Simulating the impact of forestry practices on a leguminous understory shrub and associated N fixation

Florian Delerue, Maya Gonzalez, François de Coligny, Céline Meredieu, Alain Mollier, Sylvain Pellerin, Pierre Trichet, Laurent Augusto

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The WOody Understory Dynamic in FORestry (WOUDYFOR) model

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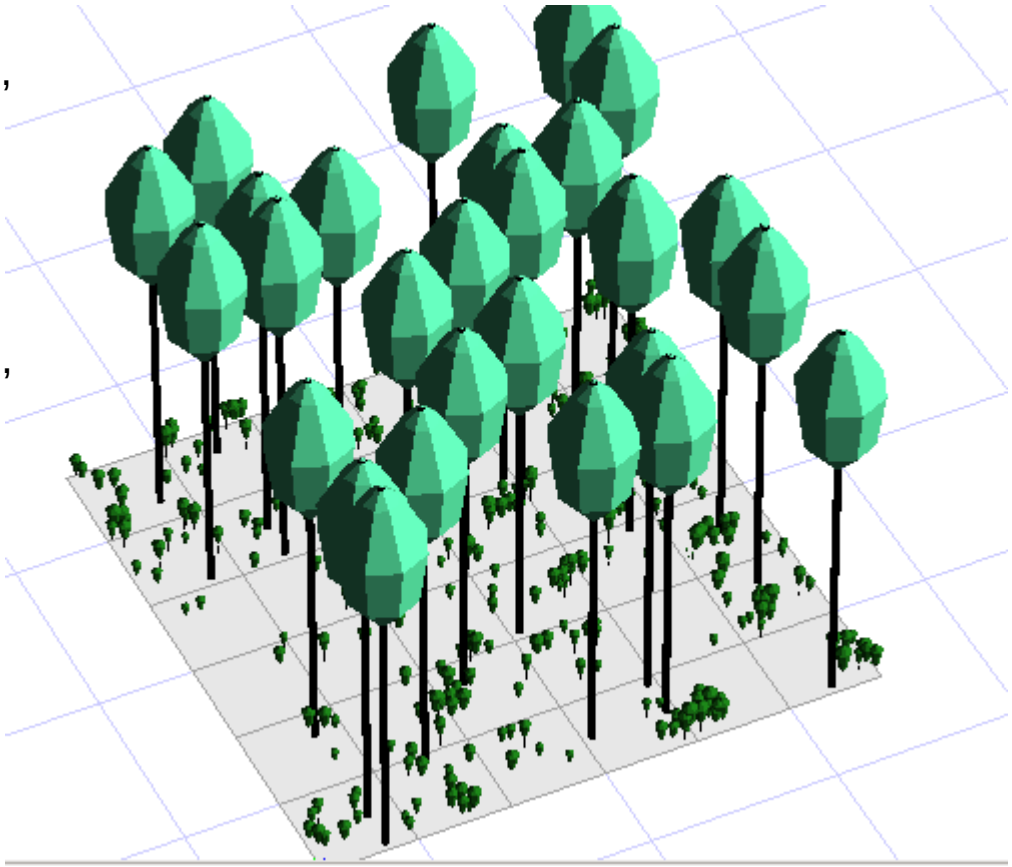
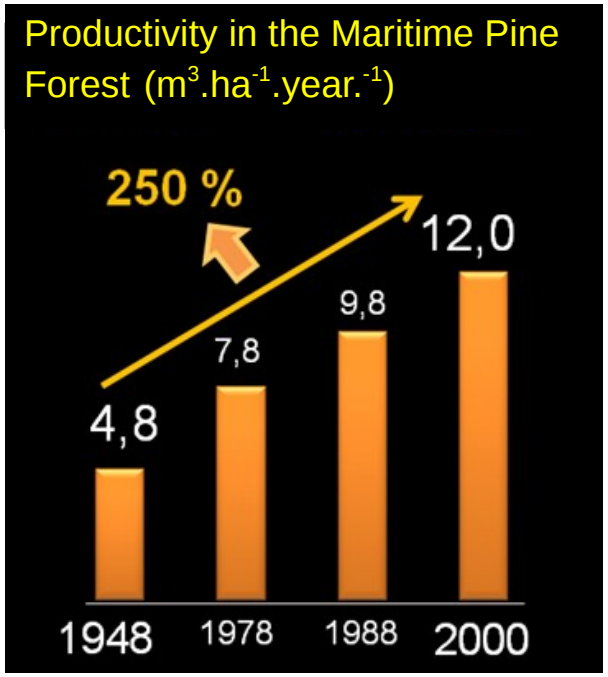




(data from National Forest Inventory)

Increasing wood productivity and the question of agronomic sustainability

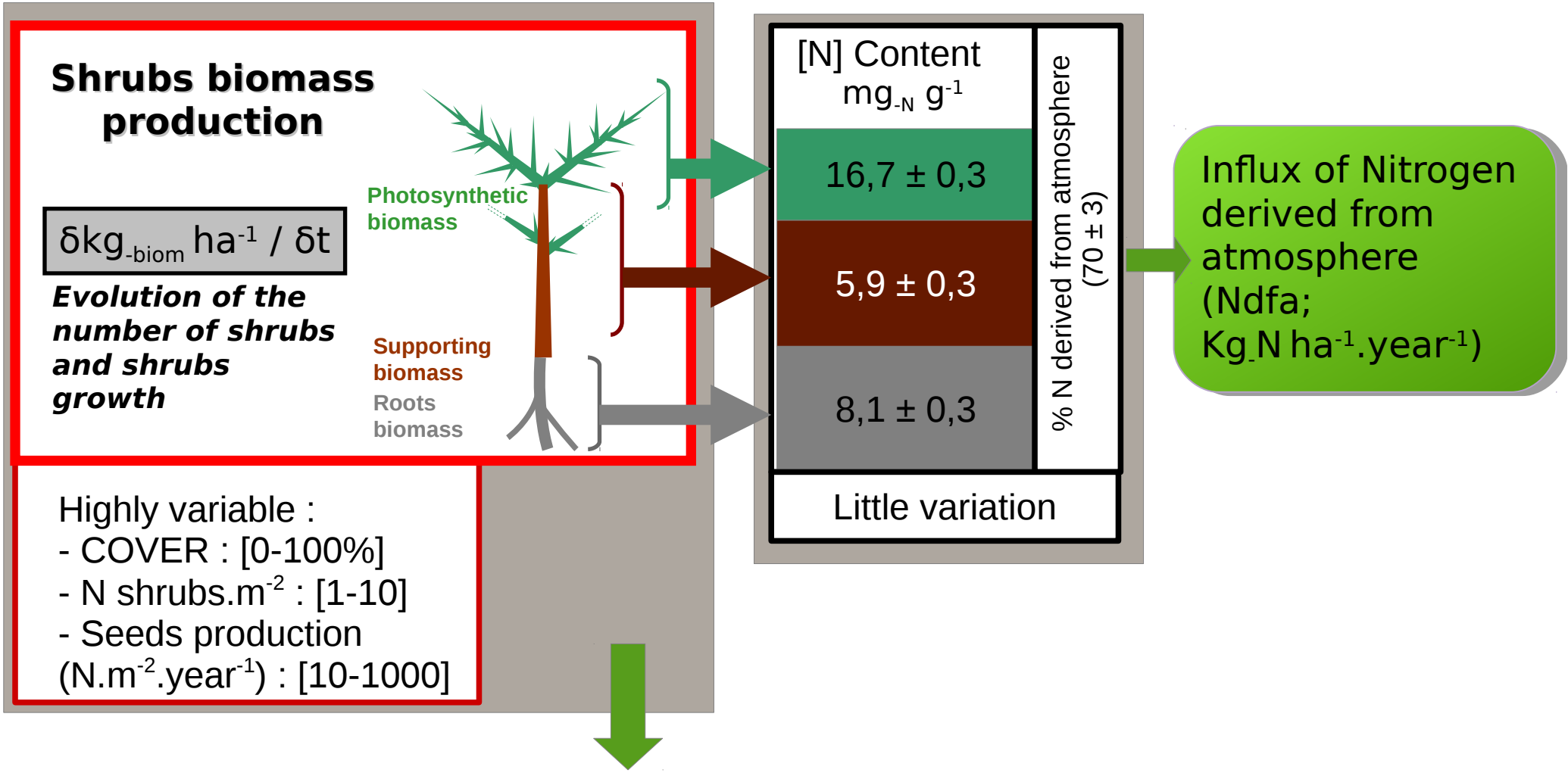
- Increasing demand of wood products for different uses : energy, paper, timber
- A cultivated forest growing on very poor sandy soils.
- Is it still possible to increase productivity in the maritime pine forest ? Without jeopardizing soils nutrient stocks ?

