Spatial controls on carbon quality along an elevational gradient in northeastern Puerto Rico

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Abstract

Understanding the spatial pattern of carbon quality and the environmental controls on carbon pools in critical zones is an integral component to explaining carbon cycle responses to climate change. We used surface (0-10 cm) and deep (11-30 cm) soil samples and density fractionation ($\rho = 1.6$ g cm^{-3}) methods to quantify total and light fraction soil carbon along an elevational and climatic gradient covering six typical forest types of northeastern Puerto Rico with similar bedrock geology (volcanoclastic) to evaluate the relative influence of measured and modeled environmental variables on the spatial pattern of total and light fraction soil carbon. When stratified by forest type, light fraction carbon (LFC), measured as proportion of whole soil carbon (WSC), decreased significantly with elevation and mean annual precipitation in the surface soils, but not in deeper soil horizons. However, due to the high variability within forest types, there were no significant differences in either LFC:WSC or LFC:whole soil mass (WSM) between forest types. A preliminary multivariate analysis revealed that there were no ubiquitous relationships between light fraction soil carbon and spatial variables, and that different combinations of climatic, topographic, biologic, and soil chemical properties controlled the spatial pattern of total and light fraction carbon at the different depths. Multivariate analysis was also able to explain more of the variability in the deep soil horizons than in the surface soil horizons.

Methods

Soil Sampling

In the summer of 2004, Gonzalez et al. (2007) selected 24 geographically separated sampling sites in 6 different forest types throughout Northeastern Puerto Rico. At each sampling location, a 25 x 25 cm soil block was excavated and quantitatively sampled as 0-10 cm and 11-30 cm layers (Gonzalez et al. 2007).

Density Fractionation

Soil samples were air-dried and passed by a Wiley mill through a 20-mesh (0.85 mm) stainless steel sieve (Gonzalez et al. 2007). Density fractionation of air-dry, sieved 0-10 cm and 11-30 cm whole soil (WS) samples from each forest type was performed with a sodium polytungstate (SPT) solution adjusted to $\rho = 1.6$ g cm^{-3}. Using a procedure modified from Sollins et al. (2006) and Barrios et al. (1996), light (LF) and heavy (HF) fraction soils were isolated for subsequent analysis. The dried LF and HF samples were ground (disaggregated) for total C/N analysis. Light fraction carbon mass (LFC) is reported as a proportion of whole soil carbon mass (WSC).

Hypotheses

H_1: The relative amount of light fraction carbon (LFC:WSC) decreases with elevation

