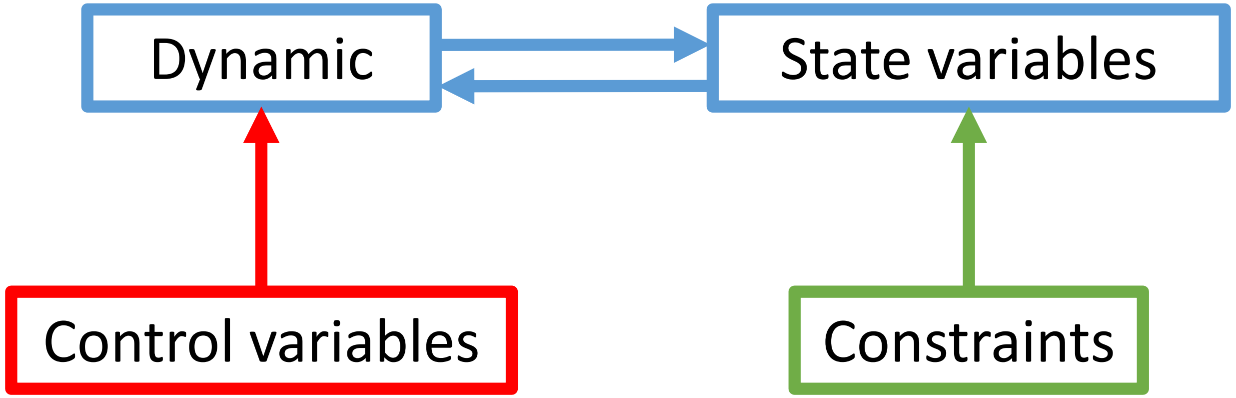
Define the control problem

Manage forest affected by climate change achieving objectives

1) System, state variables x and its dynamic f

2) Control u and its effect on the dynamic

3) Set of constraints K



Define the control problem

1) System, state variables x and its dynamic f

ForCEEPS model

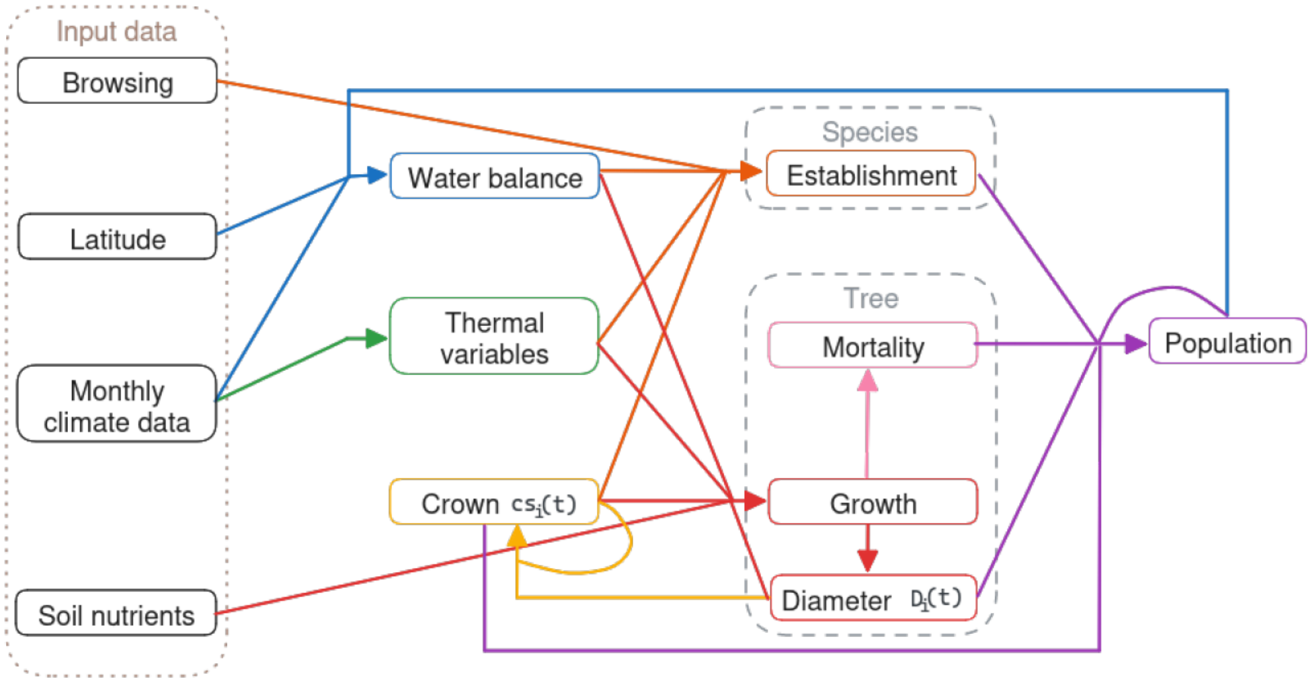
- gap-model
- multi-agent

Define the control problem

1) System, state variables x and its dynamic f

ForCEEPS model

- gap-model
- multi-agent



inspired by Morin et al. (2021)

Strong points:

- Management
- Climate effect :
  → regeneration, growth, mortality
- Long-term simulation
- Calibration for French forest

Define the control problem

1) System, state variables x and its dynamic f
2) Control u and its effect on the dynamic

Actions associated with silvicultural itinerary

- Regeneration
- Thinning

Define the control problem

1) System, state variables x and its dynamic f
2) Control u and its effect on the dynamic

Actions associated with silvicultural itinerary

- ~~Regeneration~~ → for further studies
- Thinning

Define the control problem

1) System, state variables x and its dynamic f

2) Control u and its effect on the dynamic

Actions associated with silvicultural itinerary

- ~~Regeneration~~ → for further studies
- Thinning

1) Time btw thinning

$\in$ [5, 10, 15, 20, 30, 40]

2) Thinning type

3) Objective basal area

% ou Gobj $\in$ [15, 20, 25, 30]

Define the control problem

1) System, state variables x and its dynamic f
2) Control u and its effect on the dynamic
3) Set of constraints K

Economical/ecological objectives

Define the control problem

1) System, state variables x and its dynamic f
2) Control u and its effect on the dynamic
3) Set of constraints K

Economical/ecological objectives

1) Production
   Cut wood> 3,1 m³/ha/an

2) Forest density
   Basal area > 10 m²/ha

3) Specific diversity
   Species number > 2

4) Structural diversity
   Gini of diameter ∈ [0,25 : 0,75]