Spontaneous development of leguminous shrubs

Symbiotic nitrogen fixation by *Ulex europaeus* could represent an **important influx of N in forest stands** and contribute to the maintenance of soil fertility regarding this major nutrient

Ulex europaeus
Present: 60% , Abundant: 18%

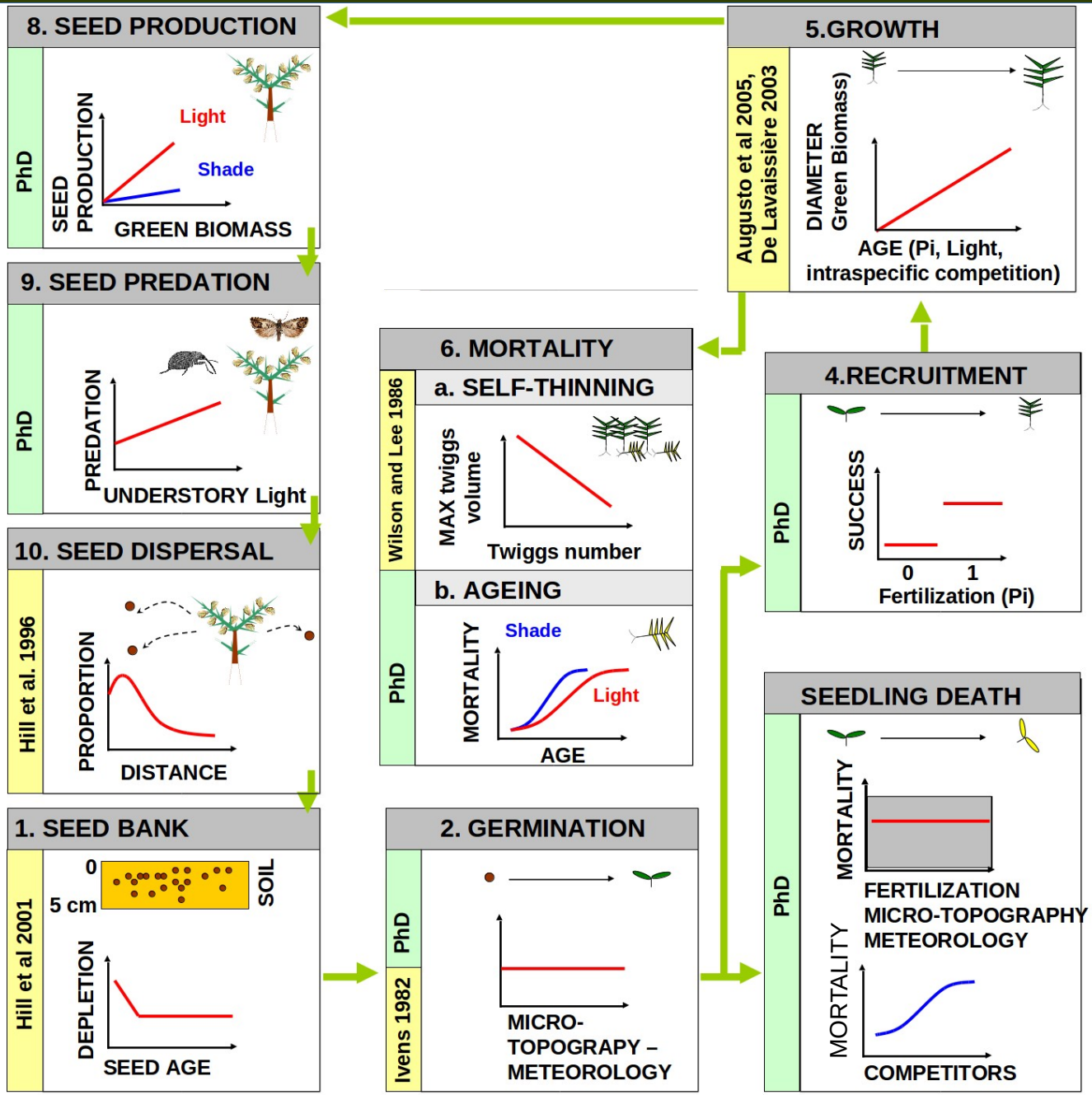
From the estimation of N influx to an ecodynamic model



Caculation of the influx of N derived from atmosphere is based on an **ecodymanic model** in the context of pine forestry ; the **WOUDYFOR** model.
The model has to simulate the shrubs dynamics according to different set of forestry practices (present and in development)

The model is based on the fine knowledge of the target species life cycle

- **Heliophilous** species (more present in pioneer phases of vegetation development)