H_2: Climatic variables have the strongest influence on soil LFC pools

Study Site

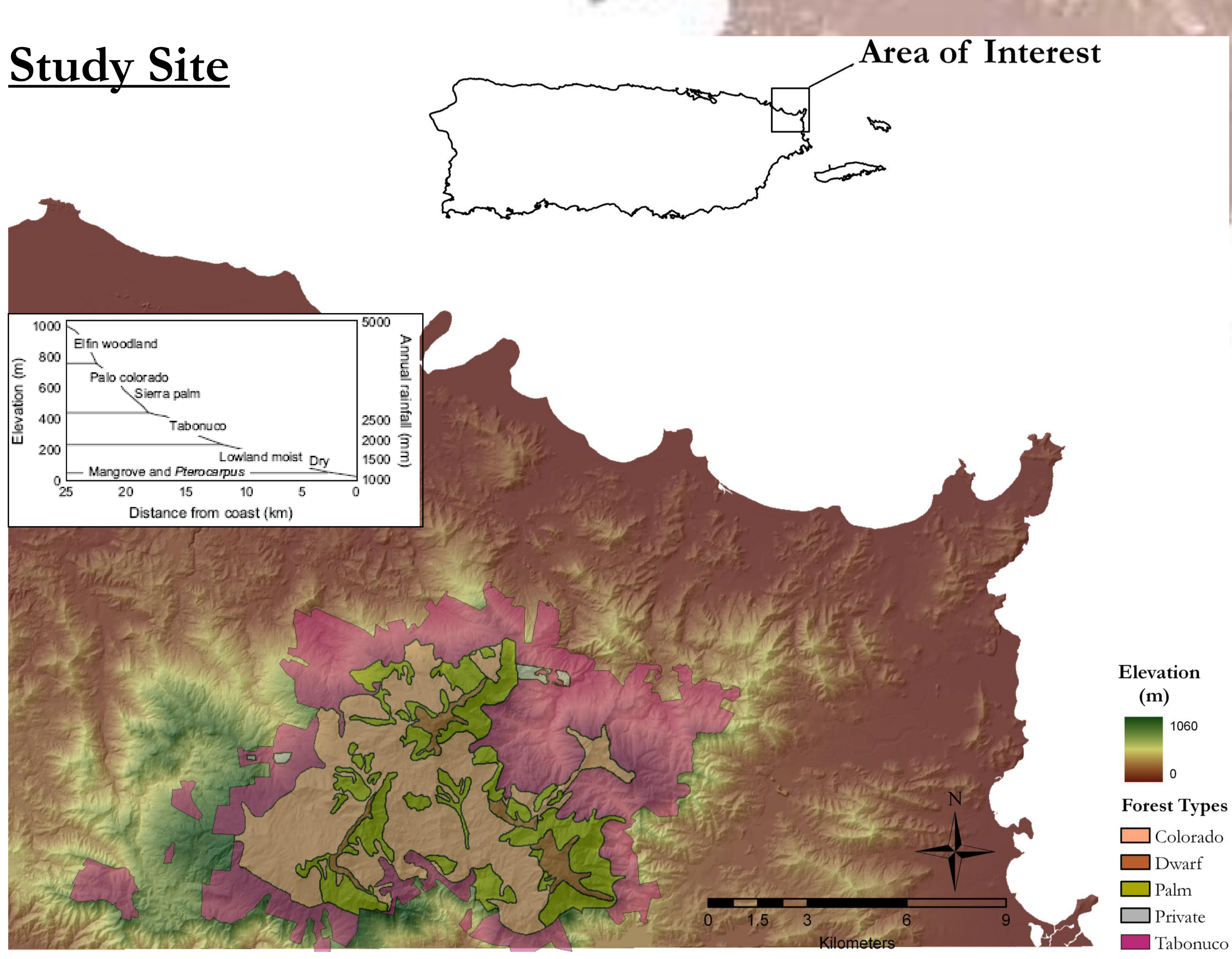

Fig. 1. Location of the study sites in northeastern Puerto Rico and the dominant forest types represented. Inset (*from*, Gonzalez et al. 2007) illustrates the elevation and precipitation gradient of the forest types within the study area.

Results & Discussion

Soil %C is strongly related to elevation and precipitation in the mountains of NE Puerto Rico.