5) Ecosystem health
   Mortality rate < 25%

Fix control problem

- Complex model
- Large set of control
  - Over 80 years = between 4 and 16 interventions → with 3 characteristics each
- Exhaustive exploration impossible

Fix control problem

- Complex model
- Large set of control
  - Over 80 years = between 4 and 16 interventions → with 3 characteristics each
- Exhaustive exploration impossible

Chosen solution: genetic algorithm

Fix control problem

- Complex model
- Large set of control
  - Over 80 years = between 4 and 16 interventions → with 3 characteristics each
- Exhaustive exploration impossible

Chosen solution: genetic algorithm

- Identify management itinerary that respect the constraints
- Translation of control problem into a genetic problem

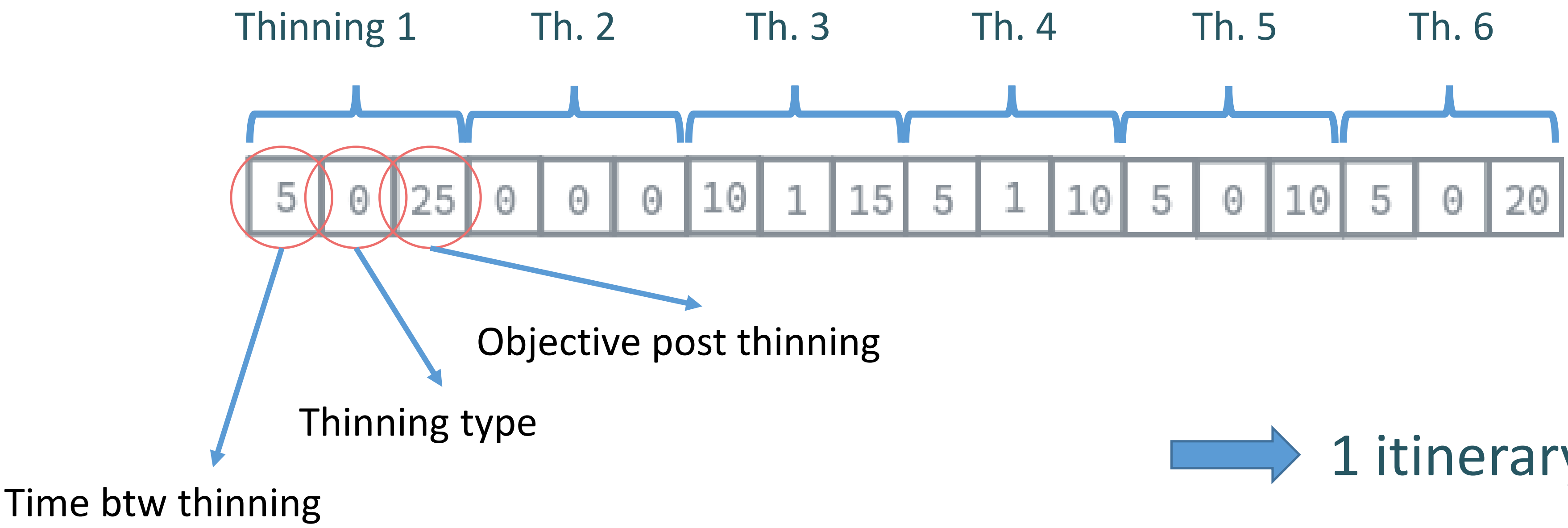
Genetic algorithm

Genetic algorithm

- **Individu** = problems solution
  - **Genome** = management itinerary
  - **Gene** = control variables (interventions characteristic = 3)

Genetic algorithm

- **Individu** = problems solution
  - **Genome** = management itinerary
  - **Gene** = control variables (interventions characteristic = 3)

