Soil properties, carbon stocks and fluxes of greenhouse gases in Andean watersheds. Soil properties, carbon stocks and fluxes of greenhouse gases (GHG) in the Fuquene watershed (Colombia)

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Introduction

The Water and Food Challenge Program approved to CONDESAN a project to pursue the *"Payment for environmental services as a mechanism to promote rural development in the upper watersheds of the tropics".* Environmental services considered include the provision of water, biodiversity conservation, prevention of soil erosion and potential for mitigation of net emission of greenhouse gases (GHG) and carbon sequestration. The project will operate in a group of nine pilot watersheds in various Andean countries. The Fuquene Watershed in the central part of Colombia, near Bogotá, was selected to initiate testing some specialize methodologies that later will be used in the assessment of the other watersheds. The Fuquene lagoon collects the water from the watershed and provides water to a vast number of villages and agricultural fields in neighboring areas. Despite numerous governmental, bilateral and private projects that have operated in the watershed, the lagoon, suffers an accelerated rate of reduction in area/water volume as well as eutrophication, due to several factors including border land recovery by ranchers, pollution of incoming water with sewage sludge, animal manure and nutrients leached from fertilizers etc. The watershed covers an area of 187000 ha. Main production activity in the watershed is intensive cattle rising. The most productive dairy farms in Colombia are likely located in this region. Total area covered by pastures (mainly *Kikuyo* grass in the lower basin and Ryegrass in the medium to upper part) is 110000 ha (59% of the area). Potato is the main crop in the watershed and is usually managed with conventional tillage, which involves major soil disturbance, which promotes soil erosion and nutrient leaching. Total area under crops is around 48000 ha (26% of the area). In recent years as a result of activities from a GTZ project, no tillage and minimum tillage systems have been promoted and are slowly gaining acceptance by potato growers. There are some 2000 ha of minimum till potato now in the watershed.

Our contribution to this project is make a quantification of the status of the most important soil physical characteristics that regulate soil function in relation to water, nutrient storage and leaching. We will also assess total carbon stocks in soils and biomass as well as net fluxes of carbon dioxide, methane and nitrous oxide in the watershed and also will quantify C stocks and GHG for the dominant land use systems. The purpose is to identify the land use systems that are more beneficial or detrimental to the environment. This information will be contrasted with information on sustainability of land use and the socioeconomic of main production systems collected by other researchers as part of the project. Win- win systems could then be promoted to help policy makers and local authorities to reorder land use in the watershed to maximize benefits for local farmers and communities as well as for neighboring receivers of water and services and for the global environment.

Materials and Methods:

Seven dominant land use systems on similar soils (hydrologic response units-HRU) were selected to fall within four transects: one longitudinal transect crossing the watershed from south to north and three perpendicular transects distributed along the main axes to spread along the watershed. Selected HRU included: Paramo native vegetation, mountain secondary forest, potato crops under conventional and minimum tillage, Ryegrass pastures, Kikuyo intensively managed pastures, and degraded land that not longer supports productive uses. These HRU were replicated three times trying to cover the spatial variability found in the watershed. A total of 21 sampling plots were selected.

Soil C stocks: In each of the 21 plots, three soil pitches (0.5 × 0.5 × 1m) were open: Pitches were located at three-altitudinal position within each plot: Upper, medium and lower part. In each pitch, composite soil samples were collected at four depths (0-5, 5-20, 20-40, and 40-100 cm) to measure bulk density and determine total Carbon stocks in soils. Soil samples will be analyzed using conventional wet oxidation methods to assess oxidable carbon and by CHN analyzers to measure total carbon. In areas where the history of land conversion from C3 type dominated vegetation (i.e native forest) to C4 dominated species (some grasses, maize, sorghum etc), or from C4 into C3 vegetation, is well known and reliable, 13C determinations will be made in soil samples to assess the rate of replacement of new organic matter and to establish C partitioning between soil pools of different mean residence times (Baledescent et al, 1998).

Soil Physical parameters: At the time of soil sampling some soil physical characteristics were evaluated *in situ*: resistance to penetration in the soil profile (using a penetrograph) and soil shear strength (using a torcometer). Samples were collected for bulk and particle density determinations measuring saturated hydraulic conductivity, air permeability, resistance to compaction, and water retention characteristics. As physical condition define how water can be store and move into the soil profile, a good understanding of the behavior of the physical soil profile in relation to water fluxes will allow to define if there are possibilities of contamination with elements coming from fertilizers or not. As also they define, the hydrologic response of the soil in relation to rainfall, they will allow to understand the relationship between rainfall and rainfall acceptance capacity of the soils, runoff production as well as the vulnerability of soils to be eroded. This knowledge will help to track sources of contamination of the lagoon and the loss of the water mirror and will be used to define solutions to control degradation problems.

