Hydrologic Activity of Deciduous Agroforestry Tree Observed through Monitoring of Stable Isotopes in Stem Water, Solar Radiation Attenuation, and Sapflow

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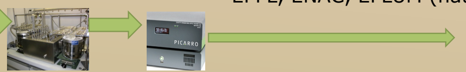
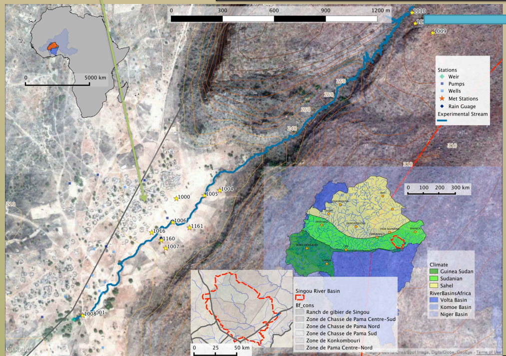


Soil and Vegetation samples were collected in sealed vials, extracted using a vacuum pump, liquid nitrogen trap (Ehleringer, Roden & Dawson 2000), and an 85ºC water bath. Water samples were collected directly. Both were analyzed with a Picarro L2130-i CRDS to obtain both O18 and DH fractions. All values are in relation to VSMOW standards.

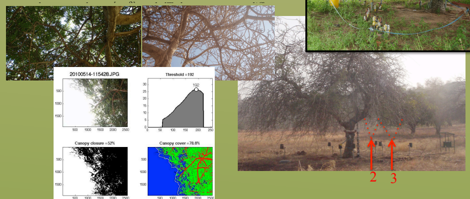


Study focuses on a single *Sclerocarya birrea* agroforstry tree which is located near an ephemeral stream which in the Singou watershed that is part of the Volta Basin, Soudanian botanical and climate zone, and is farmed by village of Tambarga, part of the commune of Madjoari. The 8 villages of this commune are somewhat isolated, inaccessible and surrounded by game reserves and national parks.

Additional meteorological measurements were taken with a network of wireless, autonomous stations that communicate through the GSM network (Sensorscope) and 3 complete energy balance and eddy-covariance stations. The same WSN stations were uniquely configured around the *S. birrea* tree to collect and transmit the sub-canopy solar radiation, throughfall, stemflow (Davis Inst.), and soil moisture (Decagon).

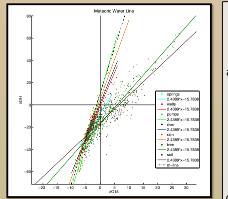
Sapflow was monitored using a Granier system consisting of a heated and non-heated probe (UP Umweltanalytische). The temperature difference between the two probes (dT) was converted to sapflux by referencing it to a minimal night time "no flow" value to obtain the sapflow density and then multiplied by the area of the sapwood.

$$F = SA \cdot 0.714 \cdot \left(\frac{dT_{nigth}}{dT_{actual}} - 1\right)^{1.231} \quad [ml/min]$$



Canopy cover, as a proxy for leaf area index, was estimated using two methods. First, the difference in solar radiation measured under and outside of the tree canopy provided a continuous measure of shading. Second, the pixels of pictures (Olympus) taken daily looking up from the radiometers (2 & 3) were separated into sky, leaf, and wood areas, and calculated as follows (Korhonen et al. 2009):

$$\text{projected Leaf Area Index} = LAI = \frac{\text{leaf area}}{\text{leaf area} + \text{sky area}}$$



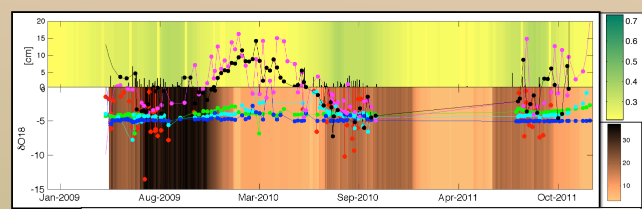
Problem

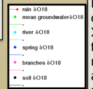
Understanding water use by agroforestry trees in dry-land ecosystems is essential for improving water management. Agroforestry trees are valued and promoted for many of their ecologic and economic benefits but are often criticized as competing for valuable water resources.