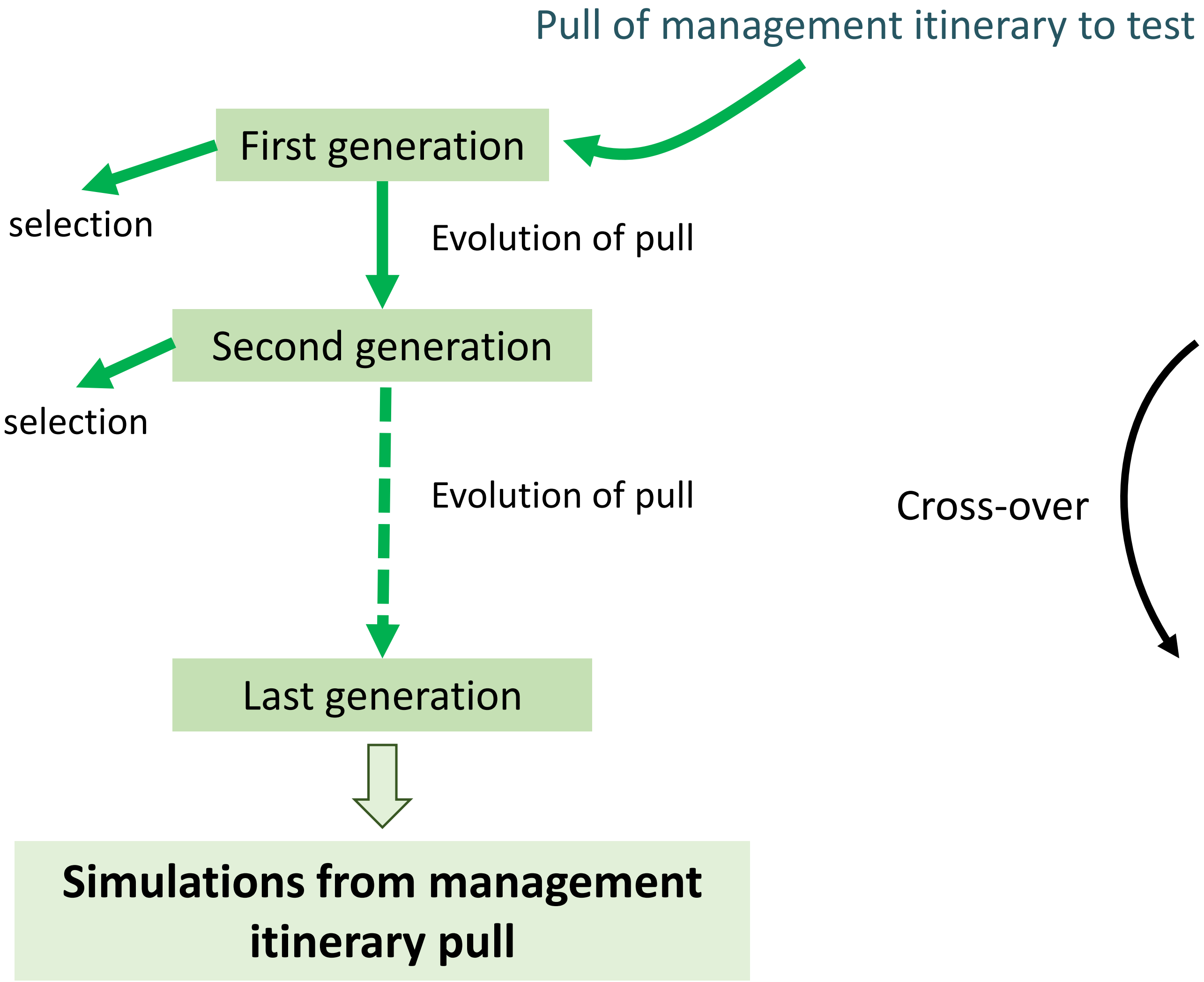


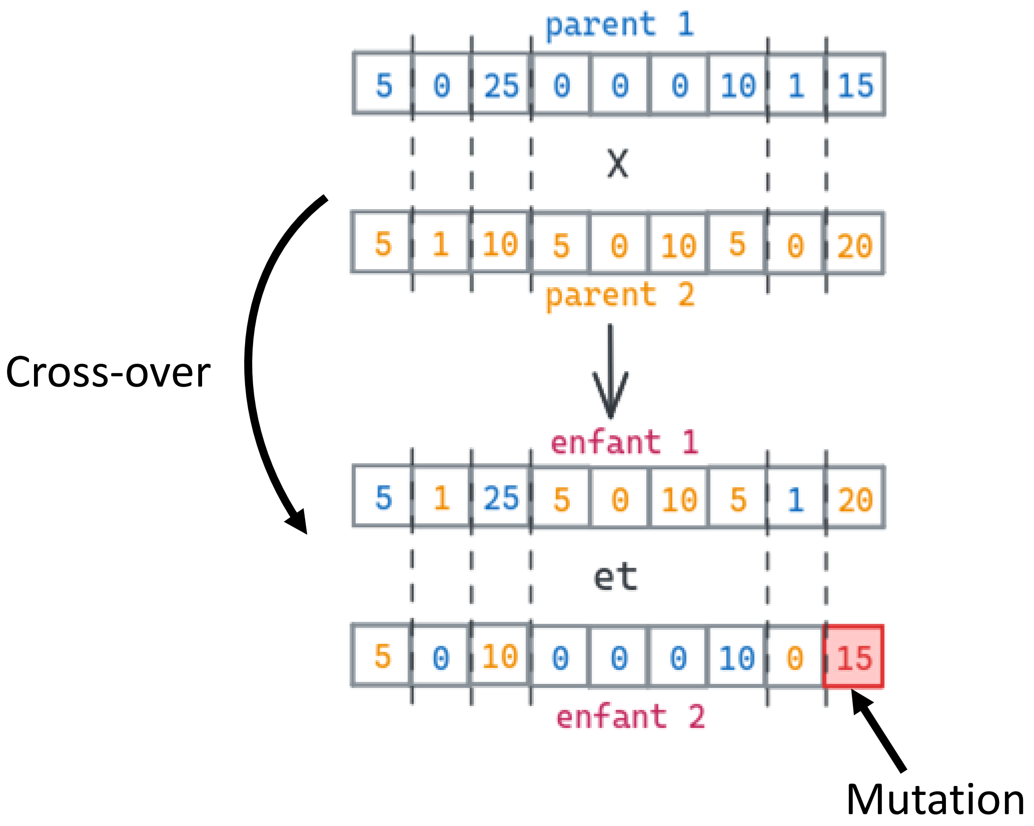
→ 1 itinerary = 30 runs

Genetic algorithm

- **Individu** = problems solution
  - **Genome** = management itinerary
  - **Gene** = control variables (interventions characteristic = 3)
- Classify solution
  - Respect of constraints

Genetic algorithm





from Malara et al (in prep)

