A climate sensitive model of carbon transfer through atmosphere, vegetation and soil in managed forest ecosystems

Denis Loustau, Virginie Moreaux, Alexandre Bosc, Pierre Trichet, Jyothi Kumari, Tovo Rabemanantsoa, Jérôme Balesdent, Claudy C. Jolivet, Belinda Elisabeth Medlyn, Sebastien Cavaignac, et al.

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Loustau[1]D., V. Moreaux[1], A.Bosc[1], P. Trichet[1], J. Kumari[1], T. Rabemanantsoa[1], J. Balesdent[3], C. Jolivet[2], B. E. Medlyn[4], S. Cavaignac[6], N. Nguyen-The[5]

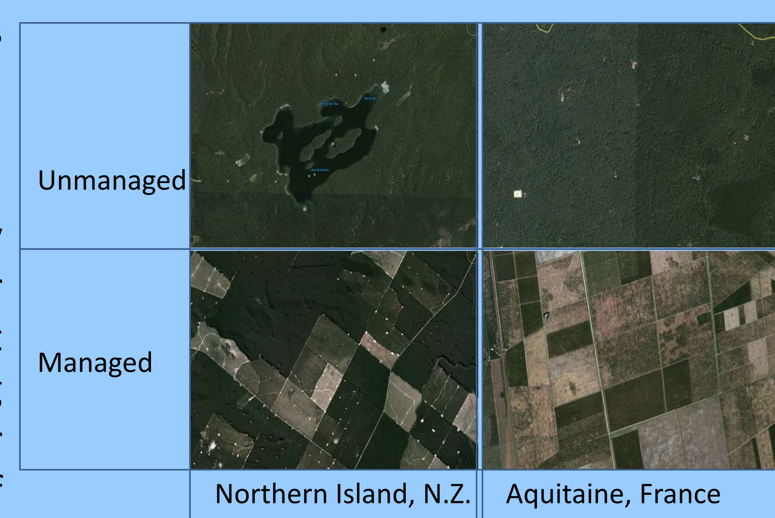
1. INRA, UR1263 EPHYSE, F-33140, Villenave d'Ornon, France. 2. INRA, US1106 INFOSOL, Orléans, France. 3. INRA, UR1119 URGSE, Aix en Provence, France. 4. Department of Biological sciences, University Macquarie, Sydney, NSW, Australia. 5. Station du Sud Est, FCBA, Grenoble, France. 6. Station du Sud Ouest, FCBA, Cestas, France.

Contact: denis.loustau@bordeaux.inra.fr

1. Introduction

Against the idea that managed forest ecosystems are more regular in time and space than unmanaged forest, observations and long term records of atmospheric exchanges from managed forests exhibit a larger time and space variability than unmanaged forests (**1**, **2**). This higher heterogeneity is mainly due to management operations highlighting the needs for accounting for management and disturbances for understanding biogeocycles and production of such ecosystems. The interplay between climate, atmospheric deposition (NO_x, NH_4, O_3), biotic agents (herbivores and pathogens) and management must therefore be accounted for to forecast the future of managed forests, their growth and wood production as well as their carbon, energy and water cycles (**3**).

Aiming at analysing the potential impacts of climate and management scenarios on forests in Europe, we have developed a process-based model, GO+, describing the main energy, mass and radiative fluxes exchanged with soil and atmosphere, as well as forest carbon and water cycles, and individual tree growth for entire forest management scenarios.



In this poster, the main model features processes are summarised and model evaluation tests against long term datasets that include extreme climate events (drought, storms) and management operations (site preparation, understorey removal, thinning, coppicing, clearcut) are illustrated.