Plant C stocks: Carbon in plant biomass will be done through allometric equations for trees and shrubs and by harvesting representative subplots of crops and pastures. Allometric equations will be developed for selected species when not available (Feldspaucsh et al., 2004).

Greenhouse gases: Fluxes of carbon dioxide, methane and nitrous oxide, the three most important GHG related to land use change and agricultural activities, are being monitored on an annual basis to follow at least a full cycle of climatic variations. One of the replications for the seven HRU was selected for monitoring gases. In each plot four replicate sampling points were selected and geo-referenced. A PVC collar (30 cm diameter, 10 cm height) was permanently installed in the soil to a depth of 8 cm. A closed vented chamber is attached to the collar at the time of gas collection. Four gas samples are collected per chamber at times 0, 10, 20 and 30 minutes (Hutchinson and Mosier, 1981). Chamber temperature is measured at every sampling time. A biweekly sampling frequency is used. Gas samples are stored in pre-evacuated glass vials and are analyzed within two weeks after collection by gas chromatography (ECD and FID detectors) for CH4, CO2 and N2O. Gravimetric soil water content is measured at every sampling time. Soil redox potential, pH and soil temperature is measured *in situ* and soil samples are collected periodically for monitoring ammonium and nitrate levels.

Integration of annual fluxes of both C and GHG will be done at the watershed level by using similar hydrologic response units and adding them using land cover data from remote sensing and GIS techniques. Once annual data is collected and the global warming potential of different HUR is calculated, a modeling process could be conducted to estimate how the reordering of land use systems in the watershed will influence the interaction with the environment.

Preliminary results:

Figure 8, shows partial data on soil shear strength for the dominant land uses found in the watershed. Data for one of the replicates is showed. The paramo sites show values of shear strength above the threshold value (60 kPa) considered as acceptable for plant growth. This is an indication of surface soil hardness even under natural condition and explains why farmers have to use tillage to overcome this limitation. No tillage systems clearly reduce surface soil strength favoring the developing of the root systems. Intensively managed pastures have resulted in very high surface strength, likely as a result of cattle trampling. Degraded soils showed the most extreme levels of soil compaction. This will surely, root establishment preventing any productive use of the soil under current conditions. Land rehabilitation strategies should be implemented to reduce these limitations to tolerable levels that allow plant growth. Soils under no tillage crops exhibit an adequate physical environment for root development.

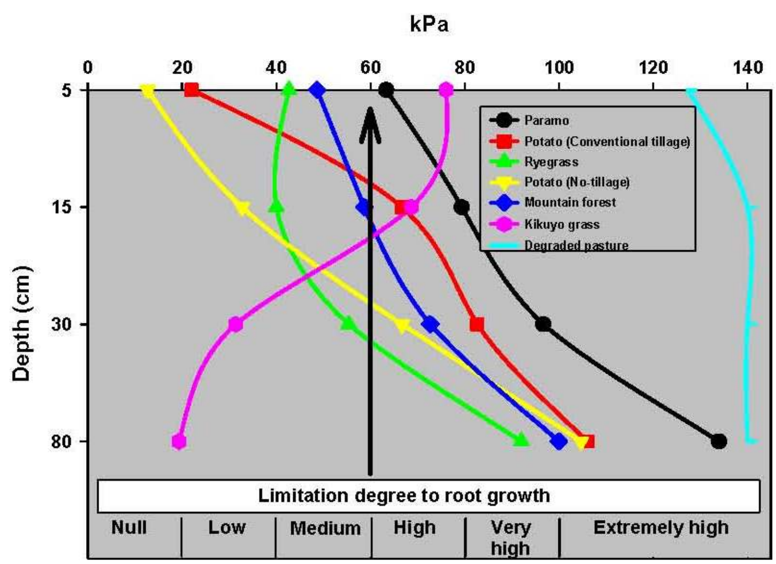

Figure 8. Soil shear strength for diverse land use systems on the upper Fuquene watershed (Colombia)