Application of the method

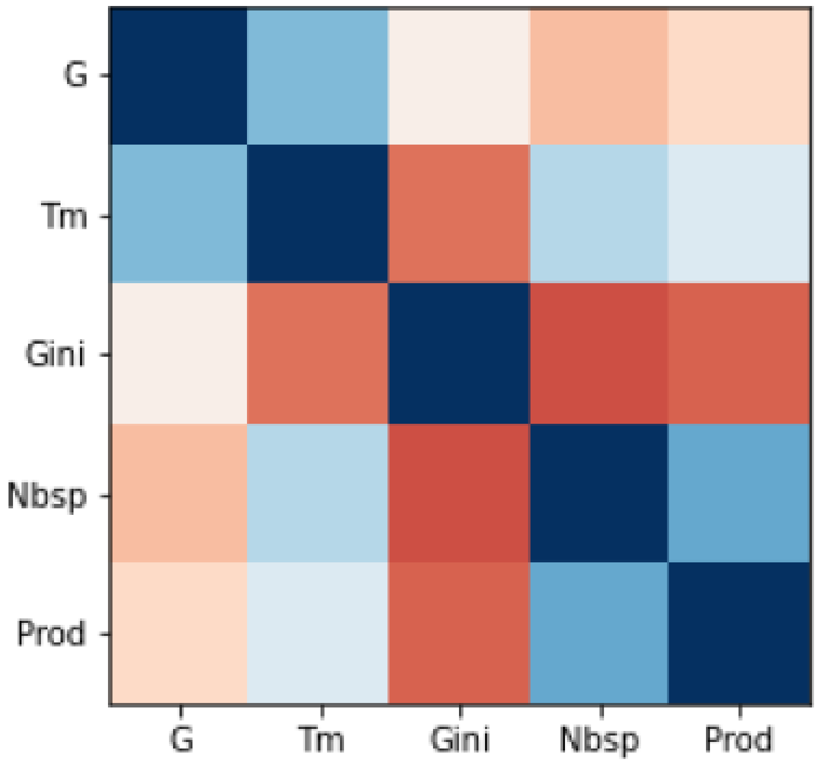
Case study

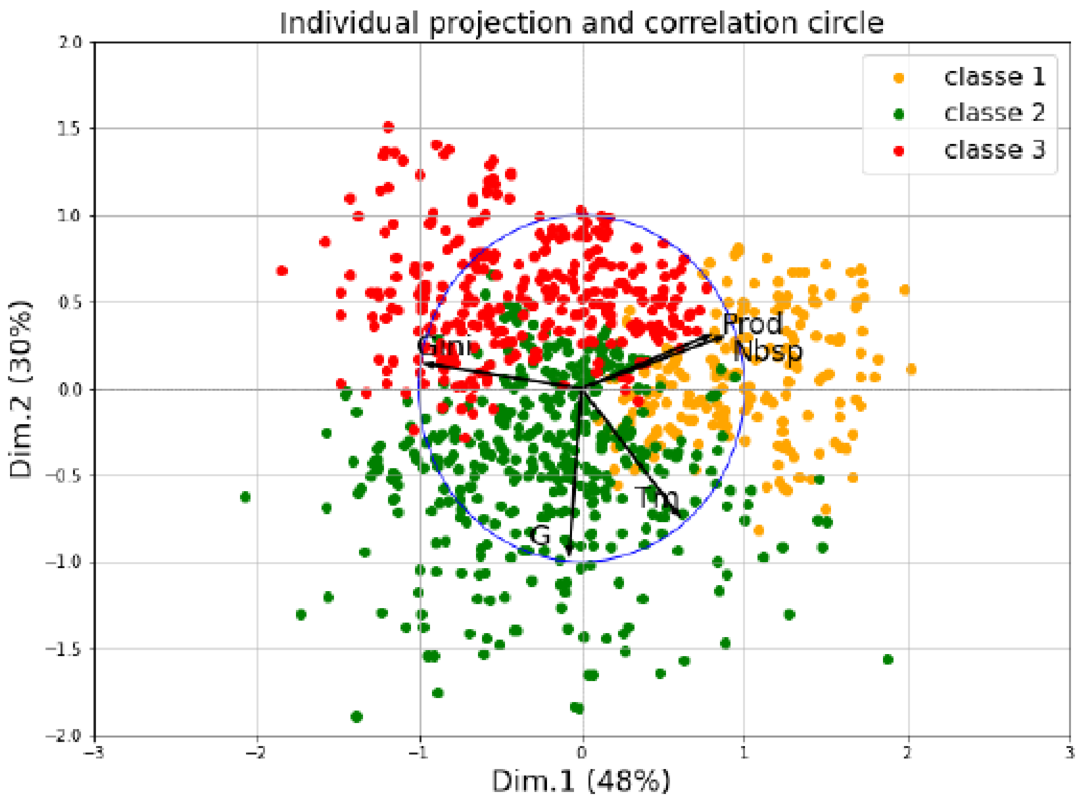
- « Forêt de Brun »
  - North-East of France
  - Sessile oak (*Quercus petraea*) and hornbeam (*Carpinus betulus*) forest

- Climatic data
  - 2 climatic scenarii : **RCP 4.5** et 8.5
  - 3 climatic models : **MPI** (CNRM and Hadgem)

