The effect of a dry spring on seasonal carbon allocation and vegetation dynamics in a poplar bio-energy plantation

Broeckx L.S., Verlinden M.S., Berhongaray G., Zona D., Fichot R., Ceulemans R.

Research Group of Plant and Vegetation Ecology
University of Antwerp, Department of Biology
Universiteitsplein 1, B-2610 Wilrijk
Belgium

Objectives

Assessment of the carbon sequestration potential of a high-density poplar plantation by

(1) examining the seasonal variations in net ecosystem exchange (NEE), photosynthesis and carbon allocation in relation to environmental parameters;

(2) studying the effect of an atypical dry spring to summer period.

An integrated analysis of different hierarchical scales (leaf level, tree level and ecosystem scale) was performed.

Materials and methods

Eddy covariance measurements:

- CO_2
- water
- energy

Meteorological parameters:

- precipitation (P)
- short-wave radiation (SWR)
- temperature (T)
- soil water potential (Ψ_s)

Soil CO_2-efflux (LiCor-8100)

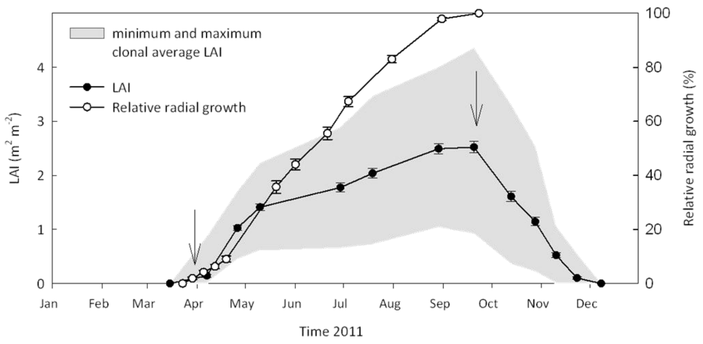
Leaf gas exchange (LiCor-6400)

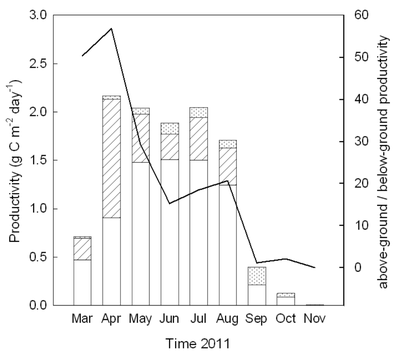
Radial stem growth (Natkon ZN11-O-WP dendrometer)

Fine root sampling (Eijkelkamp soil corer)

Tree growth

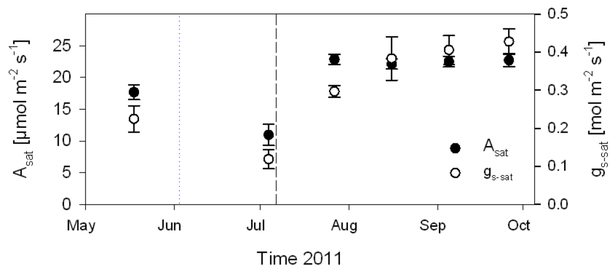
- the time between bud flush and bud set (indicated by arrows) corresponded to leaf area development up to maximum leaf area index (LAI_{max});
- stem diameter increment, reflecting stem biomass production, ended when LAI_{max} and full bud set were reached;
- leaf area development but not radial growth was affected by drought.





- high NPP/GPP ratios for leaf and stem diameter in the beginning of the growing season;
- increasing fine root production in September could indicate a shift in carbon allocation from above-ground biomass to below-ground biomass towards the end of the growing season;
- increasing fine root production was observed when soil water availability was decreasing.

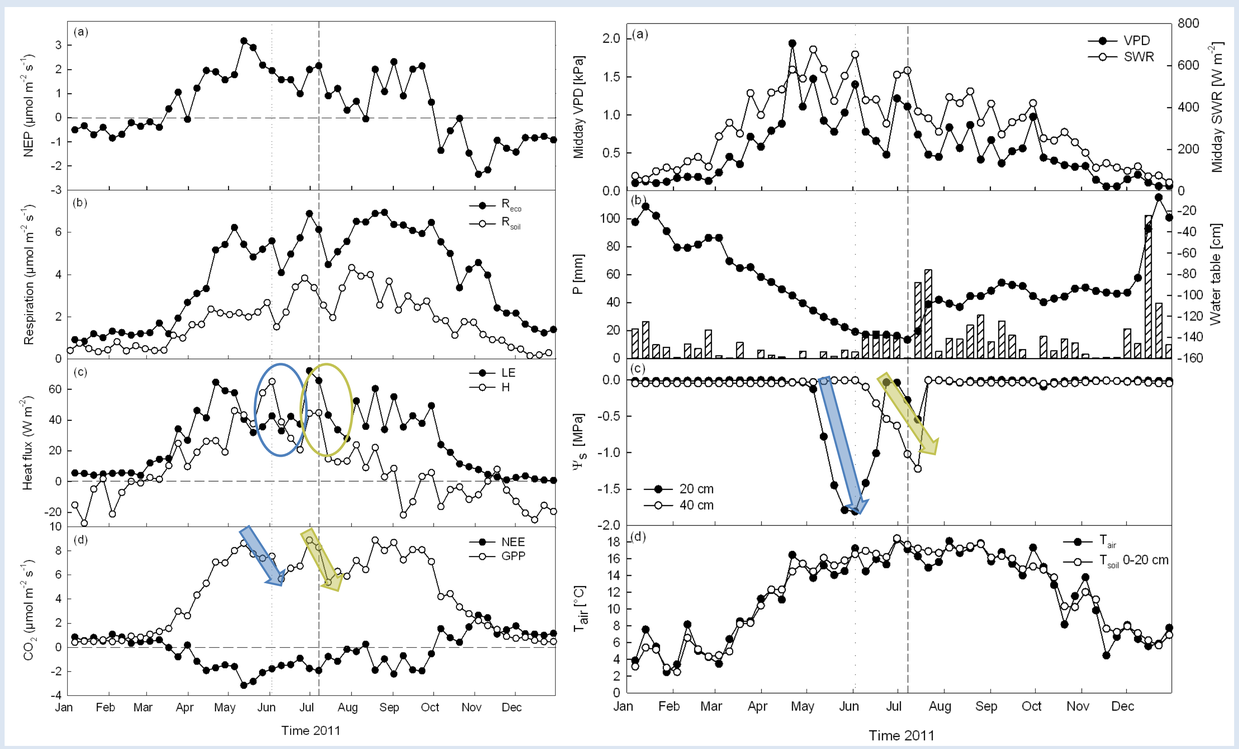
- at the leaf level, a simultaneous reduction in stomatal conductance ($g_{s\text{-}sat}$) and net assimilation rate (A_{sat}) was observed at low soil water availability;
- a short-term increase in $g_{s\text{-}sat}$ and hence transpiration could explain high GPP in response to the June rainfall, that could not be observed due to discontinuous leaf gas exchange measurements.