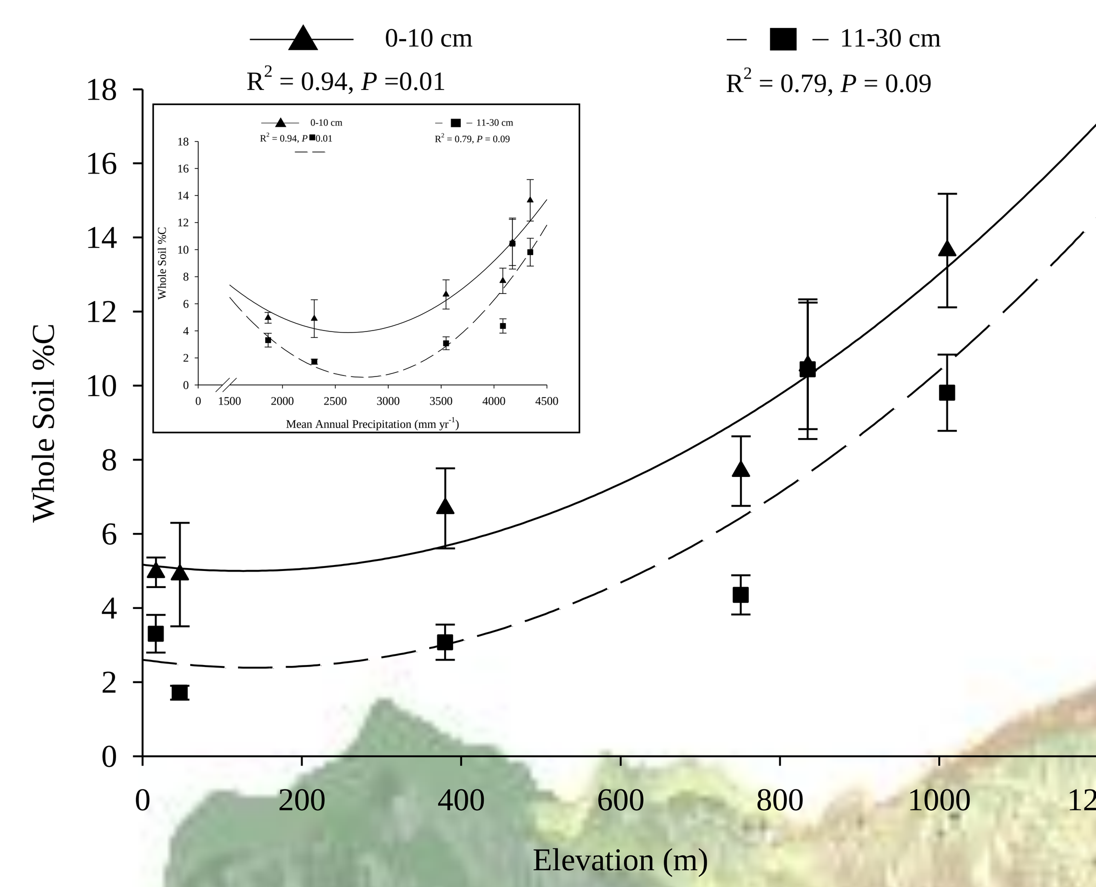

Fig. 2. Univariate linear regression showing the relationship between whole soil %C in both 0-10 cm and 11-30 cm soil layers. Symbols represent the average %C for each forest type and bars represent ±1 standard error. Inset represents the relationship between whole soil %C and precipitation.

*Soil %C is greater at higher elevations which are cooler and receive greater precipitation inputs. Changes to the climate in these forests may have implications for soil C balance and overall C storage.

Is there a relationship between light fraction soil carbon and elevation (and precipitation) in NE Puerto Rico?

