Forest management intensification: present and future impacts on carbon cycle in South-West of France

Virginie Moreaux, Alexandre Bosc, Pierre Trichet, Christophe Chipeaux, Jiangxin Gu, Denis Loustau

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1- INTRODUCTION

- Within the climatic context, **the impact of new-systems and forest intensification on greenhouse gas emissions** is a major issue.
- Forest biomass will be increasingly used to meet future renewable energy requirements [1].
- To supply this growing demand, for wood-energy, the main management strategies being considered for Southern Europe are short and very short rotation of fast growing broadleaved and coniferous plantations [2].
- Preliminary results shown here.

2- OBJECTIVES (GHG-Europe - WP3)

- **Collect data** on different type of forest ecosystems, at different growth and management stages.
- Calibrate/assess a **forest growth model**, based on biophysical processes and including forest management.
- Simulate forest productivity and GHG emissions under climate scenario A2 regionalized by Meteo-France - ARPEGE.

3- OBSERVATION

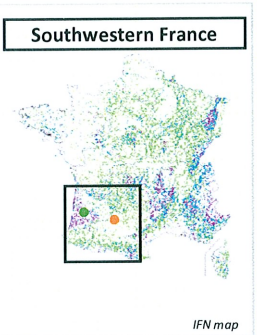
- Two sites were chosen for this purpose:

PINE site: [3-4-5-6-7-8]

- Maritime pine + N_2-fixing species
- Meteorological measurements
- Eddy flux measurements (CO_2/H_2O)
- Biomass inventories
- Soil C stocks

EUCALYPTUS site: [9-10]

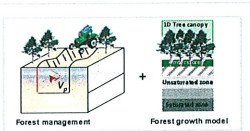
- *Eucalyptus gundal*
- Meteorological measurements
- Biomass inventories
- Trunk radial growth



IFN map

4- MODELS

- Process based model of forest growth:
  - GRAECO [11-12];
- Soil carbon dynamic and management disturbance:
  - Roth-C [12-13];
- Understorey dynamic [12-14].



5- MODEL CALIBRATION

- PINE : POST CLEAR-CUT (1), YOUNG (2) and ADULT (3) stages

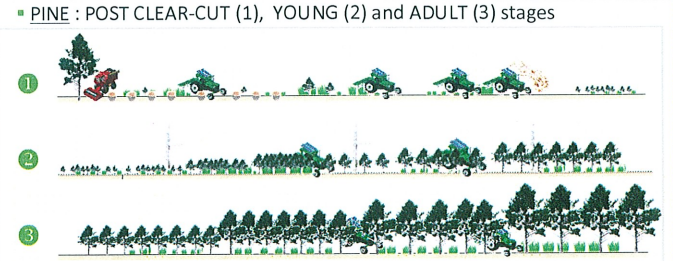
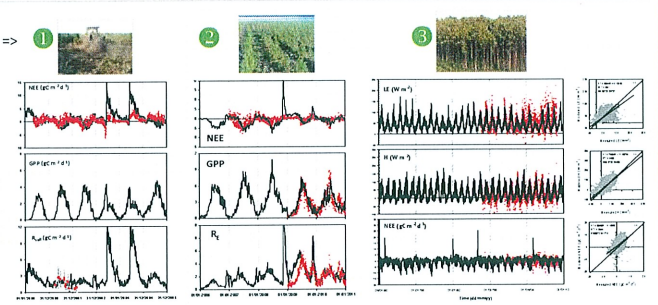
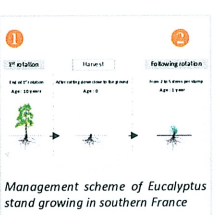


Figure of the three stages studied for the model calibration

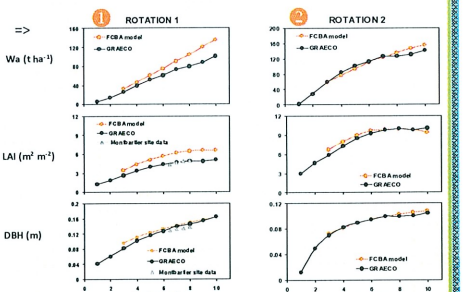


Time courses of carbon (1, 2, 3) and heat (3) fluxes for the three forest growth stages. Statistical analysis is given for the 3rd stage. Measured data are red symbols and modelled values are black lines.

- *EUCALYPTUS* : SHORT ROTATION COPPICE



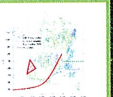
Management scheme of Eucalyptus stand growing in southern France



Evolution of the stand characteristics for the Eucalyptus rotations. In the first rotation, comparisons are made with the FCBA model [10] and measurements [9]. In the second rotation, comparisons are made with the FCBA model lonly.