The model part 1: the life cycle of the species in a forestry context

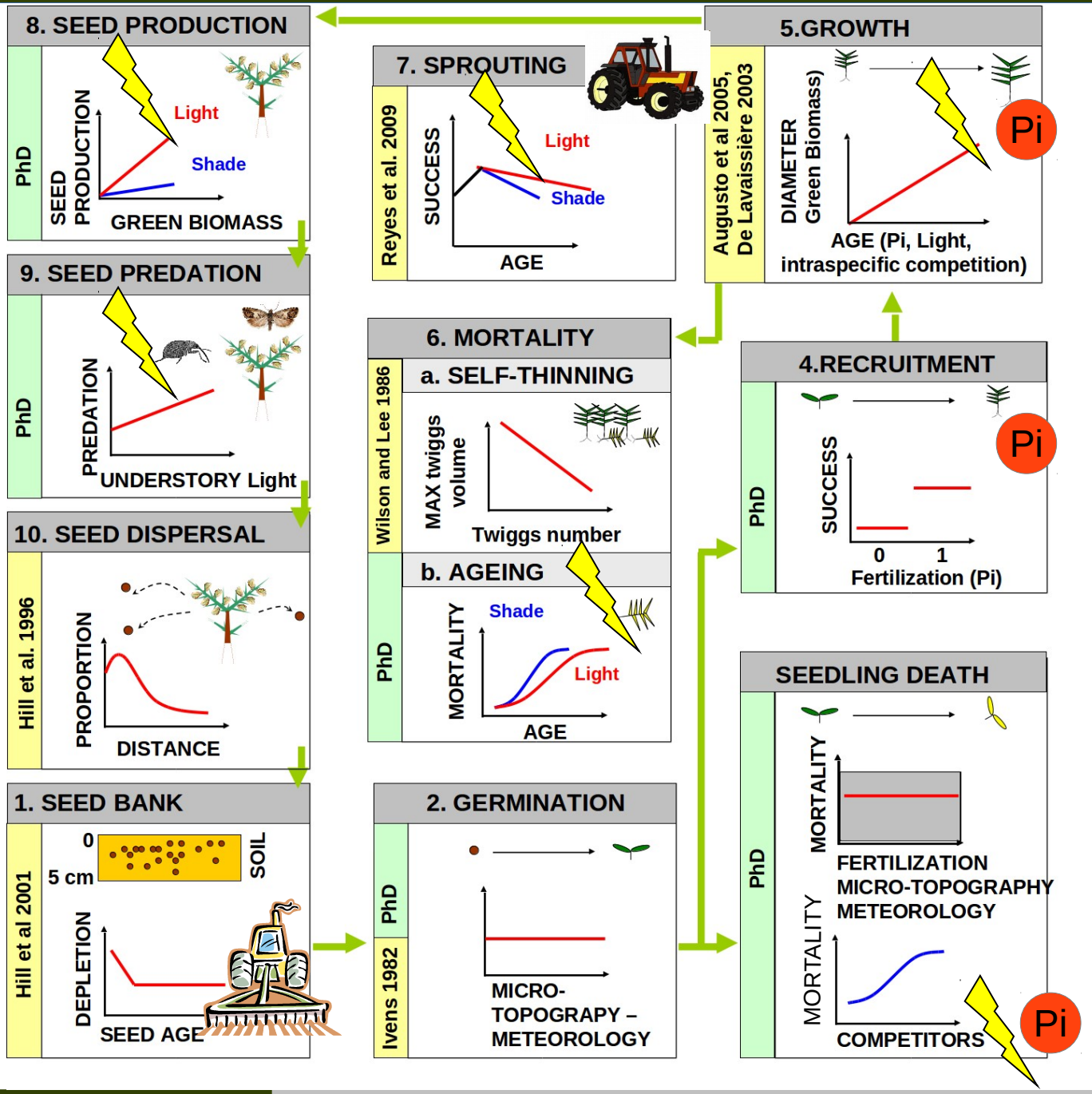
Understory light through pines canopy

Pi Fertilization in $P_2 0_5$

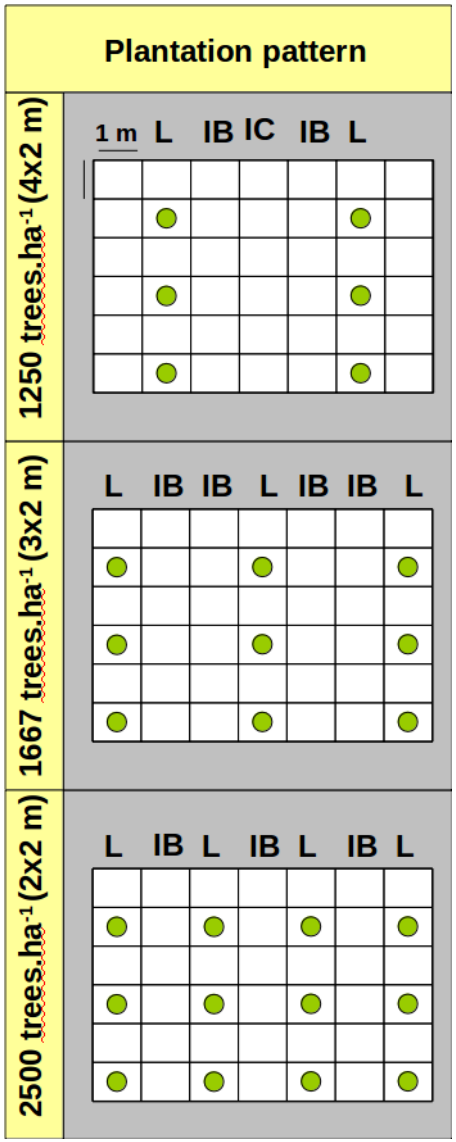
- **Ability to sprout** after a disturbance

Disturbances (thinning, cleaning)

Ploughing



The model part 2 : The forestry context and the main managment options



Itinerary 1 : standard options, 40 years rotations, several thinnings

Itinerary 2 : longer option for quality timber, 60 years rotations

Itinerary 3 : longer option for quality timber, 60 years rotations with low final density

Itinerary 4 : « Little sawing ». Short 25 years dense rotation. One thinning

Itinerary 5 : « Half dedicated itinerary ». Dense plantation and early thinning of 1/2 tree lines, then equivalent to itinerary 1.

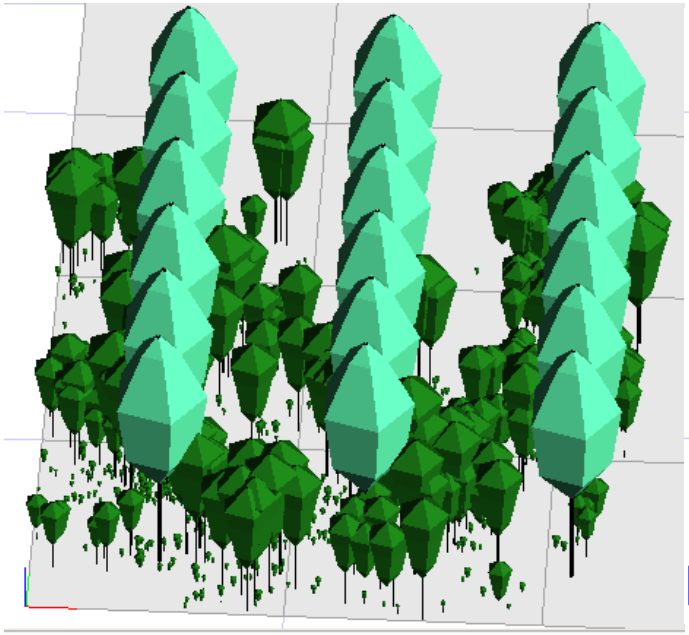
New more productive itineraries

Light and disturbance regimes for the understory greatly impacted by these management options.