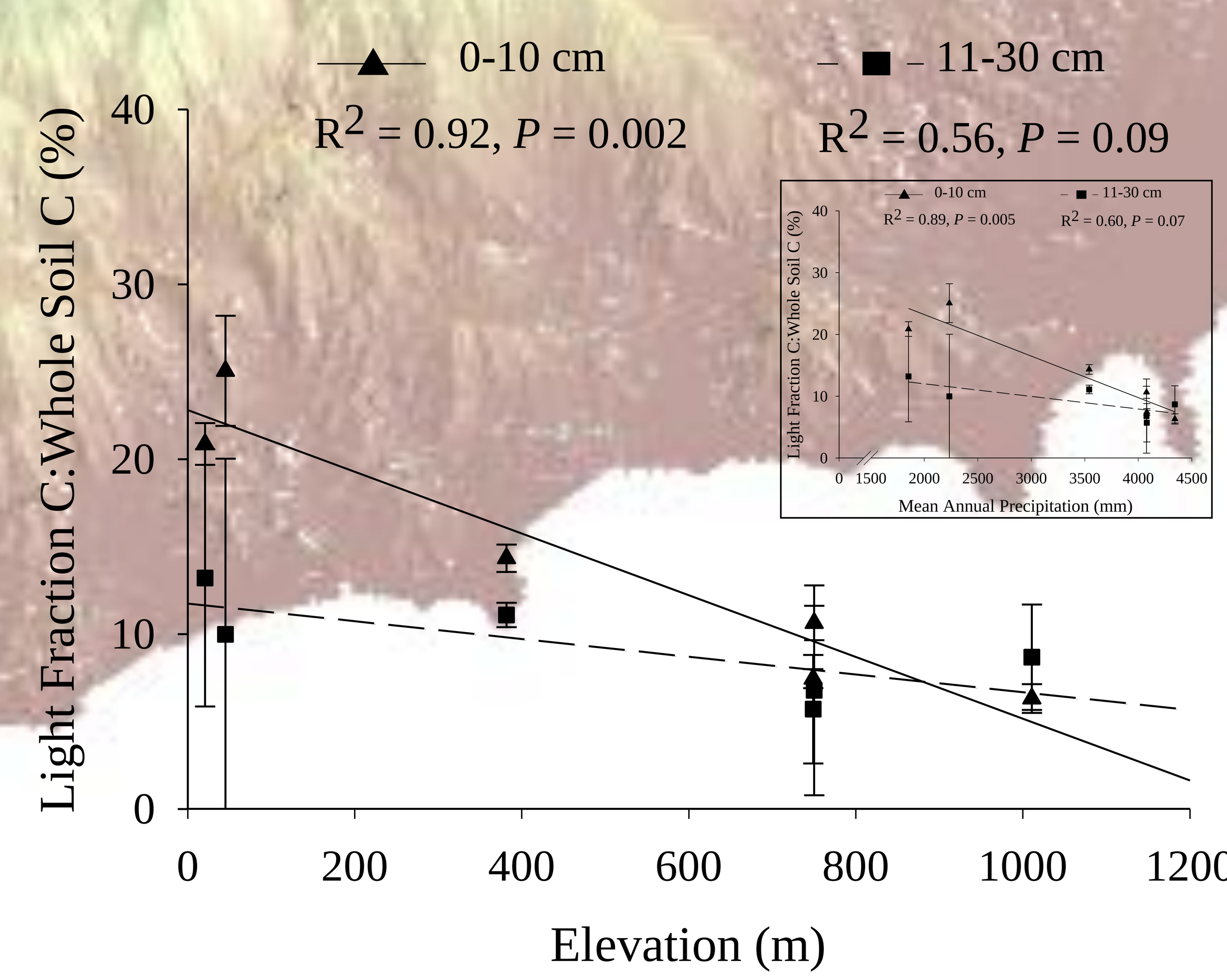

Fig. 3. Univariate linear regression showing the relationship between the LFC:WSC ratio. Symbols represent the average LFC:WSC ratio for each forest type and bars represent ±1 standard error. The inset represents the relationship between the LFC:WSC ratio and precipitation.

*The preliminary data presented here suggests that there is an inverse relationship between elevation and climatic co-variables (e.g., precipitation, temperature) and the relative amount of light fraction soil C. These trends imply that the soil C at higher elevations may be either more recalcitrant in character or physically protected.

*However, various climate predictions for this region of Puerto Rico suggest a decrease in precipitation at higher elevations, i.e., higher elevations will become drier, which may have implications for the relative amount of labile/recalcitrant soil C in these forests which could in turn influence soil C balance in the forests of the Luquillo Mountains of Puerto Rico.

Considering a variety of physical and environmental variables, are we able to determine the relative influence of those factors on light fraction soil C in these forest soils?