6. Conclusions

GO+, this model, has been kept simple enough for being run over large gridded data sets within a reasonable amount of time. Significant processes such as nutrient cycles and ozone deposition effects are not shown in this poster but are being considered as side modules to be interfaced with GO+ (**10**). Model description and tests summarised in this communication show that:

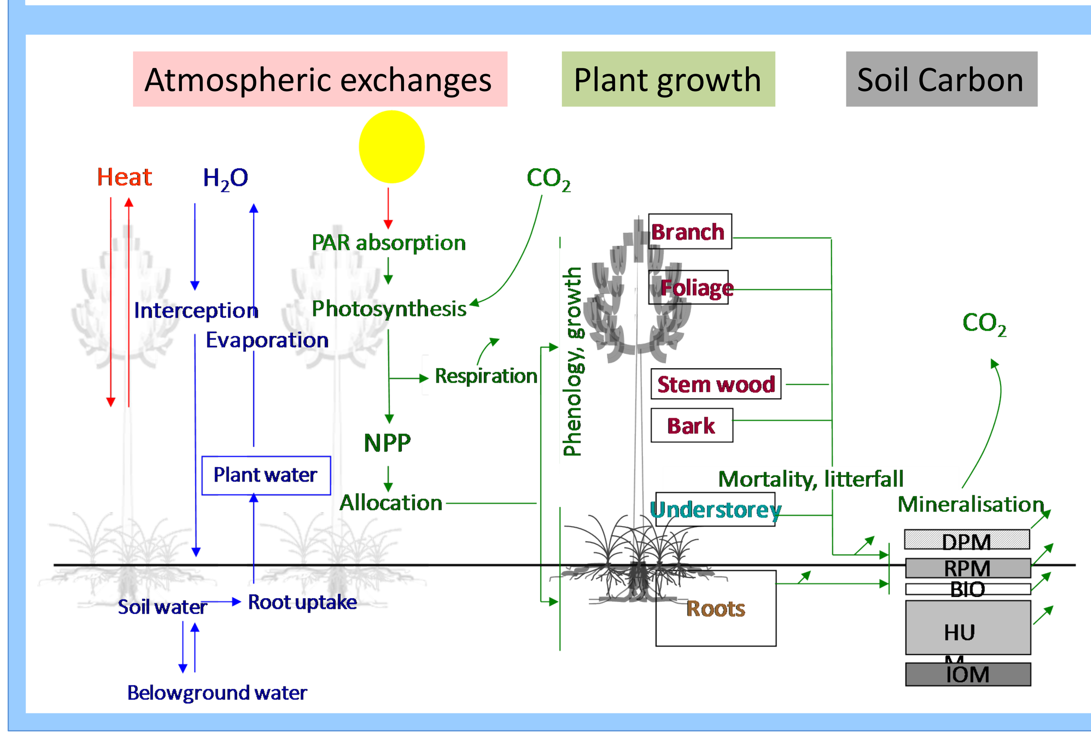
- First and second order closures of carbon and water balances are satisfied by the model, even if predictions of soil water show local discrepancies (attributed to inaccurate description of ground water);
- GO+ does not exhibit long term shift or significant bias for carbon and water fluxes ;
- Significant discrepancies are revealed regarding the effect of soil operations that are overestimated;
- Tree development , mortality and growth as well as ground vegetation's(not shown) are described realistically and management effects properly accounted for ;
- Impacts of climate events such as heat waves and soil water deficit are well captured by the model in the Pine and Eucalypt stands, both for flux and carbon and water pool changes.

