How do we can study the hability of pastoral landscapes to sequester carbon?

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Abstract

Transformation of forests to pastures and agricultural lands has had negative ecological impacts in the Latin American region. However, the implementation of silvopastoral systems to replace grass monocultures in extensive ranching could contribute to a reduction of environmental degradation, recovery of degraded pastures and increased and farm productivity. This article present some research results, as base to show the potential of silvopastoral systems to enhance the carbon storage above or belowground, These sinks, could be increase by PES strategy to stimulate the establishing silvopastoral systems. However, there are still significant gaps in the knowledge about the relations between biophysical factors and environmental services.

Keywords: environmental services; cattle; silvopastoral systems.

Resumen

La transformación de los bosques en pastizales y tierras agrícolas ha tenido negativo impactos ecológicos de la región de América Latina. Sin embargo, la implementación de sistemas silvopastoriles para sustituir a los monocultivos de pasto en la ganadería extensiva podría contribuir a una reducción de la degradación ambiental, la recuperación de pasturas degradadas y el aumento de la productividad y de la granja. En este artículo se presentan algunos resultados de la investigación, como la base para demostrar el potencial de los sistemas silvopastoriles para mejorar el almacenamiento de carbono por encima o por debajo del suelo, estos fregaderos, podrían ser aumento por la estrategia de PSA para estimular el establecimiento de sistemas silvopastoriles. Sin embargo, todavía hay importantes lagunas en el conocimiento sobre las relaciones entre los factores biofísicos y servicios ambientales.

Palabras clave: servicios ambientales; ganado; sistemas silvopastoriles.

Introduction

Silvopastoral systems are known to enhance carbon sequestration which can result in environmental benefits for farmers. Payment for environmental services (PES) is a novel experience around the world. Landell-Mills and Porras (2002) analyzed 287 cases of payment for environmental services, but most of these were related to payments for the conservation or protection of natural resources, mainly in forest. Last ten years have seen growing use of PES to finance conservation projects in developing countries (Pagiola et al., 2007). Costa Rica has been pioneering in PES projects in agroforestry systems including the silvopastoral systems. This Payments can encourage projects that enhance restoration, production, and rural development (Montagnini and Finney, 2011).

The linkage of production activities with the marketing of environmental services could constitute a route to reconvert traditional cattle systems towards eco-friendly activities, which integrate silvopastoral systems and this could represent one of the best strategies for poverty alleviation while conserving natural resources. This linkage allows the farmer to have the option of continuing to produce food, raw materials and services and at the same time, provide benefits for society and global environment. Motivated by these experiences CATIE, in association with NITLAPAN in Nicaragua, formulated a PES project on silvopastoral systems on cattle farms of this couple countries. The project "Integrated Silvopastoral Approaches for the Management of Ecosystems", was financed by GEF (Global Environmental Facility) through the World Bank and coordinated by CATIE.

The project "Integrated Silvopastoral Approaches for the Management of Ecosystems" (GEF-CATIE) promotes the establishment of silvopastoral systems. This is done by paying incentives for environmental services, mainly carbon storage and conservation of biodiversity. The hypothesis of this project is that the payment for environmental services will induce changes in land use, creating beneficial technological change in the well-being of the farmers and natural resources.

A first version of this article, was written on 2002 at the beginning of the project, but for the term of the issue is relevant to publish it as introductory material for undergraduate and graduate students interested in research topics related to PES and agroforestry systems. This article focus in a reflection on the ability of pastoral landscapes to sequester carbon and it analyze preliminary results from underground and above ground sequestered carbon, in different land uses in Esparza, Costa Rica. At the time, this was a strategy to promote eco-friendly activities under frame of Livestock, Environment and Development (LEAD) initiative.

Methodologies

The GEF-Silvopastoral Project commenced in May 2002 in the Central Pacific region of Costa Rica. The zone ranges from 50 to 1000 m.a.s.l. The annual average temperature is 27°C and annual precipitation ranges between 1500 and 2000 mm, with a relative humidity of 65-80% ; the area is classified as a tropical sub-humid zone in transition. The topography varies between flat land and hillsides with slopes greater than 50%.

For the payment of environmental services on each farm, an index of land use that represented the potential carbon storage and/or to conserve biodiversity was developed in consultation with research data and experts. Primary forest generated a greater index (2.0) and the degraded pastures and annual crops without trees provided a smaller index (0.0). To verification the potentials to accumulate organic carbon in different land uses in agricultural landscape, field measurements have been done underground and aboveground.