Reduce dimension of constraints

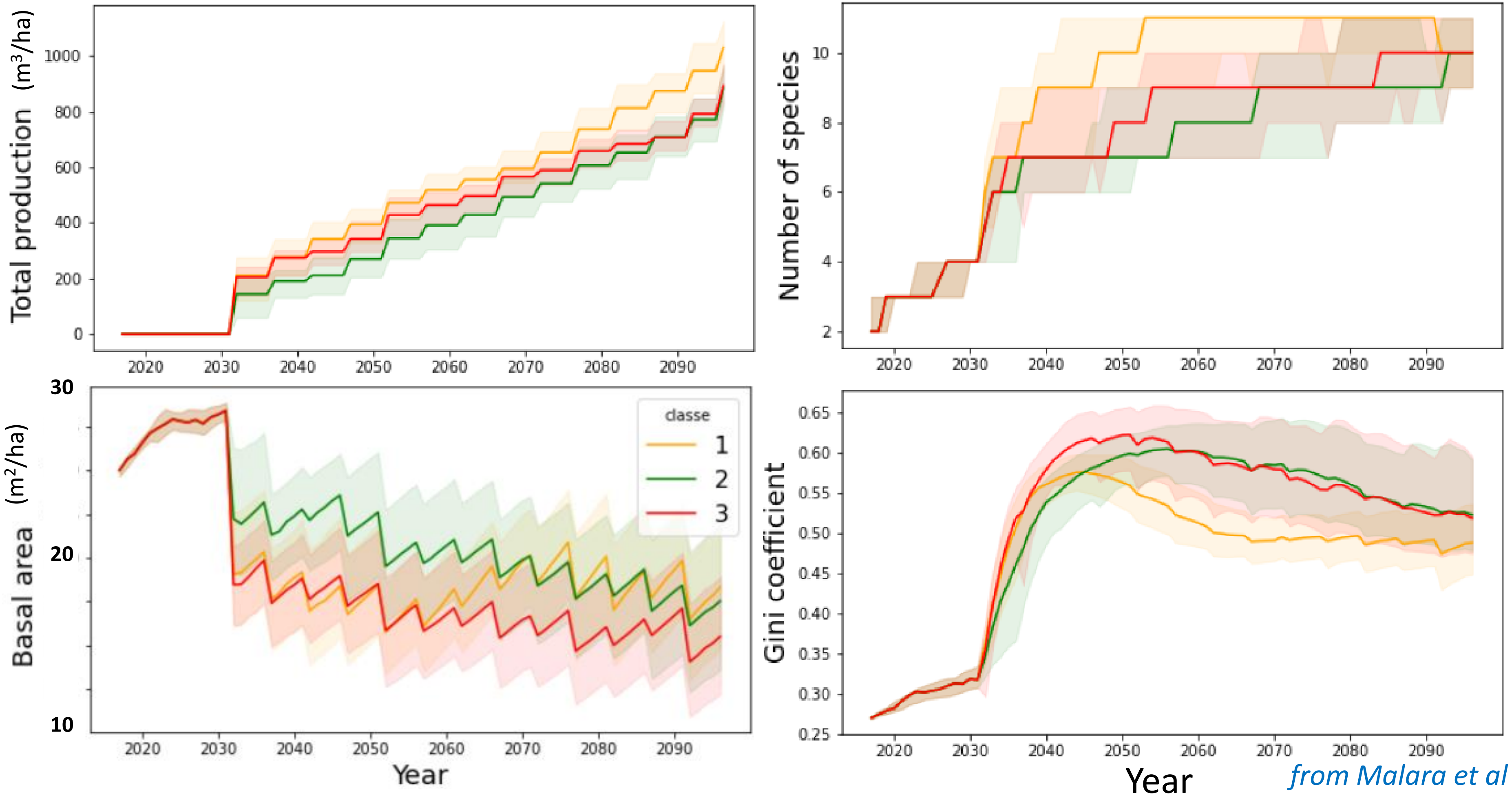
PCA of constraints





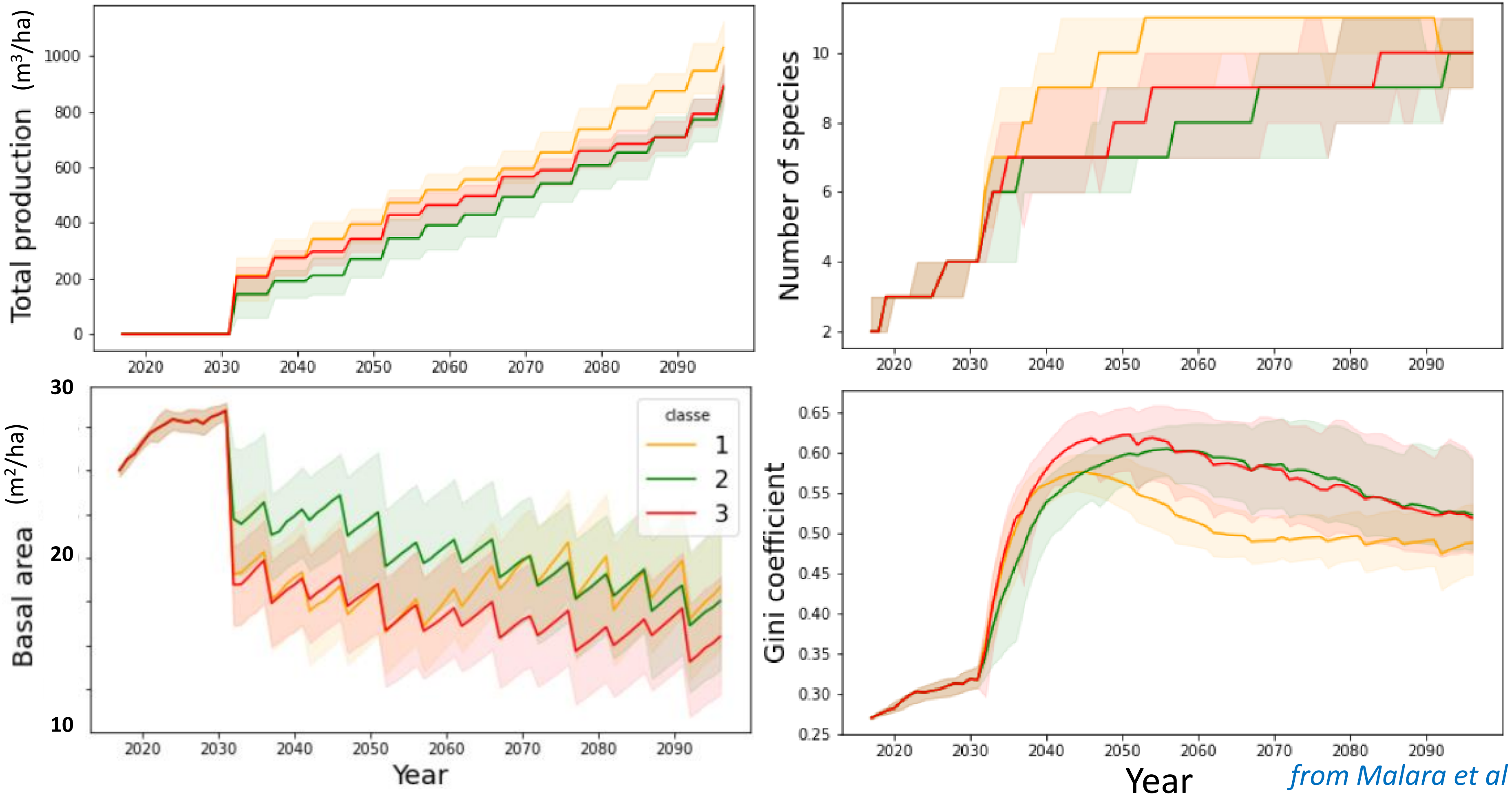
from Malara et al (in prep)

Impact of silvicultural itinerary on forest



from Malara et al (in prep)