References

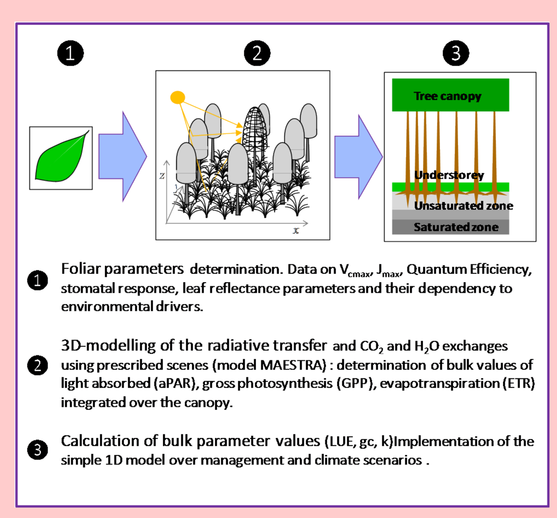
1. Hyvönen, R., G. I. Ågren, S. Linder, et al. 2007. *New Phytologist 173(3): 463-480.*
2. Moreaux et al., 2012. AGU Annual meeting, 2012. poster 493, this session.
3. Medlyn, B.E., Duursma, R. A.; Zeppel, M. J. B. 2011. Wiley Interdisciplinary Reviews-Climate Change , 2(3) : 332-355
4. Duursma, R. A.; Medlyn, B. E. 2012. *Geoscientific Model Development, 5 (4), 919-940*
5. Shaiek, O., D. Loustau, P. Trichet, C. Meredieu, B. Bachtobji, S. Garchi and M. H. El Aouni, 2011. *Annals of Forest Science 68(3): 443-452.*
6. Jenkinson D.S. and Rayner J.H. 1977. *Soil Science 123, 298-305.*
7. Jolivet C. 2000. *Université de Bourgogne, Ph.D. Thesis.*
8. Moreaux, V., E. Lamaud, A. Bosc, J. M. Bonnefond, B. E. Medlyn and D. Loustau, 2011. *Tree Physiology 31(9): 903-921.*
9. Moreaux, V. , 2012. *Bordeaux, Université de Bordeaux-1, Ph. D.thesis, 262 p.*
10. Gu J. et al. 2012. *Poster, GHG-Europe annual meeting, Bucarest, June 2012.*

2. Model

The essential feature of the model is to close the ecosystem carbon cycle from the atmosphere back into the atmosphere using essentially physical and biological processes description and including a realistic representation of forest management.



Atmospheric exchanges



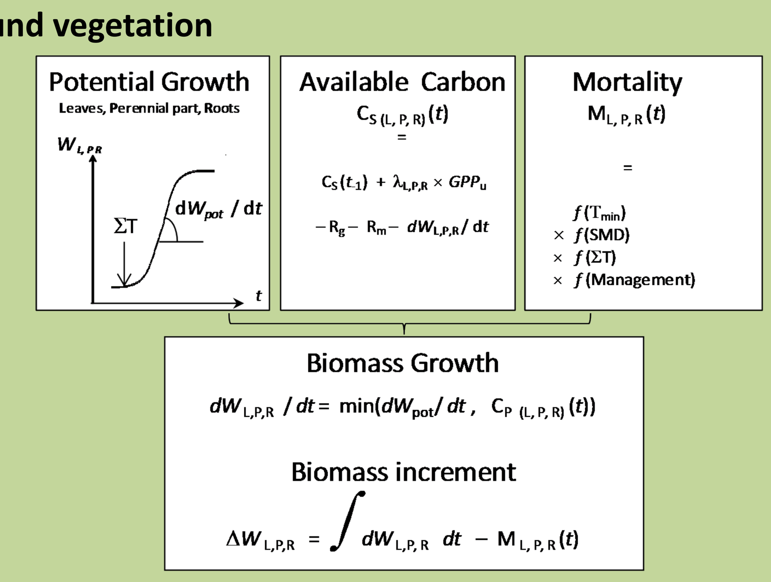
The model is based on laws of radiation transfer implemented across a 3-D canopy with distinctive tree crowns and understory (**4**) which are further degraded in 1D bulk parameters. Different leaf types, species and crown shapes are implemented. MAESTRA is used offline for calculating simplified functions describing the surface properties aggregated over three layers: albedo, canopy conductance, Light Use Efficiency (=GPP/aPAR as a function of air T & VPD, CO_2 and soil water) and light attenuation coefficient. Then, gas and momentum exchanges are modelled according to a multiple resistance transfer model. The stomatal conductance model respond to atmospheric (APAR, CO_2, VPD) and soil water according to a multiplicative Jarvis'model scheme.