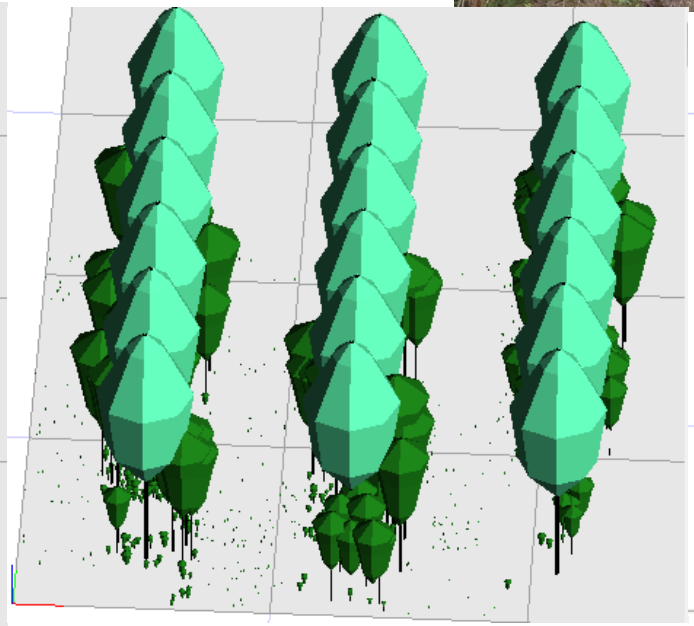
Important consequences for the ecodynamic model

The model part 2 : The forestry context : Taking into account disturbances in accordance with plantation patterns

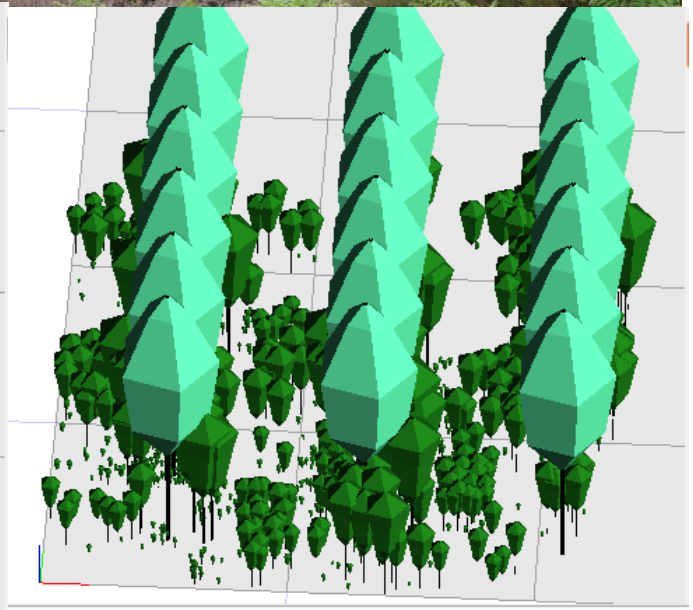
An illustration of understory mechanic control in WOUDYFOR



Before cleaning the between tree spacing



After cleaning



Sprouting and re-growth, one year later

The model part 3 : vertical vegetation layers and corresponding interactions

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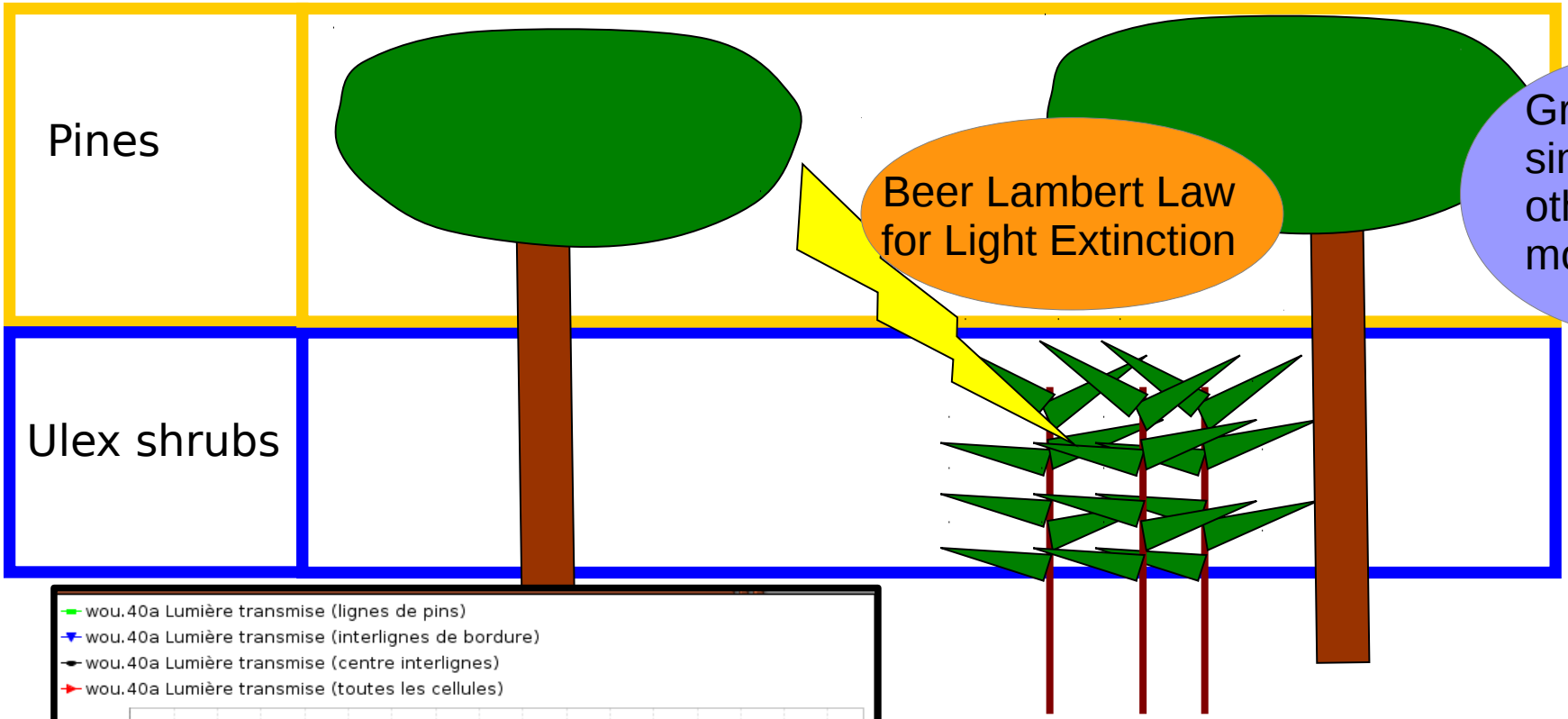
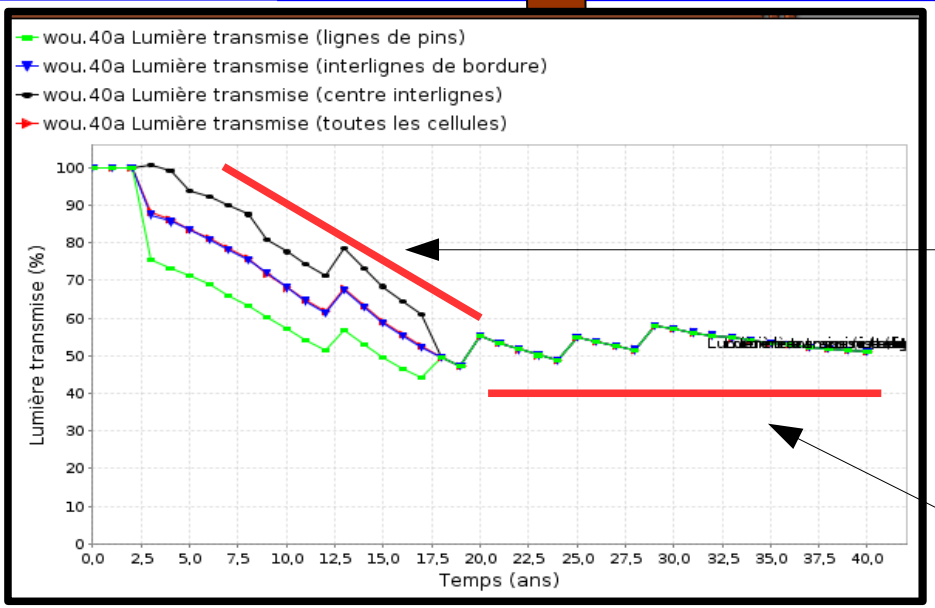