Dry spring conditions

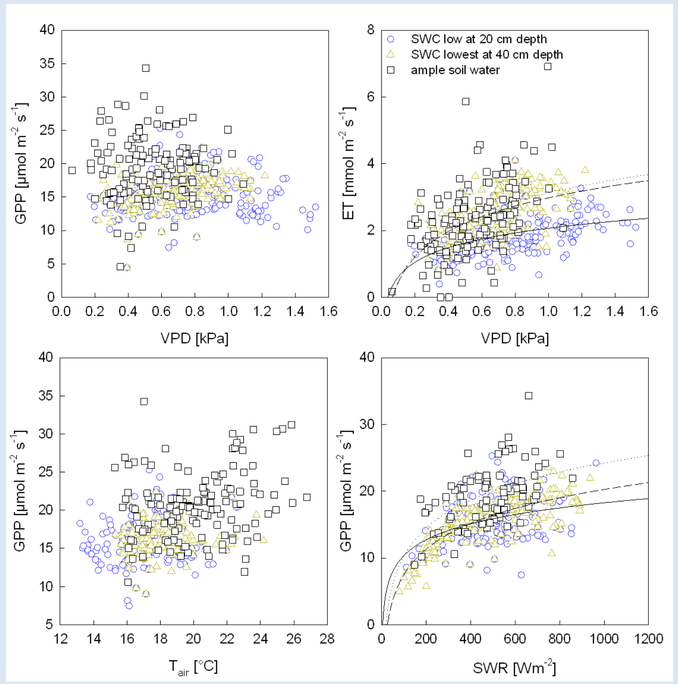
Fluxes

Meteo

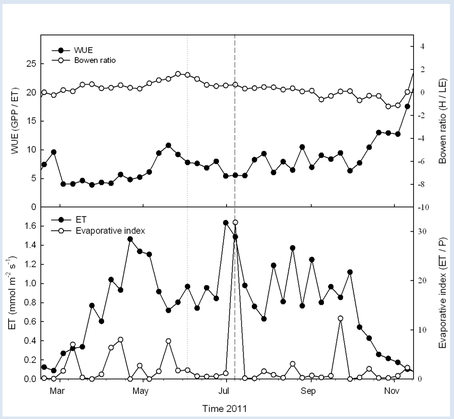


Reduced gross primary production (GPP) – when soil water potential (Ψ_s) at 20 cm depth was low – was observed when sensible heat (H) exceeded latent heat (LE), indicating reduced transpiration. Low GPP even at low vapor pressure deficit (VPD) and faster saturation of evapotranspiration (ET) with VPD emphasized stomatal control of carbon uptake.

Reduced GPP with decreased but not limiting soil water availbility was observed with a constant Bowen ratio, suggesting temperature was more important than stomatal control as the main driver of photosynthetic carbon uptake.



Water-use efficiency (WUE)



Conclusions

- *Carbon uptake period* closely corresponded to leaf area development up to LAI_{max}
- Shift to *below-ground* biomass production towards the end of the growing season
- Reduced *leaf area development* in response to low soil water availability
- Decrease in GPP
  - → *stomatal control* (VPD) with low water availability in the root zone in spring
  - → *temperature and SWR* controlled when soil water was ample in summer
- Increase in ecosystem *WUE* with decreasing soil water availability in the root zone

Contact Laura.Broeckx@uantwerpen.be

Acknowledgements
This research has received funding from the European Research Council under the European Commission's Seventh Framework Programme (FP7/2007-2013) as ERC grant agreement n° 233366 (POPFULL), as well as from the Flemish Hercules Foundation. Further funding was provided by the Flemish Methusalem Programme and by the Research Council of the University of Antwerp. G. Berhongaray holds a grant from the Erasmus-Mundus External Cooperation and D. Zona was supported by a Marie Curie Reintegration grant. We gratefully acknowledge Joris Cools for excellent technical support and Kristof Mouton for logistic support at the field site.

Reference
Broeckx LS, Verlinden MS, Berhongaray G, Zona D, Fichot R, Ceulemans R (2013) The effect of a dry spring on seasonal carbon allocation and vegetation dynamics in a poplar bioenergy plantation. Global Change Biology Bioenergy, doi: 10.1111/gcbb.12087.