Drought effects on Amazon Forests: implications for basinwide carbon sequestration

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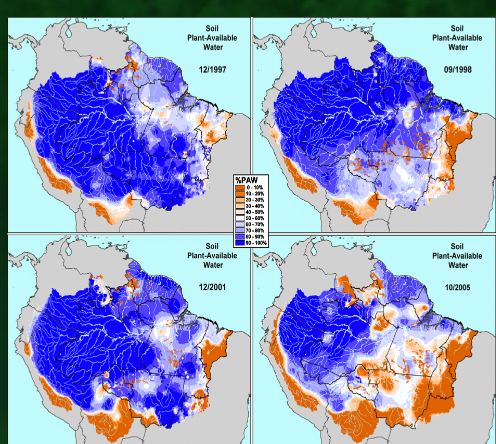
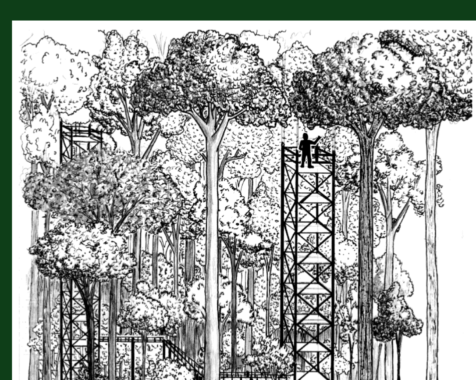
Summary:

Large areas of moist tropical forest are exposed to periodic droughts that may become more severe through global and regional climate change. But little is known of how forests will respond to greater drying. We report that an Amazon forest exposed to partial rainfall exclusion for five years exhibited unexpected responses with important implications for carbon emissions and forest fire. Although the forest initially avoided many effects of drought by withdrawing soil moisture to a depth of 15 m, the mortality of large canopy trees increased six-fold as soil moisture was depleted. Wood production declined 70% while litterfall and belowground production changed little. Forest flammability increased 100 fold through the decline of leaf area index (30%) and the accumulation of fuel on the forest floor. These drought responses caused a 10% reduction in forest carbon content and an estimated release of 2 Pg of carbon to the atmosphere from forests across the Amazon during the severe droughts of 1998 and 2005, assuming the responses can be generalized. Carbon emissions and forest impoverishment are greater where drought-induced increases in flammability lead to forest fire which, itself, may provoke further drying. Drought ranks with deforestation as one of the most serious threats to moist tropical forests.



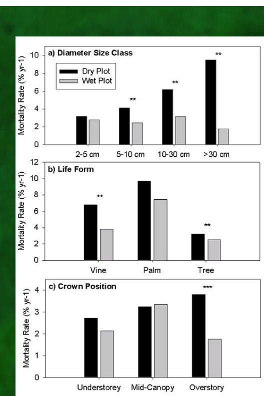
The Amazon 'rainforest' endures an annual dry season each year, but in recent years, increasingly strong El Niño events have provoked much more severe droughts than previously, and we began to wonder about the resiliance of the forest in the face of these more severe events. In 1998 we began a rainfall exclusion experiment to see how a typical Amazon lowland forest would react to severe, prolonged drought.

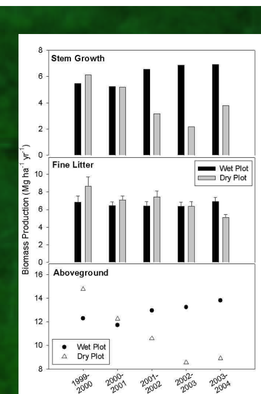
Located in the Tapajós National Forest near Santarém, in the lower Amazon basin, our experiment consisted of two one-hectare parcels (2.5 acres) of moist tropical forest - a treatment parcel and a control parcel. The two parcels are only 25 meters apart to ensure that any localized climatic factors will affect them equally. Each parcel has a 1.5 meter trench dug completely around it to isolate its soils from the soil outside the parcel. In the experimental parcel the trench was lined with plastic to channel the rainwater falling onto that parcel to a lower area 300 meters away. Above ground, each parcel has four towers averaging 30 meters in height for canopy access and weather instruments, and beneath the canopy, elevated catwalks meander through the forest to provide access for physiological measurements and observations.