Methodologies to determine organic carbon under ground was an adaptation of Amezquita et al. (2002). To determine carbon fixation in different land uses were established 9 sampling sites following a line (variable long) in direction to slope, in each land use. The sampling sites were three main calicates (1 X 1 X 1 m) and six mini-calicates (0,4 X 0,4 X 0,4 m). Two of the last were located closed at each side of main calicate.

Sampling of soil to bulk density and others chemical analyses were done in each calicates divided in four layers in depth (0-10 cm, 10-20 cm, 20-40 cm y de 40 a 100 cm). El SOC was determined by Walkley & Black (1934) technique. Bulk density was determined using the cylinder method (Forsythe 1975). Thirty six simples were taken in each land use system at same depth in three sides of each main calicates.

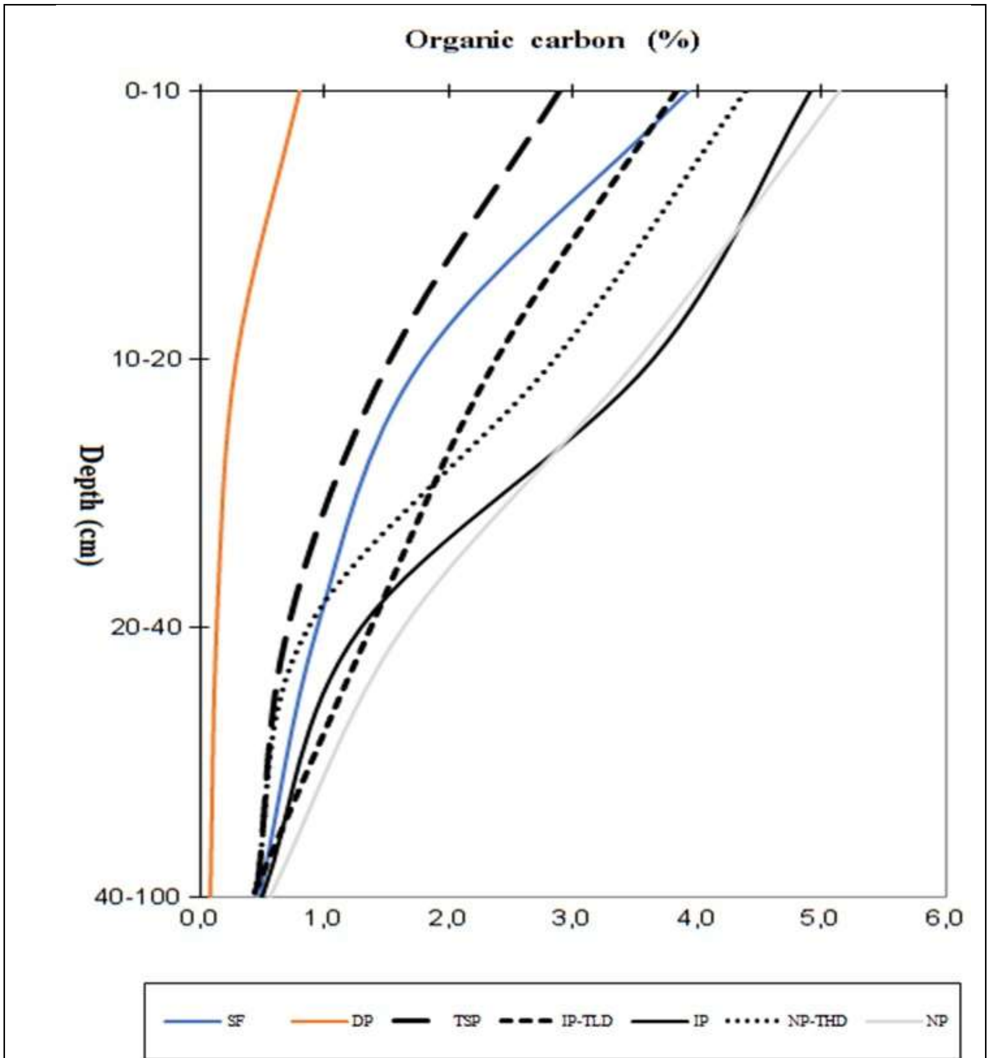
Total amount of sequestered carbon at 1 m of depth (COS in t ha^{-1}), was obtained doing the following equation: (*COS* t ha^{-1}=*a x p x fC x pm*). Were: a: area in ha, *ρ* : bulk density (t m^{3}), *fC:* COS fraction (C%/100); *pm* depth of sampling. Besides, an adjustment of bulk density was determined in soils for each land use, following to Buurman *et al.* (2004) suggestion.