Plant growth

1.Trees

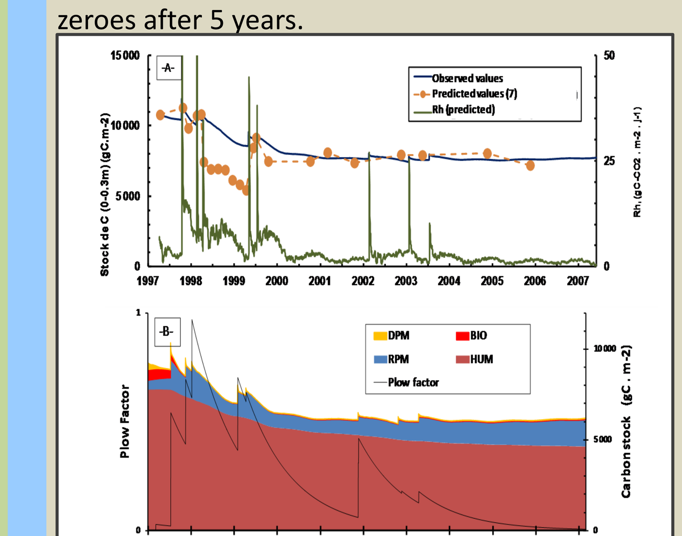
The individual growth of trees is estimated from their annual increment in carbon. The net annual increment is the difference between individual NPP and loss of sessile parts (fine roots and exudates, leaves, branches). New biomass of leaves, stem, branches and roots is calculated using species specific set of allometric equations e.g. (**5**). Mortality through natural thinnings and harvests is either prescribed by management scenario or self thinning rules.

2. Ground vegetation



Soil Carbon

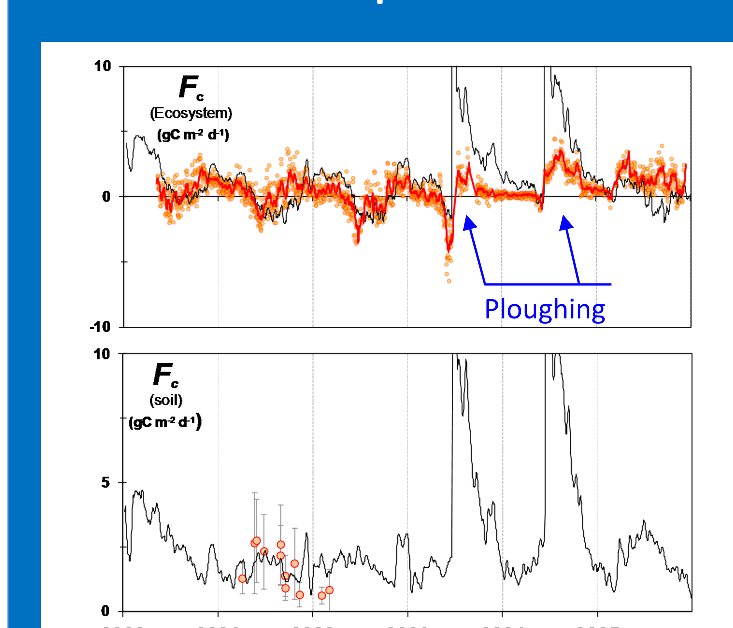
The model includes the ROTH v6.3 soil carbon cycle model with few changes (**6**): the model is enabled to account for effects of soil preparation and ground vegetation control. Following a given operation, the humification and mineralisation rates are amplified by a "plough" factor which is the soil volume fraction affected by the operation. The plough factor is attenuated with time and zeroes after 5 years.



Time course of soil carbon stock and heterotrophic respiration during the site preparation and juvenile phase following clearfell (1997) in a temperate maritime Pine Forest (SW France) (**7**).