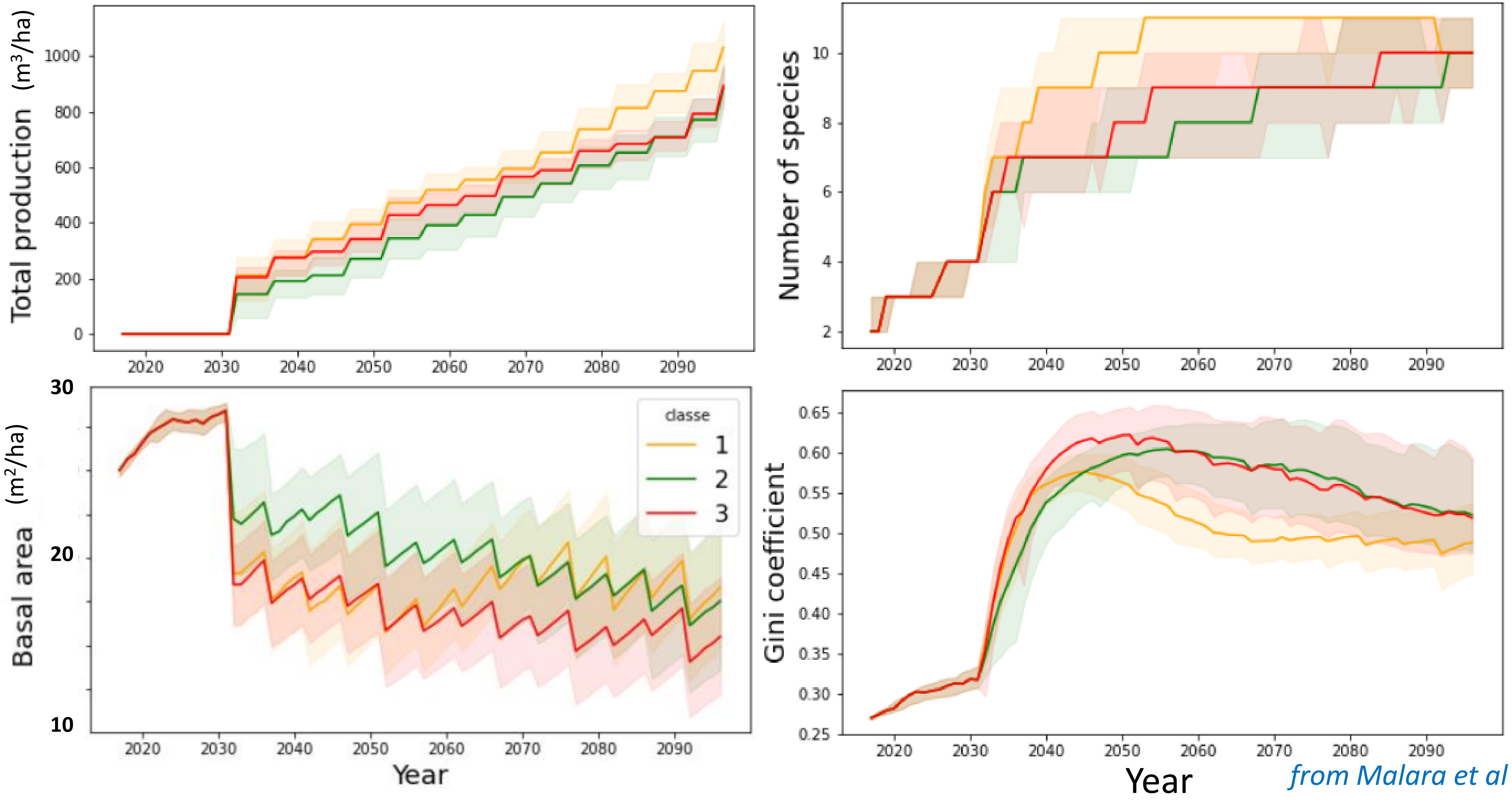
Impact of silvicultural itinerary on forest



from Malara et al (in prep)

- ➢ Differences btw groups are weak
  - → look at more contrasted itineraries

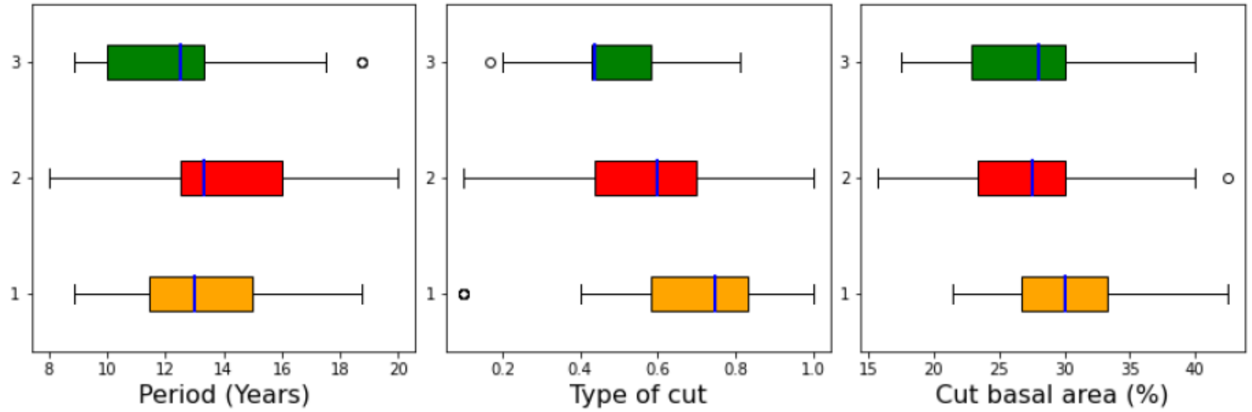
Impact of silvicultural itinerary on forest



from Malara et al (in prep)

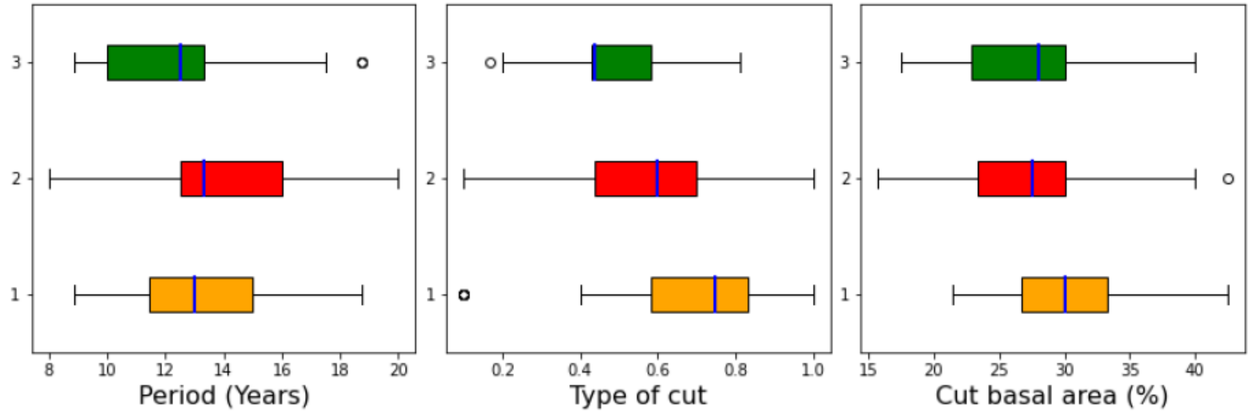
- ➢ Differences btw groups are weak
  - → look at more contrasted itineraries
- ➢ Analysis on state variables
  - → Loubna Taleb intership

Management methods respecting constraints



from Malara et al (in prep)

Management methods respecting constraints



from Malara et al (in prep)

- Period btw two thinning : 13 years
- Thinning intensity btw 25 and 30 %
- From homogenous thinning to dominant trees thinning

- Differences btw groups are weak

  → look at more contrasted itineraries

Discussion and perspectives

- Discussion of results
  - Differences in management itineraries are weak

    → "not enough restrictive" constraints, extreme cases to be studied
  - Put into perspective with current management

- Discussion of results
  - Differences in management itineraries are weak
    - → “not enough restrictive” constraints, extreme cases to be studied
  - Put into perspective with current management
- Methodological contributions
  - Development of a new decision-making method
  - Soon available on CAPSIS ?