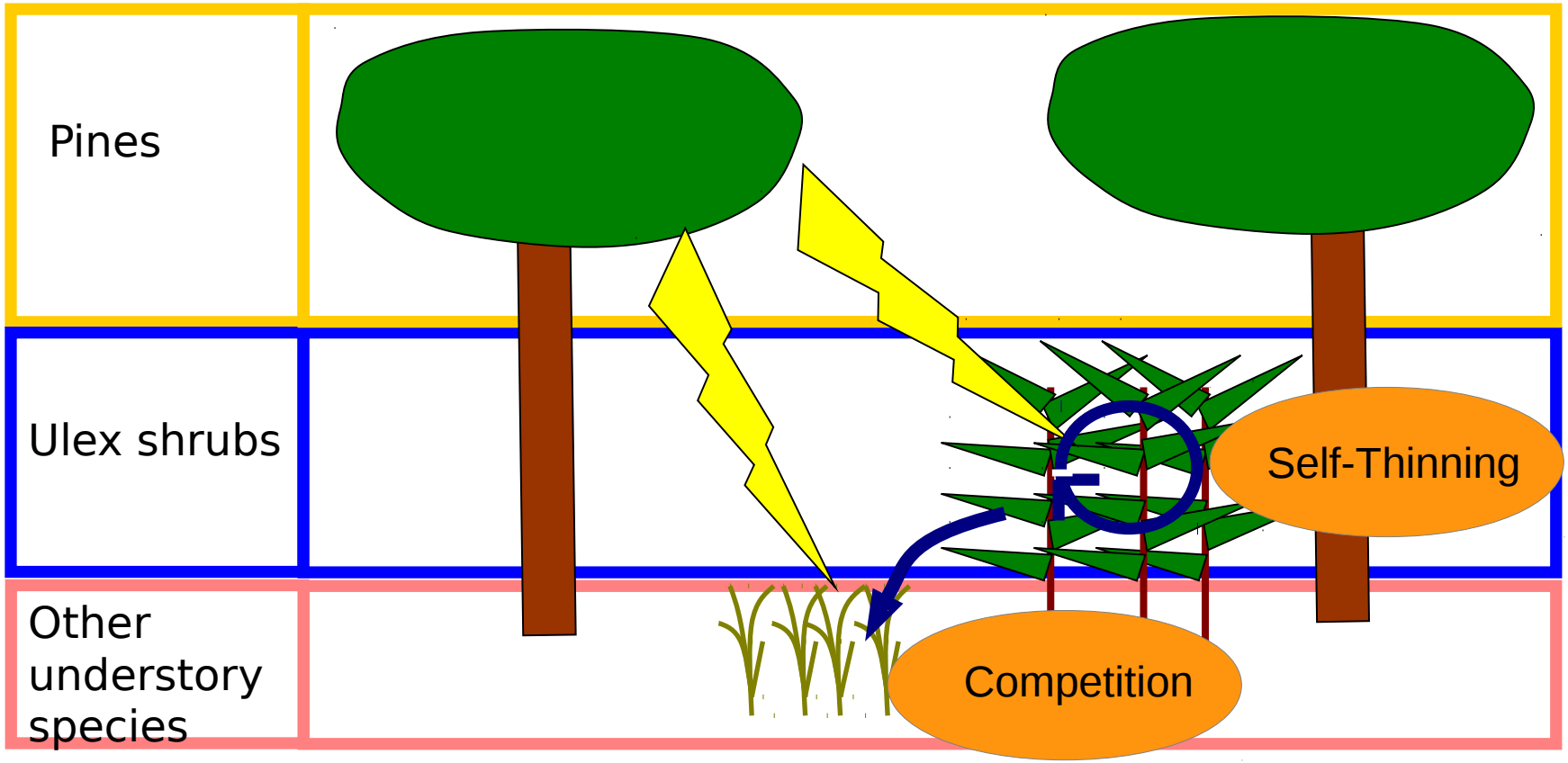


Heterogenous light in the understory according to the tree line position

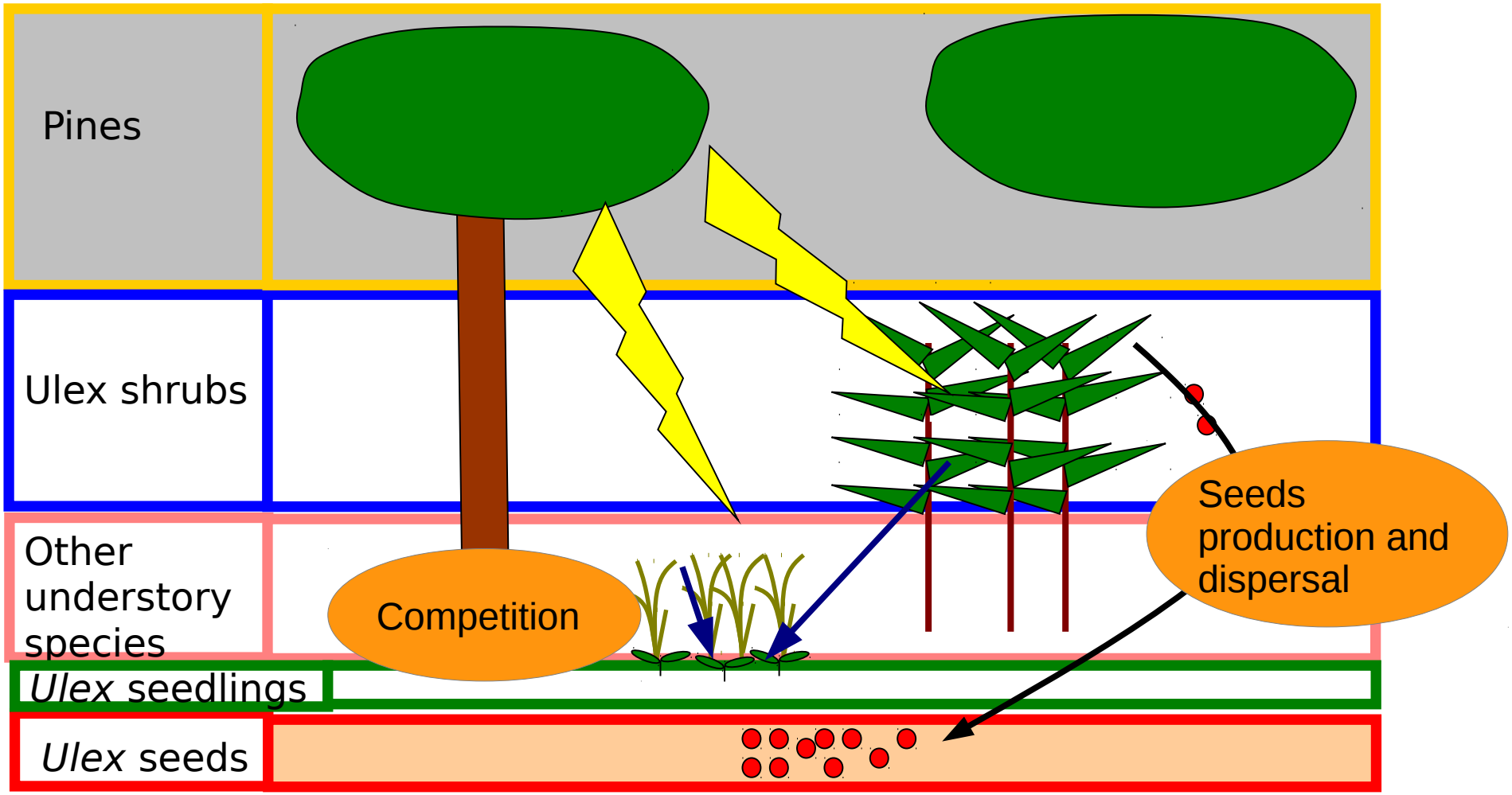
Homogenous light in the understory

The light in the understory in WOUDYFOR

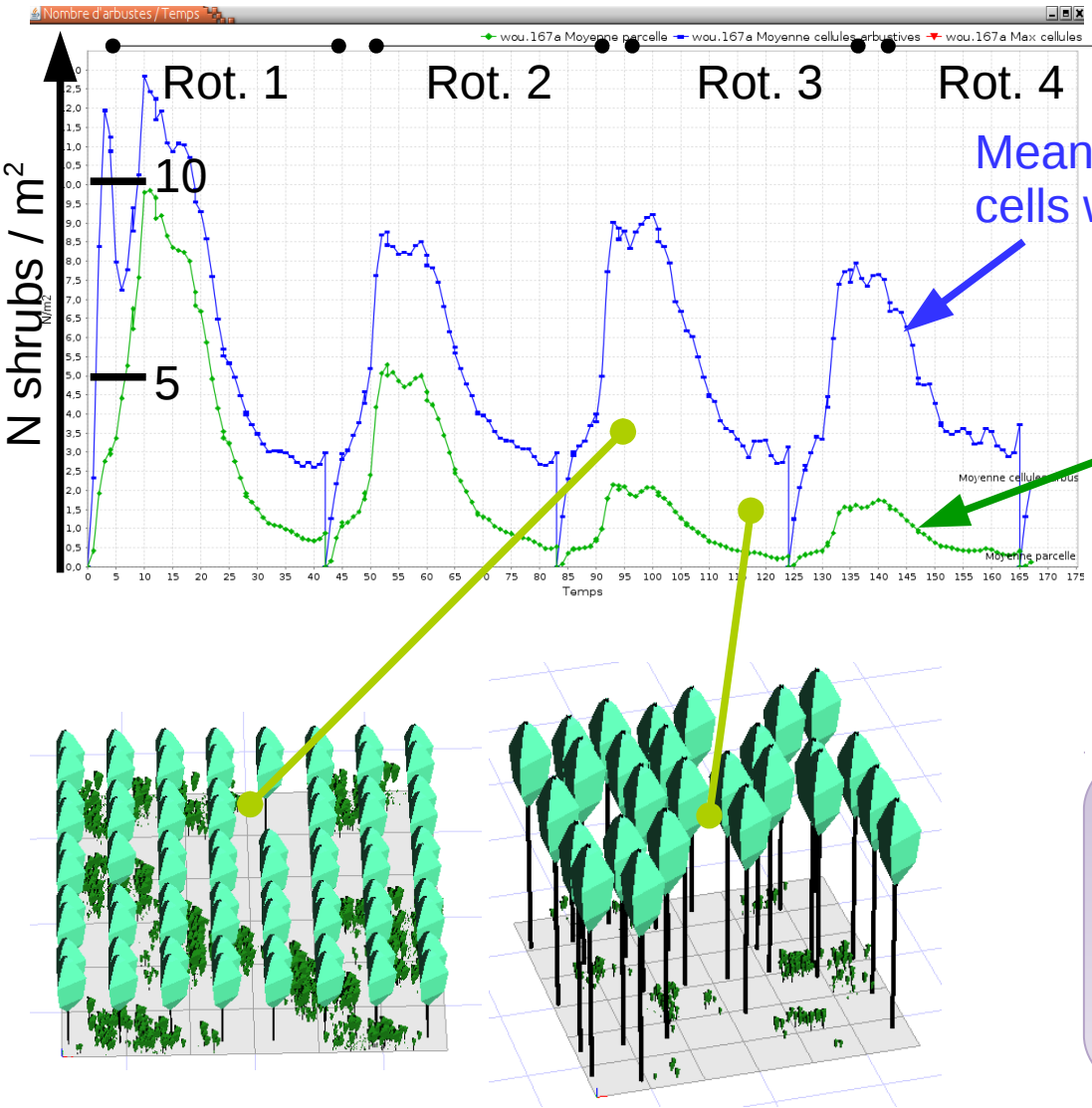
The forest context : vertical vegetation layers and corresponding interactions



The model part 3 : vertical vegetation layers and corresponding interactions



Preliminary results : coherence of **the shrub dynamic** predicted in the first **standard itinerary**



