Diffuse Reflectance Spectrometry for Assessment of Carbon Sequestration Niches and Management Opportunities in Western Kenya

Alain ALBRECHT* and Markus G. WALSH

* Institut de Recherche pour le Développement (IRD) /International Center for Research in Agroforestry, PO Box 30677, Nairobi, Kenya. Tél : +254-2-524173 or 524000.
Fax : +254-2-524001 – Email : a.albrecht@cgiar.org or m.walsh@cgiar.org

Abstract

Complex interactions between parent materials, biota and disturbance history make it difficult to conclusively attribute changes in soil organic carbon (SOC) stocks to specific land use and management practices in landscapes. In large part, this difficulty is due to the uncertainties and costs associated with measurement of carbon stocks in time and space. Thus, at present, it is not clear if sequestration, release and special redistribution of carbon can be measured with sufficient accuracy, and at low enough cost, to assign verifiable carbon sequestration credits to specific land uses and management practices. More fundamentally, in the absence of a suitable framework for measurement it is even less clear if generalizeable management principles for enhancing carbon sequestration in landscapes can be proposed at present. Therefore, the development and deployment of cost-effective measurement systems is essential from both the perspective of carbon accounting, as well as for generating further process-based understanding of the terrestrial carbon cycle and its management. Diffuse reflectance spectrometry (DRS), and is now routinely used for rapid, non-destructive characterization of a wide range of materials. Recent research has demonstrated the ability or DRS to provide accurate predictions of numerous physical, chemical and biological properties of soils. In this contribution, we illustrate how DRS is being applied to quantify plot-to landscape-level interactions between SOC, land cover and erosion history, and management regime in western Kenya. Specifically, we demonstrate that : (1.) SOC concentration, water dispersible aggregates and soil erosion exert strong historical effects on soil carbon stocks that can be usefully exploited for identifying carbon sequestration niches and management opportunities in landscapes, and (3.) that understanding the key process involved in soil carbon sequestration, further strengthen the DRS approach for precise local management of carbon sequestration niches at plot, farm and small watershed scales.

In the first part of this presentation, we highlight landscape-level patterns in other to identify under which environmental conditions carbon sequestration niches occur and to demonstrate how these may be quantified. The concept of "soil reflectance libraries" is introduced and used to predict SOC and water dispersible aggregates. In validation samples 91% of the variation in SOC concentration and 94% of the variation in the water dispersible (i.e., potentially unstable) mass fraction of soils could be explained across a broad range of environmental conditions. A spectral mixture model for differentiating between erosional and depositional phases of soils is developed and tested against $_{210}$Pb and $_{137}$ Ce radionuclide measurements. Applying model results in conjunction with natural abundance measurements of soil $\delta^{13}C$, we show that : (1.) more than 60% of the variation in SOC concentration may be explained by historical land cover and erosion effects in western Kenya, (2.) erosion phenomena as measured on a spectral scale, manifest as strongly nonlinear phase transitions relative to SOC and water dispersible aggregates, and (3.) land use systems which have been historically dominated by C_3 photosynthetic pathway carbon inputs appear to have ca. 2,5x higher soil carbon sink potentials and are ca. 15x less likely to show erosion symptoms than those historically dominated by C_4 carbon inputs. In the second part of the presentation, we examine specific processes and management opportunities by contrasting agroforestry, zero-tillage and traditional agricultural ptactices at the plot, farm and small watershed-scale. We show that SOC is the main carbon sequestration niche in this context, and that soil aggregation is the dominant process involved in protecting SOC against mineralization and erosion. Woodlots, leguminous tree fallows and to a lesser degree tillage management, show enhanced potential to sequester carbon in the soil over traditional agricultural production systems by providing greater carbon inputs and affording a higher degree of CO protection within water stable aggregates. Erosion control and the attendant carbon gains are examined at three special scales including :1m² by rainfall simulation, 80m² through erosion plot monitoring, and for a small 0,8 km² watershed using spectral unmixing.

Key-words : Kenya, DRS, Carbon sequestraion, C Niches, land uses.