- Discussion of results
  - Differences in management itineraries are weak

    → "not enough restrictive" constraints, extreme cases to be studied
  - Put into perspective with current management

- Methodological contributions
  - Development of a new decision-making method
  - Soon available on CAPSIS ?

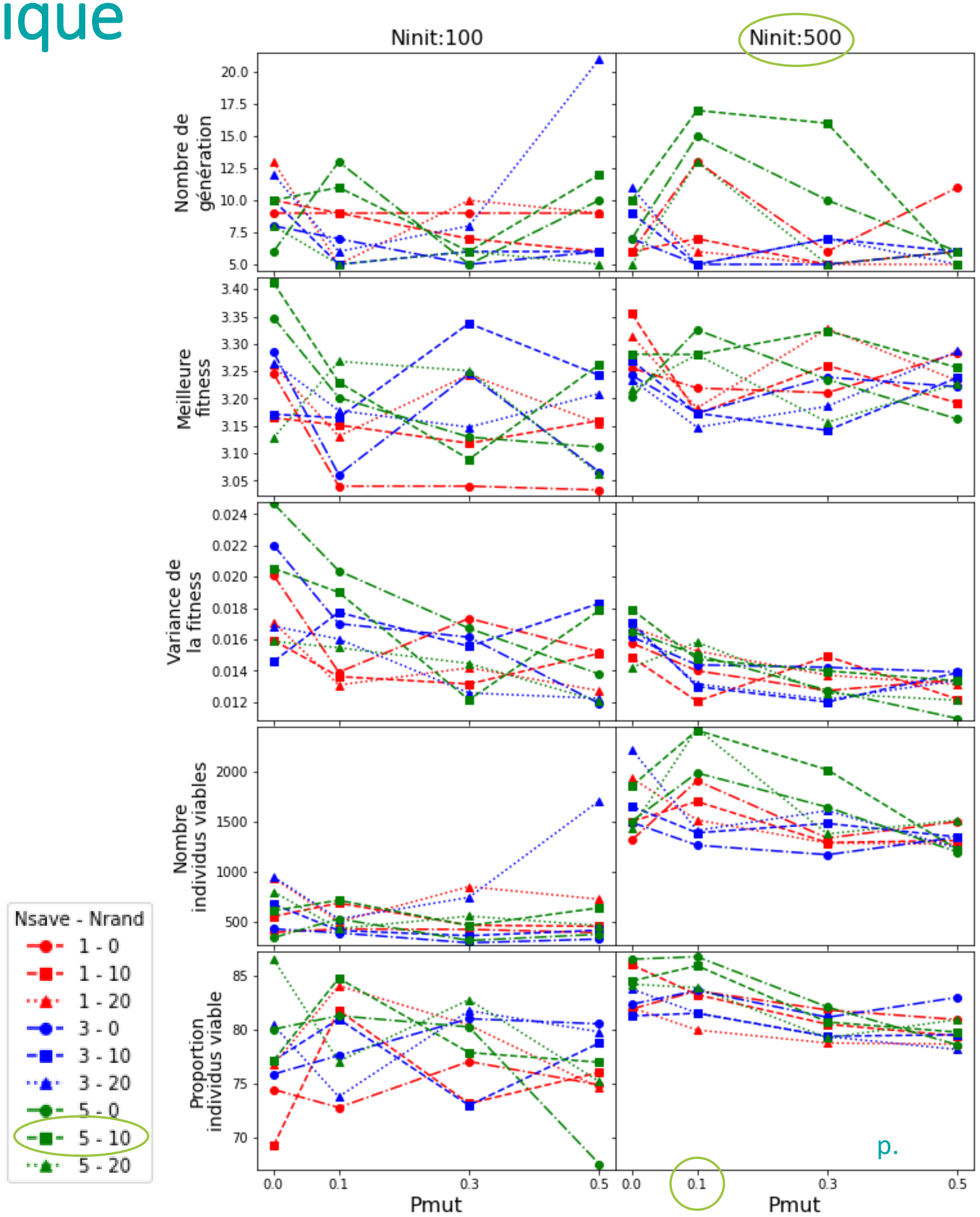
- Perspectives
  - Go further in interpretation
  - Add control variables: objective composition, control on regeneration,…

