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Net CO2 and water exchanges of trees and grasses in a semi-arid region (Gourma, Mali)

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An improved understanding of plant and soil processes is critical to predict land surface-atmosphere water exchanges, especially in semi-arid environments, where knowledge is still severely lacking. Within the frame of the African Monsoon Multidisciplinary Project (AMMA), eddy covariance and sapflow stations have been installed to document the intensity, the temporal variability and the main drivers of net CO2 fluxes, water fluxes and contribution of the trees to these fluxes in a pastoral Sahelian landscape. Indeed, although the importance of vegetation in the West African monsoon system has long been postulated, extremely few data were available sofar to test and develop land surface models. In particular, data documenting seasonal and inter-annual dynamics of vegetation/atmosphere exchanges did not exist at 15° N in West Africa before AMMA.

The site is located in the Gourma, Mali. Vegetation in this area is sparse and mainly composed of annual grasses and forbs, and trees. Vegetation is organized according to soil type and lateral water redistribution, with bare soil with scattered trees on shallow soils and rocky outcrops (35% of the area), annual grasses and scattered trees on sandy soils (65% of the area), and more dense canopies of grasses and trees growing in valley bottoms over clay soil.
To quantify tree transpiration in the overall evapotranspiration flux, sapflow measurements, associated to soil moisture measurements, have been conducted on the main tree species (Acacia senegal, A. seyal, A. raddiana, Combretum glutinosum, Balanites aegyptiaca) in a grassland site and in an open forest site, where eddy covariance fluxes measured the total flux.

Using this dataset, we have studied the effects of plant diversity on carbon and water fluxes at the foot-print scale and seasonal dynamics of fluxes due to plant phenology and variations of soil water content (SWC). Carbon fluxes were documented as well, over two years. NEE was close to 0 during the dry season even during maximum leafy period of trees, which demonstrated that trees contribute weakly to net CO2 exchange at the sandy site, where the tree cover is of the order of 3%. During the rainy period, the seasonal pattern of NEE followed LAI dynamics of the herb layer with no effect of species composition, although the species composition did change during the growing season. In 2007, the maximum value of daily NEE was strongly and linearly related to LAI except during 4 days of drought (238-244). Because of an exceptional dry year, this relationship was not found in 2008. Carbon uptake by photosynthesis (GPP) contributed up to 60-80 % of Net CO2 fluxes. During the period of maximum LAI of herbs, Light Use Efficiency (LUE, net CO2 uptake per absorbed radiation) was strongly related to Soil Water Content (SWC) of the first centimetres.
Similarly, the seasonal dynamics of Evapotranspiration (ETR) also followed the variations of SWC at small depth. During the dry season, ETR was small (0.2 mmol H2O m-2 s-1) but not zero. In fact, tree transpiration occurred throughout year. Leaf phenology was found to be the main driving factor of the seasonal dynamics of tree water use in this “dry” savanna. We also found that sapflow density was from 1.5 to 2 l dm-2 hour-1at the beginning of dry season when % of leaves on tree was maximum, showing that trees had access to deep soil water.