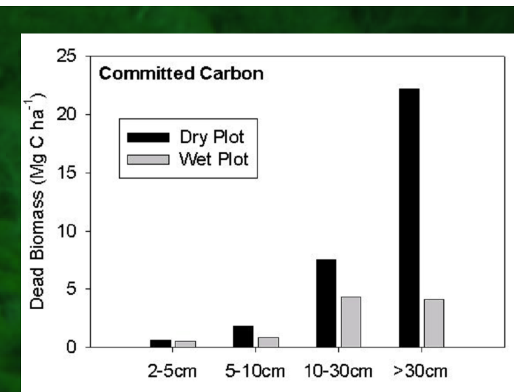


Artwork courtesy of Kemel Kalif

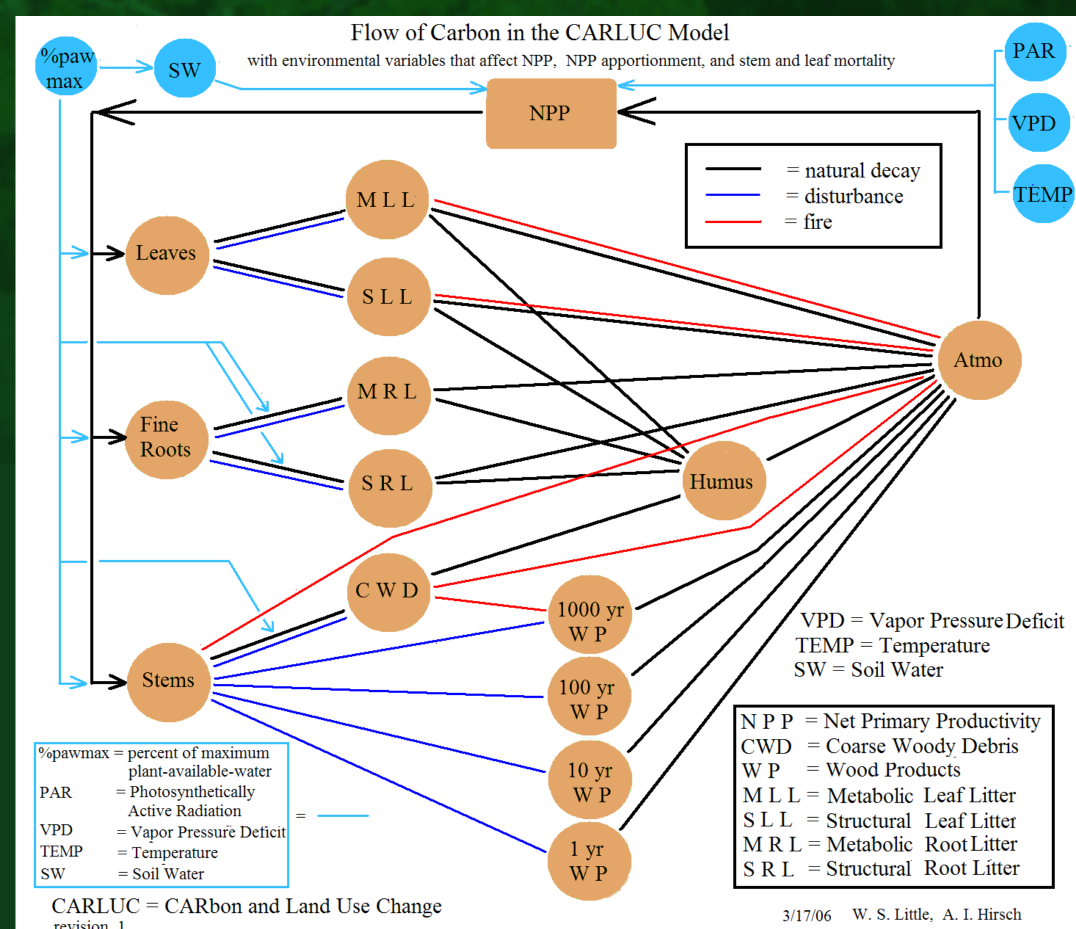
A system of elevated gutters and 5,600 plastic-covered wooden framed panels diverted most of the rainfall from the experimental parcel.For six years we monitored soil moisture, canopy density, microclimate, and tree physiology, and measured the impacts of this experimental treatment. The results surprised us: although we anticipated a reduction in leaf production associated with drought, this occurred only slightly. Rather, the forest appears to have maintained carbon investments in leaf and belowgraound production while drastically reducing allocation of NPP to stemwood. Allocation to belowground production, however, is somewhat uncertain.



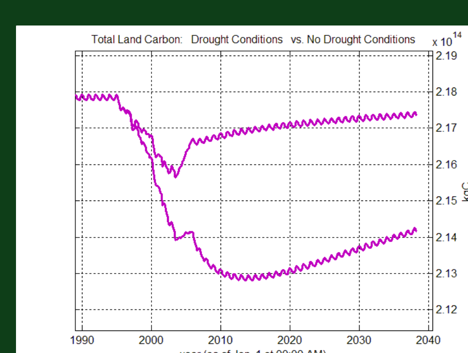




We incorporated the relationships between soil water content (plant-available soil water to 10 m depth) and (a) tree mortality, (b) leaf area index, and (c) stemwood growth, into the CARLUC (CARbon & Land Use Change) ecosystem model (Hirsch et al. 2004). In the revised model, the allocation of NPP (leaves, roots, wood) is dependent upon PAW, with the portion going to stemwoods declining at low PAW levels. PAW is estimated for the Amazon Basin following Nepstad et al. (2004) using krigged datafields of rainfall,. . . . .The model tracks 13 carbon pools, which vary as a function of NPP and its allocation, tree mortality, and decay.



Results:



Inclusion of drought effects on stemwood increment and tree mortality in the model caused a Basin-wide reduction of approximately 4 Pg of carbon in Amazon forests. These effects are above and beyond the effects of drought on NPP (e.g. Tian et al. 1998). While landscape disturbance history influences the net flux of carbon from Amazon forests for many years (Saleska, et al. 2003, Wofsy et al. 1988), drought effects on stemwood growth and tree mortality suggest that a long-term drying trend would substantially decrease the carbon content of this biome.

The relationship found through our rainfall exclusion experiment, however, must be tested in other forests.

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Financing: