December 2006

Oviposition preference and larval growth rates of Caligo memnon (Nymphalidae: Brassolinae)

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Soil Organic Matter (SOM) in agro ecosystems and intact cloud forest in The Monteverde area, Costa Rica

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ABSTRACT

Properly managed agro ecosystems have great potential for sequestering carbon as Soil Organic Matter (SOM) (Brown et al. 2002; Lal 2005). I measured % SOM, Bulk Density, Total SOM, and Root Biomass in two agro ecosystems, forest fragment, and intact cloud forest in Cañitas and Monteverde, Costa Rica. These data were analyzed to see if agro ecosystems and forests differ in carbon sequestering ability. I found significant differences in % SOM and Bulk Densities between agro ecosystems but when Total SOM was calculated, results were not significant. Analysis on Total SOM alone suggests that agro ecosystems and forest in Monteverde have an equal ability to sequester SOM. However, root biomass may have an important role. When significant data from Average Root Biomass was added to Total SOM to calculate an estimate of belowground carbon data became significant. Intact forest was significantly higher in combined Root Biomass and Total SOM than the agro ecosystems and forest fragment. Though the data suggests that agro ecosystems in Monteverde are capable of sequestering considerable amounts of Total SOM, including Root Biomass illustrates the importance of conserving intact forest to maximize carbon sequestration.

Resumen

Los agro ecosistemas apropiadamente manejados tienen gran potencial para el embargar del carbón como Materia Orgánica de Tierra (MOT) (Brown et al. 2002; Lal 2005). Medí % MOT, la densidad del bulto, SOM total, y la Biomasa de raíces en dos agro ecosistemas: el fragmento del bosque, y el bosque nuboso intacto en Cañitas y Monteverde, Costa Rica. Estos datos fueron analizados para averiguar si el agro ecosistema y bosques difieren en la habilidad de embargar el carbón. Encontré las diferencias significativas en él % MOT y las densidades del bulto entre los agros ecosistemas pero cuando MOT Total fue calculado, los resultados no fueron significativos. El análisis de solamente MOT Total sugiere que estos agro ecosistemas y el bosque en Monteverde tienen habilidades iguales para embargar MOT. Sin embargo, la biomasa de raíces puede tener un papel importante. Cuándo los datos significativos del Promedio de la Biomasa de raíces fueron agregados al MOT Total para calcular una estimación de carbón bajo la tierra los datos llegaron a ser significativos. El bosque intacto tuvo apreciablemente más Biomasa combinada de raíces y MOT Total que los agros ecosistemas y el bosque fragmentado. Aunque los datos sugieren que los agro ecosistemas en Monteverde son capaces de embargar unas cantidades considerables de

SOM Total, incluyendo la Biomasa de raíces ilustra la importancia de conservar el bosque intacto para llevar al máximo el secuestro del carbón.

INTRODUCTION

The impact of human activities on climate change is clear; since CO_2 emissions first spiked at the beginning of the industrial age, atmospheric carbon has increased by 30% (Vitousek et al. 1997). Warming has led to a 10% decrease in snow cover and ice extent since the 1960's and this trend is likely to continue. The recently released Stern Review on the economics of climate change identified many more negative impacts of global climate change such as increased flood risk from glacial melting, lowered crop yields, and widespread increases in disease outbreaks (Stern 2006). From an ecological standpoint climate change has been implicated in global species declines, including the loss of 67% of *Atelopus* spp. (Pounds et al. 2006).

While the largest producer of greenhouse gasses, the United States, still remains unwilling to ratify the Kyoto Protocol, numerous methods have been identified to either reduce emissions or sequester carbon on a global scale. By extrapolating the amount of land needed to sequester sufficient atmospheric carbon Wright and colleagues (2001) identified forests as the only realistic method. However, poverty and high demand for land makes implementation unlikely. A plausible alternative with great potential is the use of various agro ecosystems including secondary forest agroforestry, plantations, and improved pastures to increase the Soil Organic Matter (SOM) pool (Lal 2005).

Under proper management, the top 48 tropical and subtropical developing countries could sequester 2.3 billion tones of carbon in the next 10 years alone, and for a profit of 16.8 billion dollars according to one estimate (Niles et al. 2002). Recovering secondary forest on abandoned land has been found to recapture nearly all soil carbon lost from historical forest within 50 years (Brown and Lugo 1990). Effective shade coffee plantations can sequester 46.7-236.7 tons C/HA (Dejong et al. 1995). Pasture, while lacking in above ground biomass, has the capacity for great (SOM) sequestration, comparable or even greater than surrounding native forest (Lugo 1986). Other studies have further identified the effectiveness of pasture for restoring soil carbon to degraded ecosystems (Neill et al. 1997; Rhoades 2000; Trumbore et al. 1995).