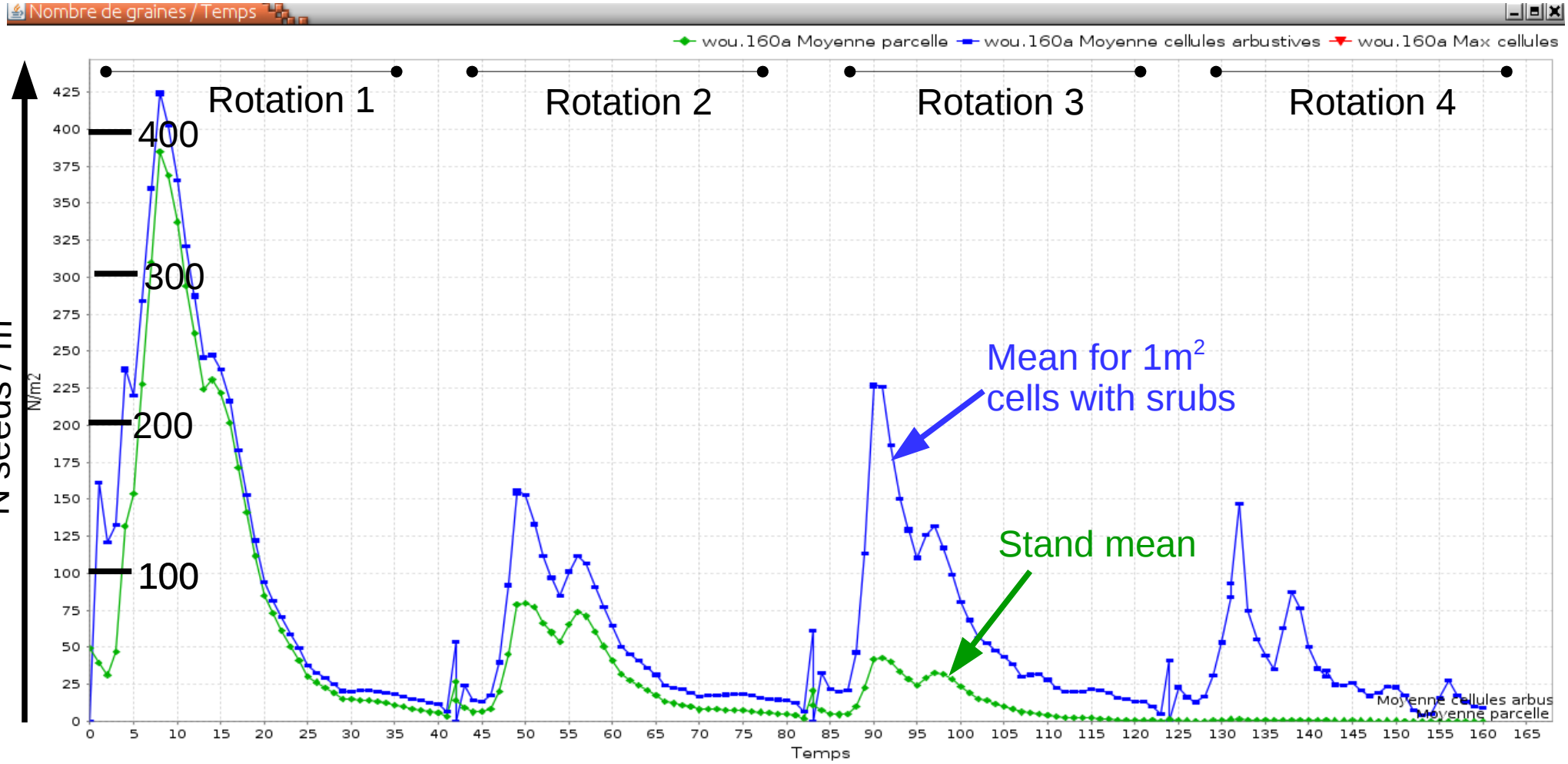
Mean for 1m² cells with srubs

Stand mean

In the region, between 1 to 10 shrubs /m² in average in forest stands with Ulex presence (Delerue et al, 2013)

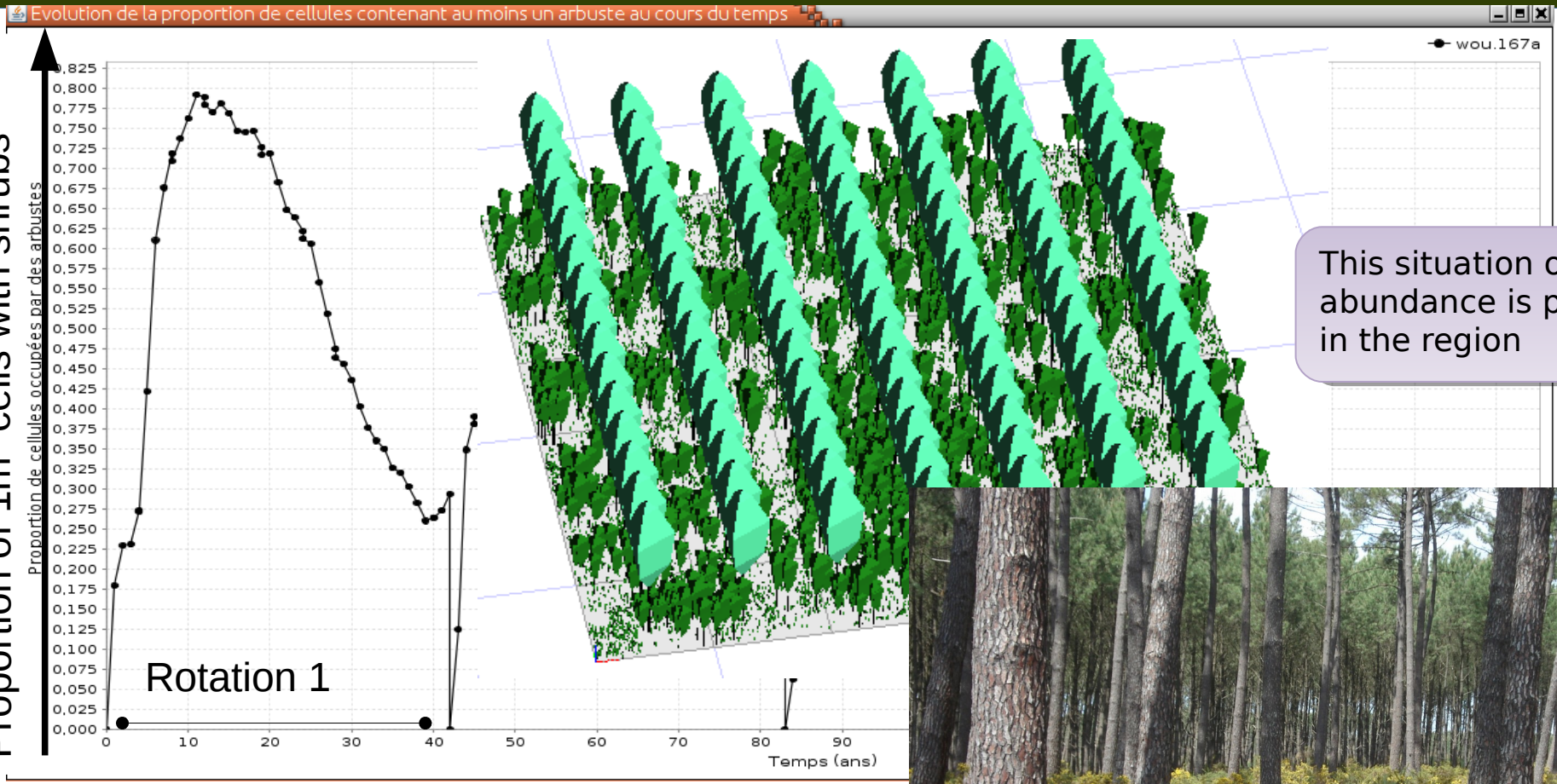
The pioneer dynamic of the species is predicted repeatedly along forest rotations, but with variations in the abundance predicted after the first rotation between simulations

Preliminary results : coherence of **the shrub seed banks** predicted in the first standard itinerary



In the region, a former study (Gonzalez et al, 2010) found in average between 200 and 400 seeds.m^{-2} in forest stand in presence of *Ulex europaeus* in the understory

