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

To cite this version:
Florian Delerue, Maya Gonzalez, François de Coligny, Céline Meredieu, Alain Mollier, et al.. Simulating the impact of forestry practices on a leguminous understory shrub and associated N fixation. Annual meeting of the CAQSIS network, Mar 2017, Bordeaux, France. hal-03194985

HAL Id: hal-03194985
https://hal.inrae.fr/hal-03194985
Submitted on 9 Apr 2021

HAL is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers. L’archive ouverte pluridisciplinaire HAL, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d’enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.
Simulating the impact of forestry practices on a leguminous understory shrub and associated N fixation

The WOody Understory Dynamic in FORestry (WOUDYFOR) model

Florian Delerue: EA 4592 G&E – Bordeaux-INP, Pessac, France
Maya Gonzalez: UMR 1391 ISPA – BSA, Gradignan, France
Francois de Coligny: AMAP, INRA, CNRS, IRD, Université Montpellier, Montpellier, France
Céline Meredieu: UMR 1202 BIOGECO – INRA, Cestas, France
Alain Mollier: UMR 1391 ISPA – INRA, Villenave d'Ornon, France
Sylvain Pellerin: UMR 1391 ISPA – INRA, Villenave d'Ornon, France
Pierre Trichet: UMR 1391 ISPA – INRA, Villenave d'Ornon, France
Laurent Augusto: UMR 1391 ISPA – INRA, Villenave d'Ornon, France
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?

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.
From the estimation of N influx to an ecodynamic model

**Shrubs biomass production**

\[ \delta k_{biom} \text{ ha}^{-1} / \delta t \]

*Evolution of the number of shrubs and shrubs growth*

- HIGHLY VARIABLE:
  - COVER: [0-100%]
  - N shrubs m\(^{-2}\): [1-10]
  - Seeds production (N m\(^{-2}\).year\(^{-1}\)): [10-1000]

**[N] Content mg N g\(^{-1}\)**

- 16.7 ± 0.3
- 5.9 ± 0.3
- 8.1 ± 0.3

% N derived from atmosphere (70 ± 3)

Little variation

**Influx of Nitrogen derived from atmosphere (Ndfa; Kg N ha\(^{-1}\).year\(^{-1}\))**

Calculation 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).
Forestry practices, leguminous shrub and influx of nitrogen

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

- **Heliophilous** species (more present in pioneer phases of vegetation development)
Forestry practices, leguminous shrub and influx of nitrogen

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

- **Ability to sprout** after a disturbance

**Understory light through pines canopy**

- Fertilization in $P_2O_5$

**Disturbances** (thinning, cleaning)

**Ploughing**

**Soil depletion**

- **Seed bank**
- **Seed dispersal**
- **Seed predation**
- **Seed production**
- **Sprouting**
- **Growth**
- **Recruitment**
- **Mortality**
- **Seedling death**

**PhD**

- **Pros**
- **Cons**

**Pi**

CAQSIS 2017
The model part 2: The forestry context and the main management 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.

Important consequences for the ecodynamic model:

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

New more productive itineraries:
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
Forestry practices, leguminous shrub and influx of nitrogen

The model part 3: vertical vegetation layers and corresponding interactions

- Pines (canopy)
- Ulex shrubs
- Understory high
- Other understory species (low)
- Ulex seedlings
- Ulex seeds
The model part 3: vertical vegetation layers and corresponding interactions

**Beer Lambert Law for Light Extinction**

- Heterogenous light in the understory according to the tree line position
- Homogenous light in the understory

The light in the understory in WOUDYFOR

**Forestry practices, leguminous shrub and influx of nitrogen**

CAQSIS 2017
The forest context: vertical vegetation layers and corresponding interactions

- Pines
- Ulex shrubs
- Other understory species

- Competition
- Self-Thinning

Forestry practices, leguminous shrub and influx of nitrogen

CAQSIS 2017
Forestry practices, leguminous shrub and influx of nitrogen

The model part 3: vertical vegetation layers and corresponding interactions

Pines

Ulex shrubs

Other understory species

Ulex seedlings

Ulex seeds

Competition

Seeds production and dispersal

CAQSIS 2017
Preliminary results: coherence of the shrub dynamic predicted in the first standard itinerary

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.
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**

During the first rotation, predicted shrub abundance 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

**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).

N losses due to wood harvest: [6-8] Kg-N/ha/year in this kind of itinerary with pine stem harvest only (Augusto 2014)
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 characteristic 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 explicitly nested in a dynamic forestry context?
Aknowledgments

Many thanks to:

- Nicolas Beudez for his help implementing the model
- The whole « Unité Expérimentale » of Pierroton for its help regarding experimental field studies during my PhD.
- All colleagues from ISPA UMR for their advice and technical help during this work (Alexandre Bosc, Christophe Nguyen, André Schneider, David Achat, Mark Bakker, Jean Christophe, Domec, Nathalie Gallegos, Céline Gire, Sylvie Millin, Sylvie Niollet, Loïc Prudhomme and Stéphane Thunot)