The significance for SOM in carbon sequestration, productivity, and sustainable use is great, both globally and in the tropics especially. Seventy-five percent of terrestrial carbon is found in soils and of that 14% (216 Pg) is found in the tropics (Houghtan et al. 1985; Lal 2005). Higher temperatures can increase the rate of carbon decomposition in the tropics to four times that of temperate areas, but greater biomass accumulation in the tropics makes content equal (Jenkinson and Ayanaba 1977; Sanchez 1982). This has implications for effective management to maximize carbon sequestration, as biomass accumulation needs to be maximized and decomposition minimized. For instance, Nestel (1995) found that increased sun exposure in sun coffee monocultures leads to increases in soil temperatures, decreased water, which can cause soil degradation. Root biomass has been shown to directly increase C in pasture through depth and proliferation (Choné et al. 1991). Though this is just a portion of total organic deposition contributing to SOM, root biomass can further influence SOM by stabilizing erosion, soil moisture, and temperature (Lal 2005).

Under the current Kyoto protocol only one of the three agro ecosystems discussed, agroforestry, is marketable for ecosystem service payments (UNFCCC 2002). Brown and colleagues argue that this is a mistake and that there are numerous opportunities through sustainable agriculture to sequester carbon (Brown, S. et al. 2002). The objective of this study is to address this issue by identifying if agro ecosystems and forests differ in carbon sequestering ability. Furthermore, this study provides a first look on SOM sequestration in agro ecosystems of Monteverde, Costa Rica, and will thus provide a basis for further study. Based on past research illustrating high SOM sequestration in agro ecosystems, I predict there will be no significant differences between pasture, coffee, forest fragment, and intact forest.

Methods

Study Site

Four sample sites were used in the Monteverde area, one at the Monteverde Biological Station (intact forest) and the other three (coffee, pasture, and forest fragment) at the farm of Don Victor Torres, in nearby Cañitas. The farm was chosen for access to agroforestry (secondary forest fragment), coffee plantation, and pasture. It is assumed that these agro ecosystems are at equilibrium and are effectively sequestering carbon due to proper management.

Bulk Density (BD)

Bulk density measurement was adapted from Field and Laboratory Investigations in Agroecology (Gliessman 2000). Five composite samples to 15 cm were taken at each site using a 2 cm diameter soil core. The five composite samples were taken at 10 m, 30 m, 50 m, 70 m, and 90 m and consisted of three sub samples at each location. A drying oven was not available so samples were dried in the attic of the biological station for three days with an average temperature of 26.87 C°. Once dried, samples were weighed and density was calculated.

% SOM & Total SOM

At each site, eight composite SOM samples were taken along a 100 m transect. Each sample was composed of 5 sub samples taken every 2.5 meters, from 0-10 m, 12.5-22.5 m, 25-35 m, 37.5-47.5 m, 50-60 m, 62.5-72.5 m, 75-85 m, and 87.5-97.5 m. At each sub sample, aboveground vegetation was removed and soil was excavated to 15 cm using a hand trowel. Soil was then mixed and put through a 2 mm sieve to remove rocks and roots. Samples were then sent to The Ministry of Agriculture Soil Laboratory in San Jose for analysis. Total SOM (g/m^3) was the percentage of Bulk density comprised of SOM and was calculated by multiplying % SOM with Bulk Density.

Root Biomass (RB)

A total of 40 samples were collected, 10 from each site, at 5 m, 15 m, 25 m, 35 m, 45 m, 55 m, 65 m, 75 m, 85 m, and 95 m. At each distance a total of 10 sub samples were collected from 0-10 m perpendicular to the transect using a 2 cm diameter soil core at a depth of 15 cm. Samples were then washed using an adaptation of the Central Plains Experimental Range Root Washing Protocol, dried in the attic of the biological station for 3 days, and weighed (Milchunas).

Analysis

All data were averaged and standard error calculated. Significant differences between data sets were identified using a Kruskal-Wallis test.