3. Evaluation

1. Atmospheric fluxes

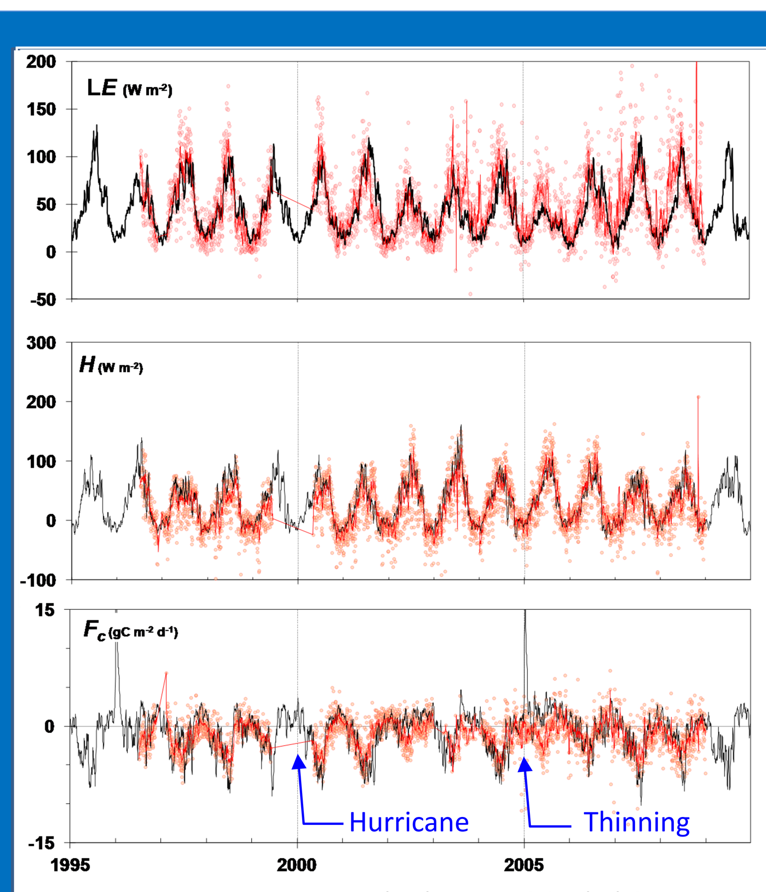


———— : Model prediction.

● , ———— : Data observed.

(Lines are moving averages, n=10).

1. Site preparation and plantation. Net ecosystem CO_2 flux ($F_{c\ ecosystem}$) and soil ($F_{c\ soil}$) from a pine forest site following clearcut (**8**).



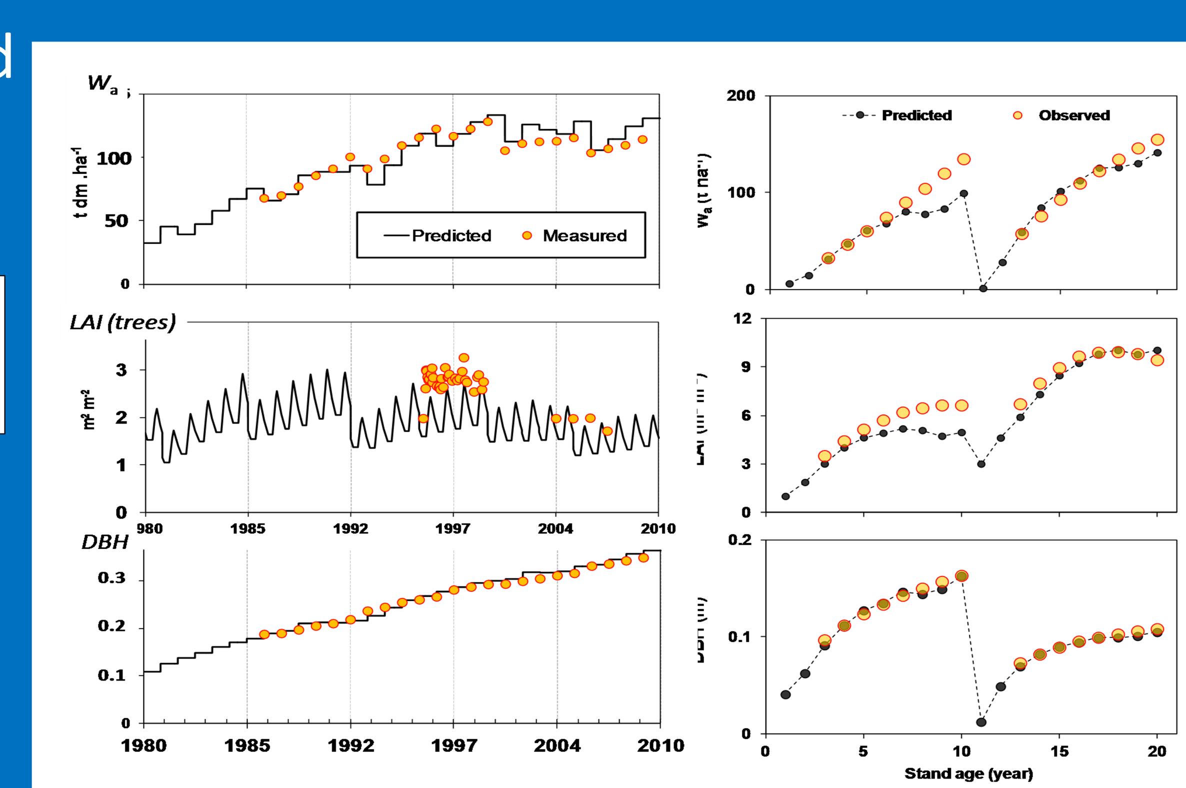
2. Mature stage. Latent (*LE*), sensible (*H*) heat and CO_2 fluxes (F_c) from a pine stand seeded in 1970 (Fr-Le Bray Fluxnet site).