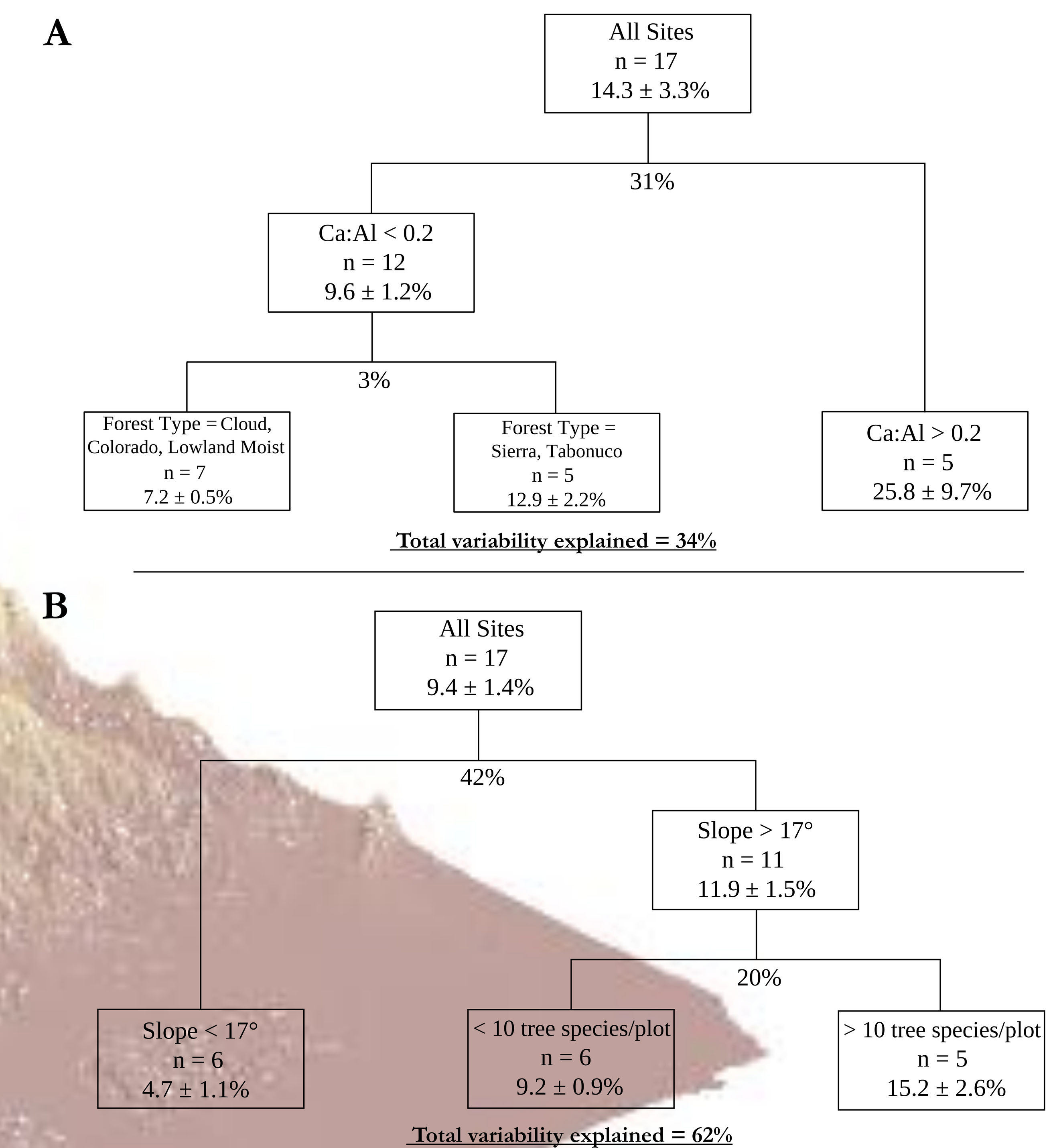

Fig. 4. Multivariate regression tree (MRT) analysis of the LFC:WSC ratio in the 0-10 cm **(A)** and 11-30 cm **(B)** layers. Individual boxes represent groups determined by the splitting criterion presented and are defined by the number of sites (n) and the mean **±** 1 standard error LFC:WSC (%) of those sites. The amount of variability explained by each split is represented as a percentage at each node.

*Despite the strong relationship between light fraction carbon and elevation, and those co-variable climatic factors, preliminary MRT analysis indicated that a broad range of soil chemical, biologic and topographic factors had stronger relationships with LFC.

*Soil chemistry was the dominant influence on LFC in the upper soil horizons (0-10 cm) which suggests geomorphic and geologic influences on the relative amount of LFC in these forests, though the current model was only able to capture ~34% of the variability within the LFC:WSC data.

*MRT analysis was able to explain more of the variability in LFC:WSC data in the deeper horizons and indicated that measures of landscape position (i.e., slope) and biodiversity (# of tree species) had the strongest relationships with the relative proportion of LFC in these forest soils.

Future Work

*In the summer of 2010, the network of sites will be extended to include locations on contrasting bedrock geology (granodiorite) to facilitate a comparison of carbon quality relationships across different rock types.

*Additional sites within the current network will be sampled in a effort to reduce within forest-type variability and increase the analytical power of the MRT analysis.

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References

Barrios, E., *et al.* 1996. Organic matter in soil particle size and density fractions from maize and legume cropping systems. Soil Biol. Biochem. 28:185–193.

Gonzalez, G., *et al.* 2007. Earthworm communities along an elevation gradient in Northeastern Puerto Rico. Eur. J. Soil. Biol. 43:S24–S32.

Sollins, P., *et al.* 2006. Organic C and N stabilization in a forest soil: evidence from sequential density fractionation. Soil Biol. Biochem. 38:3313–3324.