Results

Root biomass was significant, and was highest in intact forest and lowest in coffee (Kruskal-Wallis: X2 = 29.44 DF = 3.00 p = 0.00). Coffee was significantly lower than the next lowest sites, pasture and intact forest which were statistically equal (Figure 1a). BD was also significant but followed opposite trends, highest in pasture and lowest in intact forest (Kruskal-Wallis: X2 = 16.62 DF = 3.00 p = 0.00) (Figure 1b). Similar to RB, intact forest had the highest % SOM, but pasture was lowest instead of coffee (Kruskal-Wallis: X2 = 20.68 DF = 3.00 p = 0.00). Forest fragment % SOM was also significantly less than intact forest (Figure 2a). When Total SOM was calculated, results were not significant and averages were statistically equal (Kruskal-

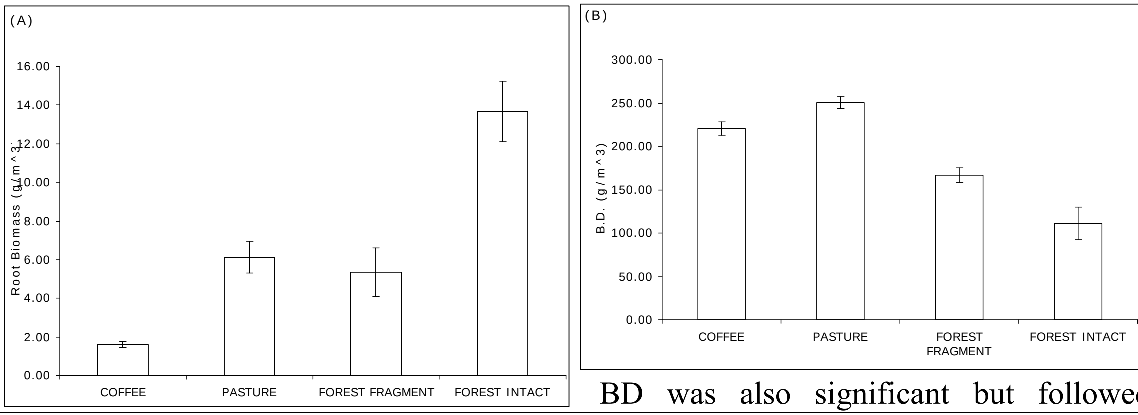

Figure 1: Average Root Biomass (g/m^3) (A) and Average Bulk Density (g/m^3) with standard error bars at the Torres' Farm in Cañitas and the Biological Station in Monteverde. Root Biomass and Bulk Density showed an inverse relationship.

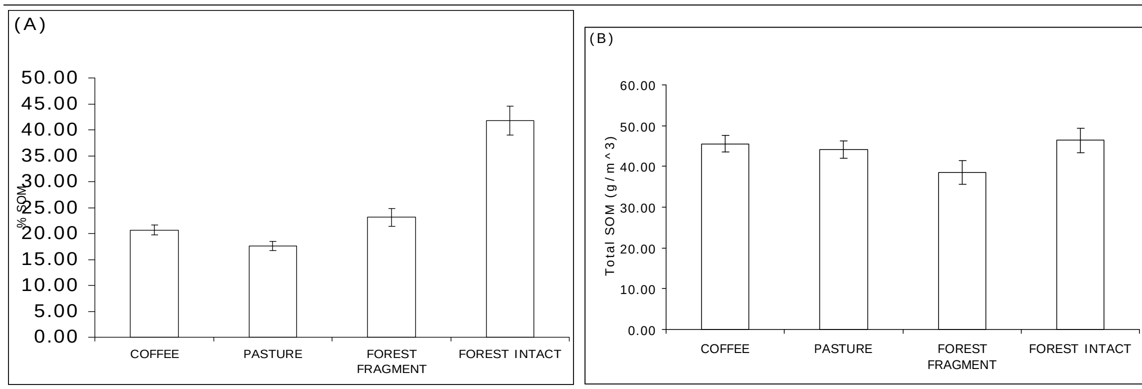

Figure 2: Average % SOM (A) and Average Total SOM (g/m^3) with standard error bars at the Torres' Farm in Cañitas and the Biological Station in Monteverde. While Average % SOM was significant, Average Total SOM (g/m^3) was not.