Thank you

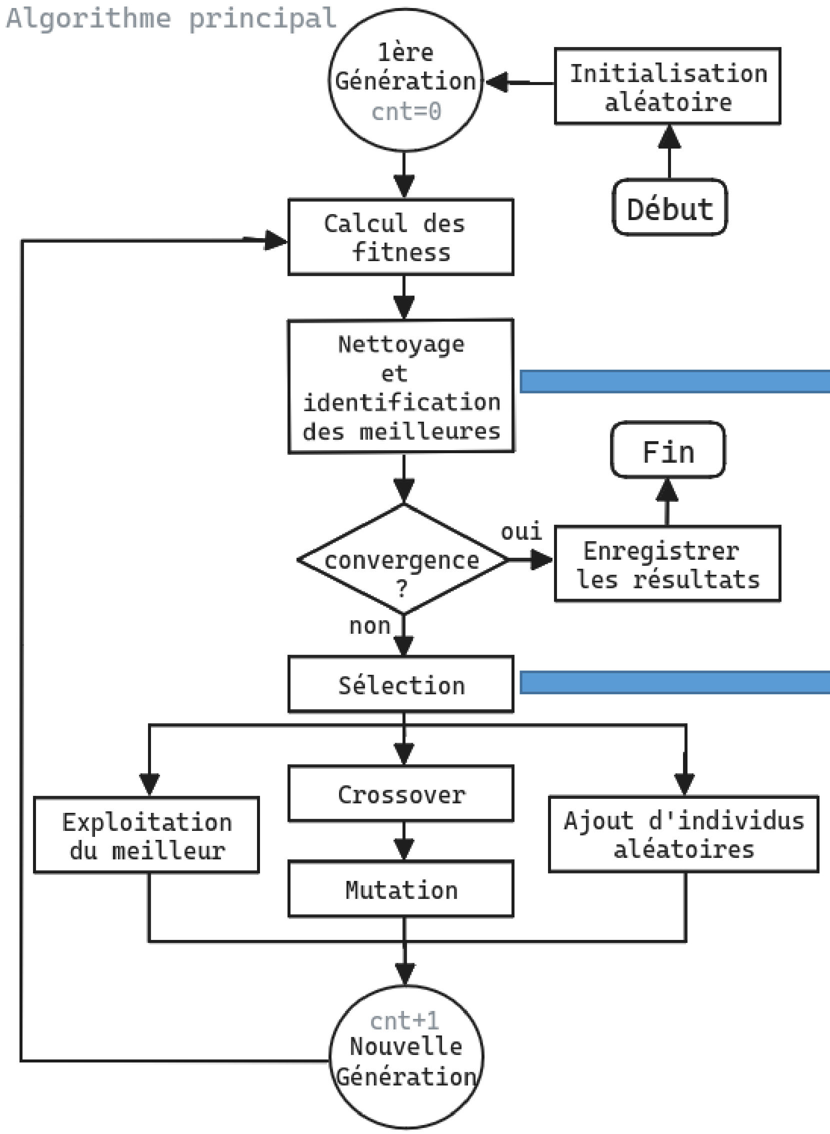
Algorithme génétique

Analyse de sensibilité

Ninit = 500
Nsave = 5
Pmut = 0,1
Nrand = 10



Genetic algorithm

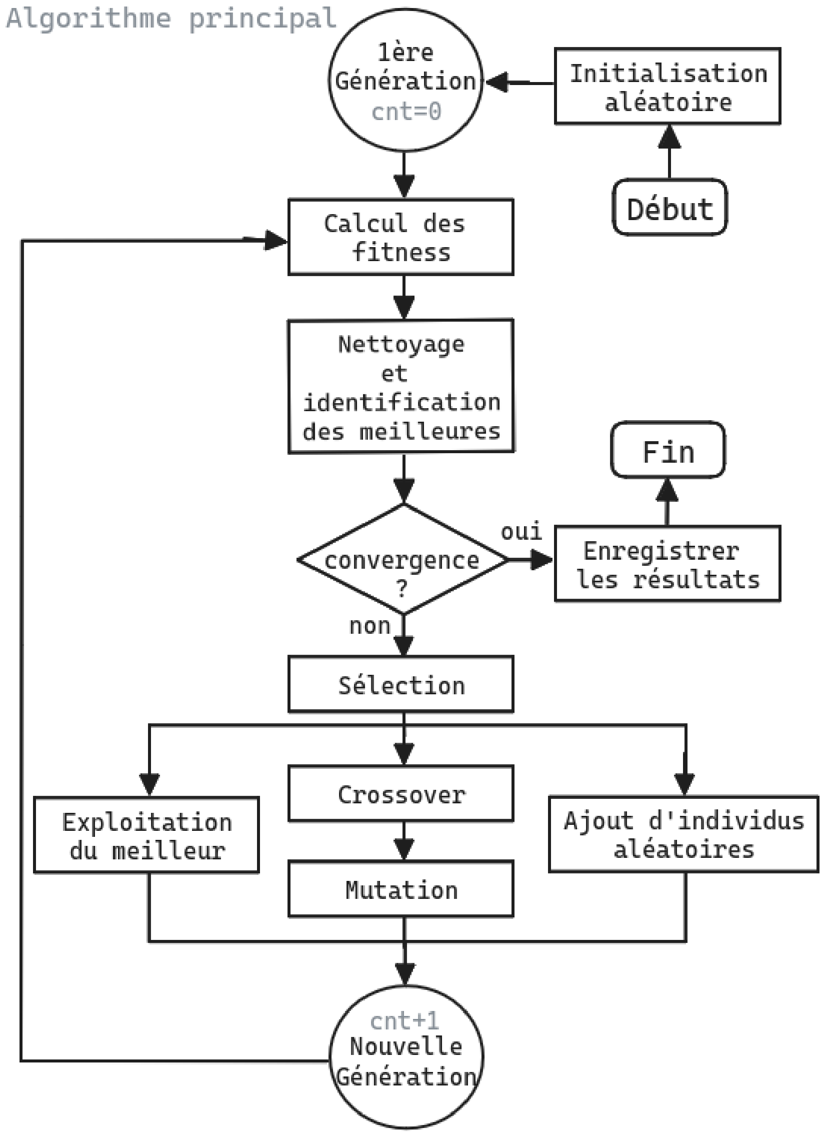


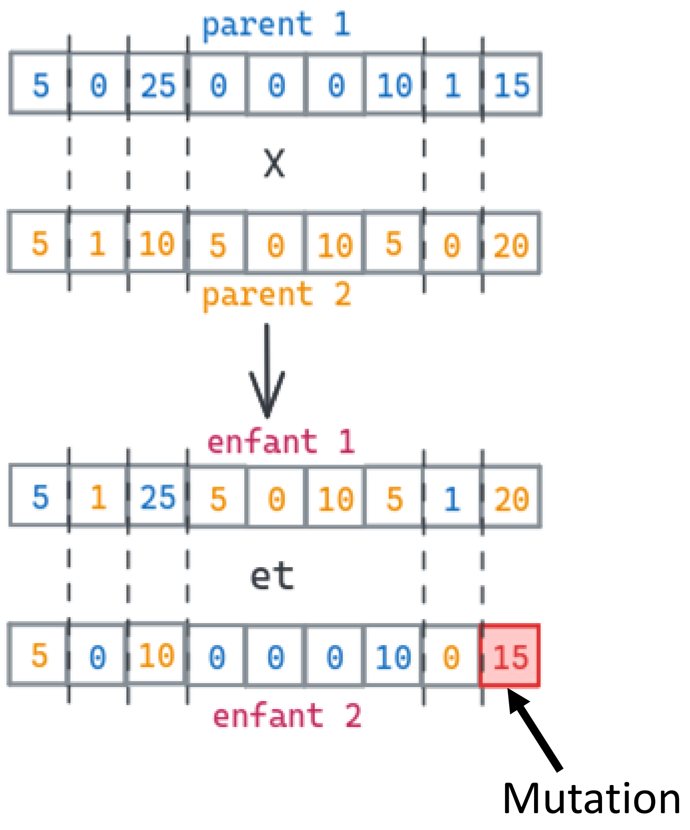
Elimination of silvicultural itinerary considered as unviable

Selection of silvicultural itinerary to keep for next generation

from Malara et al (in prep)

Genetic algorithm





from Malara et al (in prep)

	G 1	G 2	G 3
Wood production	1	3	2
Basal area	2	1	3
Species number	1	3	2
Gini coefficient	3	1	1
Mortality rate	=	=	=
Period	=	=	=
Type of cut	1	3	2
Cut intensity	1	3	3