4. Evaluation

2. Tree growth and biomass carbon pools

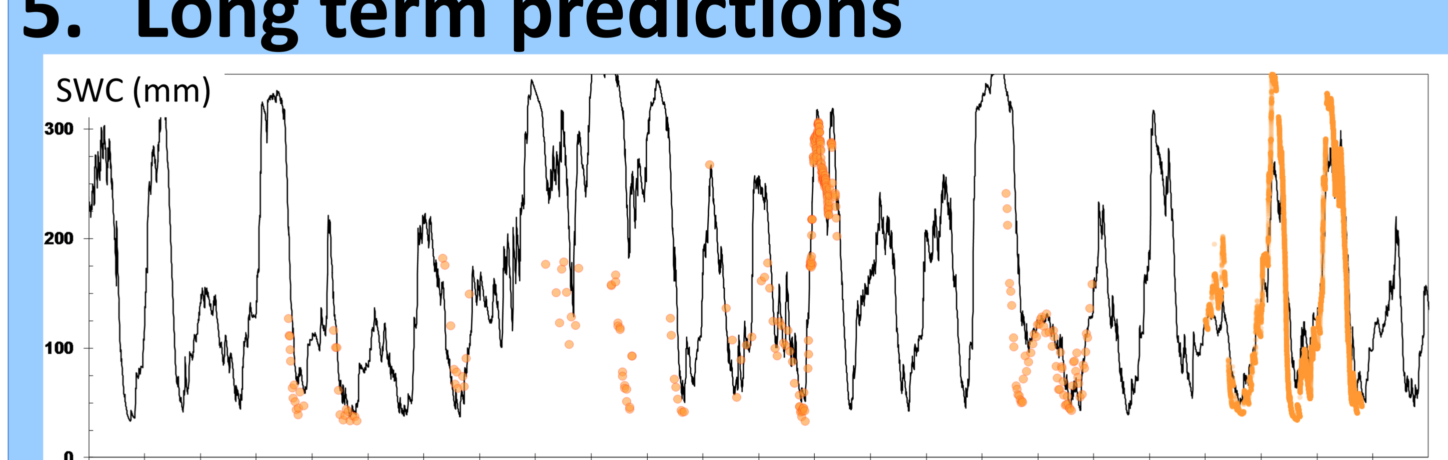
● ———— : Model prediction.

● : Data observed.