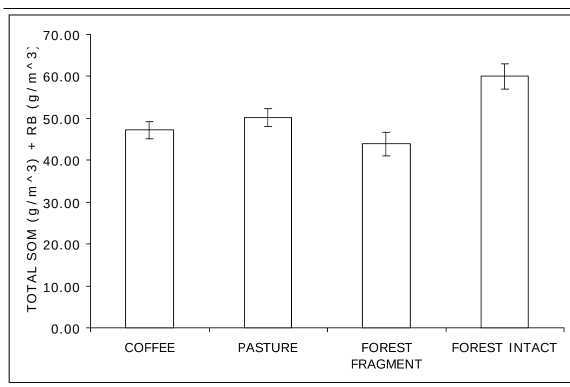

Figure 3: Average Combined Total SOM (g/m^3) and Root Biomass (g/m^3) with standard error bars at the Torres' Farm in Cañitas and the Biological Station in Monteverde. Data was significant, suggesting belowground carbon sequestration was greatest in intact forest.

Wallis: X2 = 4.15 DF = 3.00 p = 0.25) (Figure 2b). Adding RB to Total SOM provided significant results with intact forest having the highest value (Kruskal-Wallis: X2 = 9.32 DF = 3.00 p = 0.03) (Figure 3). Forest Fragment was significantly less than Intact Forest (Figure 3).

Discussion

The significant results from BD and RB show an inverse relationship between the two across all sites. Low BD in intact forest is likely due to high litter fall and as a consequence has made root proliferation easier, which explains high RB occurring there (Figure 1a,b). BD was high in pasture and coffee which is explained by human and livestock compaction occurring at those sites (Figure 1b). Interestingly, RB in pasture was much greater than coffee despite its BD. High BD in pasture did restrict roots to being very fibrous which explains why RB is so much less than it is in intact forest. Coffee RB may have been further reduced due to weed trimming and monoculture. While RB for forest fragment was statistically equal to pasture, it was significantly lower than intact forest. Much less understory was observed during sampling of forest fragment than intact forest, which may have contributed to this finding.

Similar to RB, % SOM also showed an inverse relationship to BD (2a,b). As soil is compacted, its composition of SOM decreases while inorganic matter increases. These data may also be supported by comparing RB to % SOM. Greater RB in intact forest suggests that there is also a greater amount of decomposing and already decomposed roots which would directly add to % SOM. Furthermore, indirect properties of roots, such as erosion, temperature, and moisture control could be further influencing % SOM.

The inverse relationship between BD and % SOM equalized values for Total SOM, making differences between sites not significant. These data suggest that pasture, coffee, and forest fragment at the study site can sequester equal amounts of Total SOM (Figure 2b). Past research in pasture, secondary forest, and coffee all support these findings (Rhoades 2000; Lugo and Brown 1992; Dejong, et al. 1995). However, Total SOM is not a complete picture of belowground carbon. Adding RB to Total SOM made data significant which shows the importance of RB in belowground carbon sequestration. Intact forest was significantly higher than the other three sites due to the direct and indirect contribution of RB (Figure 3).

The results of this study have numerous implications and questions for further understanding of belowground carbon sequestration in the Monteverde area. Though intact forest is significantly different and greater in sequestration ability, the agro ecosystems studied appear to be sequestering high amounts of SOM. Further research is needed to determine if this is a trend across Monteverde, if SOM is stable, and what management techniques are most effective at increasing SOM within agro ecosystems. Additionally, unintended consequences of management decisions which lead to the release of other greenhouse gases such as N_2O or cause other environmental problems must be identified. The most important implication of this study is the importance of intact forest for carbon sequestration. Results suggest that belowground carbon storage is greatest in forest; this study did not even discuss the great amounts of above ground biomass which exists in both understory and canopy of the Monteverde cloud forest. Furthermore, the value of intact forest for its ecosystem services such as watershed protection, biodiversity, air quality, and even tourism must be recognized. Diversity of forest vegetation may even be a contributing factor to increased SOM in intact forest.

Acknowledgements

I would first like to thank mi familia Tica for an incredible experience on their farm in Cañitas. Nery, you are an awesome cook, sorry I was late to meals so much! Thanks to Mauricio for taking me out harvesting coffee and all of the kids for giving me a workout from so much playing. And many thanks to Don Victor for the use of his beautiful farm in my study. Thanks to Karen Masters for dealing with all my last minute questions and making this study possible. Cam and Tom are the best TA's ever, props for not freaking out from so many ridiculous questions from me and the other 29 students. Thanks to Aidee, Grant and Katie L. for all the excellent help.

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