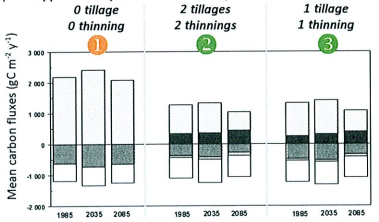
- Model that can reproduce carbon exchanges of different forest management systems
- Low bias over the whole rotations for the two cases.
- But: over-estimation of respiration fluxes at the time of disturbance (Pine case) due to modelling options of soil carbon decomposition.
- Low gap obtained for the *Eucalyptus* site at the end of the rotation due to specific soil and meteorological conditions compared to the generic growth and yield model [10] in terms of soil and climate characteristics.

6- CLIMATE CHANGE AND CARBON CYCLE



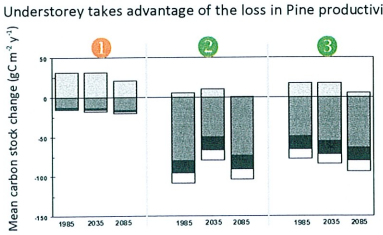
IPCC- A2 Climate scenario

Eucalyptus coppice: *3×10 years* — *0 tillage* — *0 thinning* (1)
Pines: 2×15 years — *2 tillages* — *2 thinnings* (2)
Pines: 1×30 years — *1 tillage* — *1 thinning* (3)



Mean annual values of CO_2 fluxes averaged over the three time slices and over the entire rotation of the three management options. Downward fluxes are counted positively.

- The *Eucalyptus* stand remains a strong carbon sink along the entire century, whereas the pines options, including several forest practices, become close to neutrality with the drying climate.
- GPP increases between 1985 and 2035 for the three forest options, but the benefit of CO_2 fertilization is counterbalanced in 2085 by an increase in temperature and drought.
- Heterotrophic respiration is reduced in 2085 due to a drying soil that induces an inhibition of the organic matter decomposition and due to a reduction in soil carbon input associated to the decrease in tree productivity.
- Understorey takes advantage of the loss in Pine productivity in 2085.



Mean annual change in the carbon stock of the different soil components over the three time slices and over the entire rotation of the three management options. Upward fluxes indicates a gain in soil carbon storage.

- The *Eucalyptus* stand accumulates carbon in the soil until 2035 and becomes close to neutrality in 2085 associated to lower rate of carbon stored in the resistant component related to the potential reduction of tree productivity and litterfall.
- Mineralization of organic matter is stimulated by tillage frequencies (Both Pine options).

7- CONCLUSION

- Forest management, in view of short rotations of different tree species, is the main driver of change in carbon cycle and potentially in other GHG cycles.
- Model projections are consistent with the trends in carbon cycle dynamics in response to climate change as given in [15].
- Importance of including the nitrogen cycle to assess the N_2O emissions (see Gu et al.'s poster)
- The model combined with Gu's model will be next implemented over a 200 000 ha water catchment area in the south west of France, for the 1990-2010 period and compared with generic model projections (Orchidée-FM [16], Isba-A-gs [17]) (GHG-Europe- WP5)

AKNOWLEDGEMENTS

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REFERENCES

[1] IPCC 2011. Special report on Renewable Energy Sources and Climate Change mitigation. 24p.
[2] Lesgourgues et Drouineau 2009. *Innovations agronomiques*. 6:101:112.
[3] Berbigier et al. 2001. *Agric.For. Meteorol.* 108:183-197.
[4] Kowalski et al. 2003. *Glob. Change. Biol.* 9:1051-1065.
[5] Kowalski et al. 2004. *Glob. Change. Biol.* 10:1707-1723.
[6] Jarosz et al. 2009. *Biogeosc. Disc.* 6: 2755-2784.
[7] Stella et al. 2009. *Biogeosc.* 6:2957-2971.
[8] Moreaux et al. 2011. *Tree Physiol.* 31:903-921.
[9] Moreaux et al. 2012. *Plant Ecol. Diversi.* Sous presse.
[10] Cavaignac et al. 2011. FCBA info. Fiche n°1. 7p.
[11] Porté 1999. Ph.D. Thesis, Univ. Paris XI, Orsay, France. 160p.
[12] Moreaux 2012. Ph.D. Thesis, Univ. Bordeaux 1, France. 282p.
[13] Jenkinson et Rayner. 1977. *Soil Science.* 123:298-305.
[14] McMurtrie and Wolf. 1983. *Ann. Bot.* 52: 437-448.
[15] Brisson et al. 2010. *Livre vert CLIMATOR.* 336p.
[16] Bellassen et al. 2001. *Ecol. Model.* 222: 57-75.
[17] Calvet et al. 1998b. *Agric. For. Meteorol.* 92: 73-85.