Question

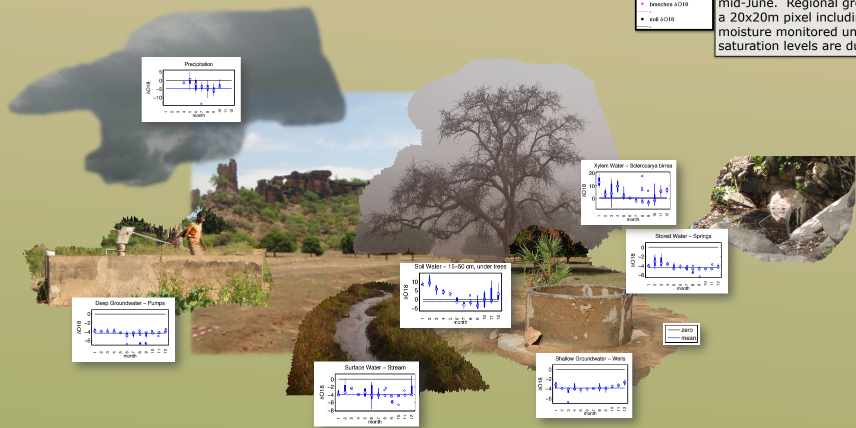
How do the isotopic signature of flows through the watershed from precipitation through surface and groundwater, vegetation, and soil evolve seasonally?

Does data collected using 4 innovative methods (stable isotope analysis, canopy observation, sapflow, and solar radiation attenuation, confer on times of leaf out, access to groundwater, and hydrologic connectivity?

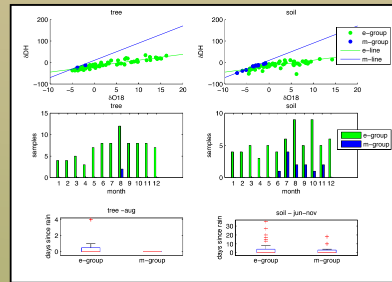




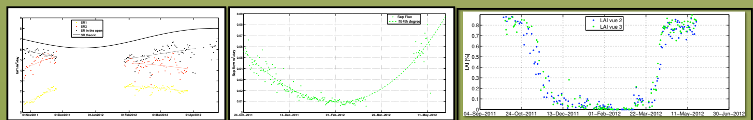
Examination of the time series of O18 values confirm that soil and xylem water are coupled, becoming enriched during the dry season and depleted during the rainy season. Xylem water drops to groundwater levels in early March when trees access groundwater for leafing out, however soil water does not reach this level until soil moisture increases in mid-June. Regional greenness is observed with the Modis-NDVI product (NASA GSFC) for a 20x20m pixel including the agroforestry tree, shown in green to yellow shading. Soil moisture monitored under the tree canopy. Note that difference in 2009 and 2010-2011 saturation levels are due to a change in instrument from ECTM to 5TM (Decagon).



- Rain water is depleted over the course of the rainy season (May – October), supporting understanding of the African Monsoon system.
- Stored water is fairly constant, with a slight enrichment January- April.
- Surface water is enriched as it becomes disconnected from the ground water, January to March.
- Shallow groundwater is enriched October to January.
- Deep groundwater is constant.
- Xylem water is enriched from November to April.
- Soilwater is enriched from December to May.



The relationship between the DH and O18 concentrations of water extracted from Soil and Tree samples do not fall along the meteologic water (m-)line with a slope of 8 and y-intercept of 10. In order to explore whether, this was a seasonally driven test, we grouped samples into an "evaporated group" or a "meteologic" group based on the smaller residual to the m-line or to the evapotranspiration (e-) line with a slope of 2.76 and an intercept of -17.13. Although more soil samples were found along the m-line during the m-line during the rainy season than tree samples or dry season soil samples, there was no significant difference in days since rain for any group, suggesting that xylem water is always under evapo-transpiration stress and soil water has undergone evaporation soon after a rain event.



Analysis of canopy cover through photographic analysis and solar radiation attenuation from October 2011 shows onset of leaf-loss to occur in late October and be compete by mid December. Leaf out occurred in early April. Sapflow demonstrates a similar slowing, reaching a minimal rate in February 2012. Theoretical solar radiation according to Whiteman and Allwine (1986).

Visual observation of tree confirms conclusion that tree access deep ground water in March and April, before rain begins and before soil is connected to groundwater.

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This conclusion was supported by analysis of stable isotopes, sap flow, and canopy cover.

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Results from the research are being integrated into a local outreach project to improve local use of agroforestry.

We would like to thank Rolf Siegwolf and the plant physiology group at PSI, Pierre Adil-Abdelmoula as well as all field help.