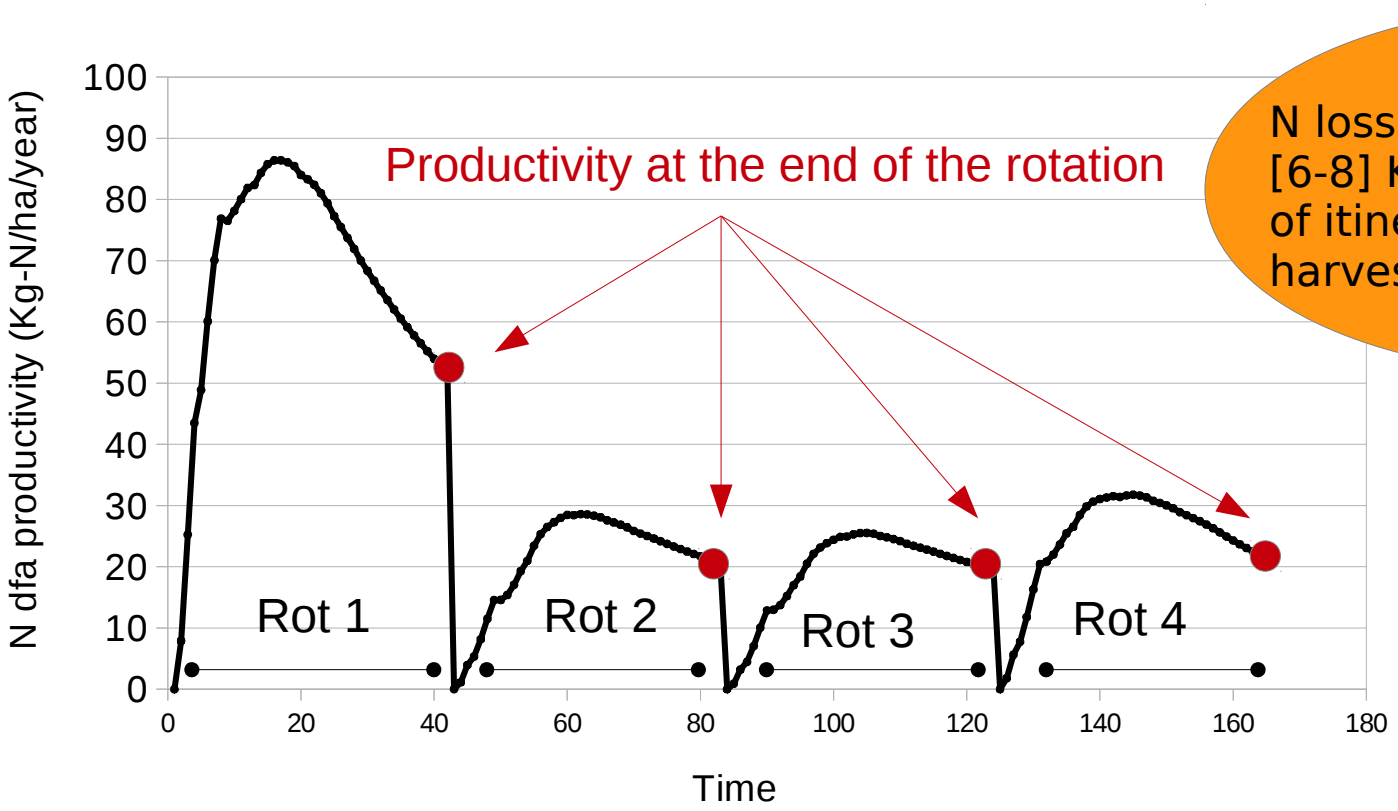
Preliminary results regarding the **influx of N derived** from atmosphere



This situation of high abundance is possible in the region

During the first rotation, predicted shrub abondance is high even after the pioneer phase => Atmospheric N influx of 50 Kg-N.ha^{-1}.year^{-1} (see next slide)

Preliminary results regarding the **influx of N derived** from atmosphere



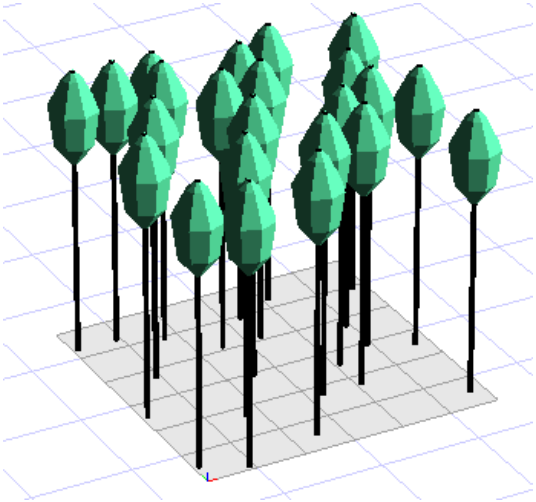
N losses due to wood harvest : [6-8] Kg-N/ha/year in this kind of itinerary with pine stem harvest only (Augusto 2014)

First rotation : influx of atmospheric N of 50 Kg-N/ha/year, with a peak of 90 Kg-N/ha/year during the pioneer phase. In other contexts (where *Ulex europaeus* is an invasive weed) reported influx of atmospheric N exceeds 100 Kg-N/ha/year (Magesan et al, 2012).

Next rotations : the predicted productivity is more variable between simulations (from a few up to 30 Kg-N/ha/year ; 20 Kg-N/ha/year above).

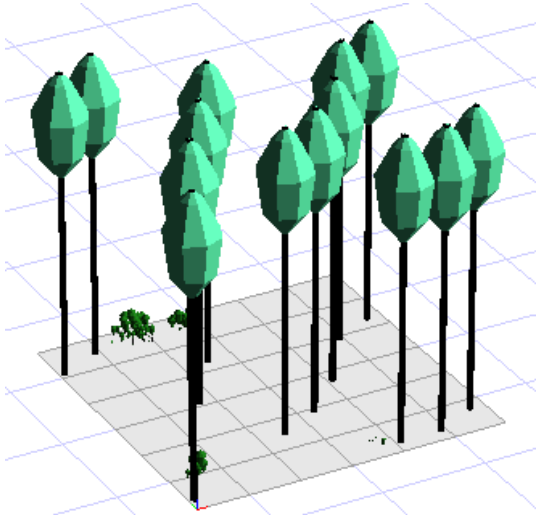
Preliminary results regarding the **influx of N derived** from atmosphere : **the other longer itineraries**

Itinerary 2 : longer option for quality timber, 60 years rotations



View after two rotations : shrubs are eliminated

Itinerary 3 : longer option for quality timber, 60 years rotations with **low final density**



View after two rotations : some shrubs remain in the understory. Influx of N comparable to Itinerary 1.

Results consistent with the heliophilous caracteristic of the species.

Simulations for the other itineraries (Little sawing ; 25 years rotation / Half dedicated ; 40 years rotations) are not possible at the moment because of lack of pines growth data.

Conclusion and perspectives

- Preliminary results consistent with *Ulex europaeus* dynamic knowledge in the region. Validation of model results can start and still to be made

- Predicted atmospheric N influx often superior to N losses due to wood exports in the standard itinerary, but :
  - Positive balance regarding N fluxes does not mean that the equilibrium holds for all nutrients.
  - Some other practices can increase N losses (residues harvest)

- Shorter rotation options are likely to lead to higher atmospheric N influx, but N exportations will increase too.

- The understory has a functional central rôle in forest system, even intensively managed. In the pine forest, it represents the large majority of the LAI and RAI (Gonzalez et al, 2013). How many models focussing on the understory dynamic and explicitely nested in a dynamic forestry context ?

Aknowledgments

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