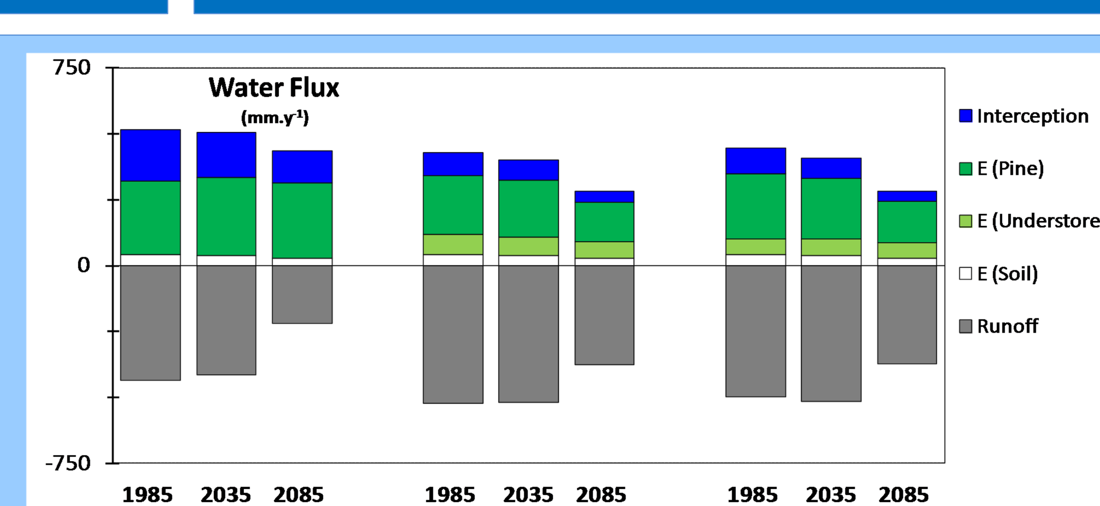


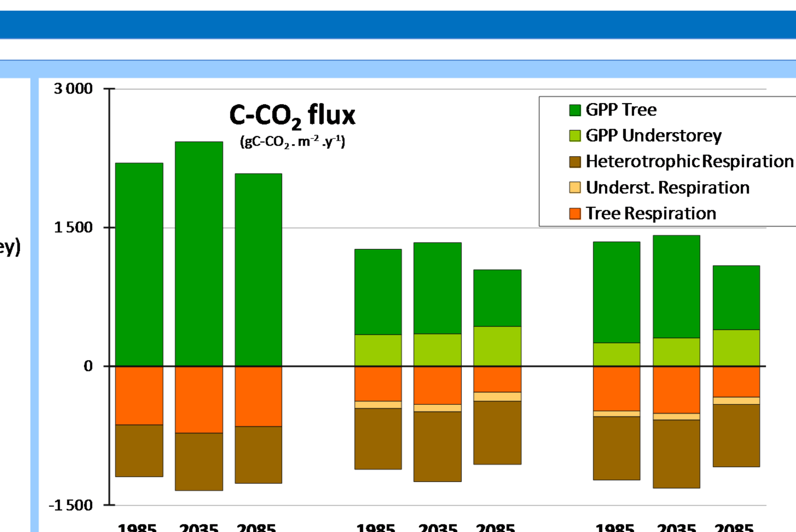
Aboveground biomass (W) , LAI and mean tree diameter (DBH) along rotations of Pine (10-40 year, left, Le Bray site) and Eucalyptus coppice (**9**).

5. Long term predictions



Observed (orange circles) and predicted (black curve) soil water content in a mature Pine stand (Le Bray site) from age 15 to 38-year. Data are spatial averages calculated from n=5 to 20 soil profiles. GO+ was initialised in 1970. It predicts correctly the periods of soil water deficit (1989, 1990, 1997 2002, 2005) but overestimates winter values due to too slow groundwater discharge.





Data shown are rotation-averaged annual values for 3 management scenarios representative of intensive production forests in Southern Europe (**9**). GO+ simulated three climate periods (1985, 2035, 2085) of the A2 scenario at Bordeaux city location. For the near future(2035) the water balance modelled is conserved, whereas the effect of the enhancement in temperature and CO_2 causes a net increase in photosynthesis (GPP) and production (not shown). Beyond, rainfall reduction constrains the water and carbon balances for both Eucalypt coppice and Pine standards in 2085. Simulations shown include only climate and management changes.

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