To determine carbon above ground in biomass of trees and bushes, allometric biomass equations were used. Field simples were took from circler plot (area: 1000 m2) established around of each main calicate (radio: 17.84 m). Thus, the total area of sampling was 3,000 m2 in each land use. In the plots individual species were identified and also the dap was registered. Also the specie and height palms was registered. ANOVA's and LSD Fisher test were ran in INFOSTAT software to determine statistical differences between both different land uses and different depths of soil.

Results

Carbon belowground of soil

Total amount of organic carbon were low in soils under degraded pastures and higher in soils under secondary forest with 26.48 ± 10.91 and 297.63 ± 72.56 t ha^{-1}, respectively ($F_{6,16}$= 9.54, P=0.0002). Another land uses evaluated showed similar amounts of organic carbon (Ibrahim, et al, 2007). In general terms, the different land uses showed that is in the 0-10 cm belowground of soil were it showed higher proportions of OC (figure 1).



Adapted of Chacon 2005.

Figure 1. Distribution of organic carbon (%) at different lawyers in depth of soil, Esparza, Costa Rica.

Results determined in this study are accords with another studies developed in tropical countries, for example, Delaney (1997) reported quantities of OC in soils under forest in Venezuela (125 ± 8.3 t ha^{-1} of OC at 1 m depth) which were similar to the dates found in Costa Rica. On the other hand, some studies done in the Brazilian Amazon indicate that the pastures incorporate higher amount of OC in the first cm in depth of soil than others land uses (De Camargo et al. 1999). Fisher and Thomas (2004) concluded that introduced pastures on the former grasslands have been a net sink for about 900 million t (Mt) C, while conversion of the forest has been a net source of about 980 Mt C, leading to a net source of about 80 Mt C for the central lowlands as a whole. Losses of soil organic carbon (SOC) are lower when changes to pastures, than other crops (Veldkamp 1993), in fact, many pastures act as carbon sinks (Fitter et al. 1997).

Carbon above ground biomass

Total amount of carbon above ground biomass (dap of trees ≥ 5cm) showed significant differences ($F_{4,14}$= 6.24, P= 0.0042, natural log.) between land uses evaluated. Secondary forest and wood tree forest were the land uses that sequestered higher amount of organic carbon, with 90.78 and 92.42 t/ha respectively.

Ibrahim et al (2007) based in Ruiz (2002) suggest that this dates are according with organic carbon in biomasa above ground reported in different tropical land use, for example 8.18 ± 3.0 t ha-1, in native pastures with trees; 12.54 ± 3.6 t ha-1, in improved pastures with trees, and 17.55 ± 3.6 t ha-1 in secondary forest

An estimation of total amount below ground (1 m. depth of soil) and above ground (biomass of trees) of carbon stocks was done like hypothetical exercise. The results of ANOVA showed significant statistical differences between land uses ($F_{6,17}$= 5.21, P= 0.0033), were the secondary forest had higher total amount of organic carbon storage (297.6±72), and the degrades pastures had lower total amount (26,5±10,9) of carbon organic fixed (Table 1).

Table 1. Total amount of organic carbon (Canopy biomass ≥ 5 cm dap) plus organic carbon below ground (1 m. in depth) in different land uses, Esparza, Costa Rica.

	Land uses						
	SF	DP	TSP	IP-TLD	IP	NP-THD	NP
Organic carbon (t/ha)	297.6±72,6c	26,5±10,9a	187.48b	119.16ab	139.48b	128.54ab	143.00b

Ibrahim et al. 2007

SF: Secondary forest, **DP:** degraded pasture, **TSP: Tree species plantation** (Teak), **IP-TLD:** improved pasture with low density of trees, **NP-THD:** natural pasture with high density of trees, PNS: natural pasture without trees. Different letters mean significant statistical differences LSD Fisher Alfa:=0.05.

Conclusion

This article show results which must be improved along of the time, because the changes in the carbon stocks of soil only can detected in long time. Probably that is related with the long cycles required to convert the labile fractions to recalcitrant fractions of organic matter. However, the evidences show a trend to have higher carbon stocks in land uses with more tree cover than degraded pastures. In addition, there are different factors that could influence the storage of organic carbon underground, for instant, the history of the land uses and the agricultural practices done in this soils. A systematic study in each land use must be done for improve this study.

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