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Relationship Between Carbon Budget And Forest Fires In Acid Soils Under Atlantic Climate Conditions.

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Abstract

In order to asess the effects of forest fires on the carbon budget of acid soils under Atlantic climate conditions, the oxidizable carbon amount accumulated in the soil A horizon was measured in two river basins which differ with regard to their frequency of forest fires. Five canopy types according to the combination of soil erosion status and vegetation units have been defined. Soil organic carbon was measured in both canopies and vegetation indexes: NDVI (Normalized Difference Vegetation Index), fAPAR (Absorbed Photosintetically Active Radiation) and LAI (Leaf Area Index) were calculated.

Key words: soil carbon budget, forest fires, vegetation index, NDVI; fAPAR; LAI.

Rapport Entre Le Budget De Carbone Et Les Feux De Forêt Dans Les Sols Acides Sous Des Conditions Climatiques Atlantiques

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Résumé analytique

Pour étudier les effets du feu de forêt sur le budget de carbone des sols acides dans les conditions climatiques atlantiques, on a mesuré le carbone organique du sol dans l'horizon A sur deux bassins de fleuve qui diffèrent dans la fréquence des feux de forêt.
On a défini cinq types de canopy de la combinaison des unités de végétation et le status de d'érosion du sol. Pour chaque type de couche végétale on a utilisé les sigles: NDVI (Normalized Difference Vegetation Index), fAPAR (Absorbed Photosintetically Active Radiation), LAI (Leaf Area Index), et actions de carbone de sol.

Mots clés: budget de carbone des sols, feux de forêt, végétale sigles, NDVI; fAPAR; LAI.

1. Introduction

Fire is a major disturbance that can impact upon soil carbon stocks in a forest ecosystem. This impact depends on fire temperature and duration, soil organic carbon (SOC) stock and its distribution in the soil profile, as well as change in the decomposition rate of SOC following fire (Page-Dumroese et al., 2003).

On the other hand, fires tend to transfer carbon from vegetation to detritus and soil, or to volatilize soil carbon into the atmosphere. The amount of carbon transferred depends on factors such as fire intensity, soil type and depth, and ecosystem carbon content, which depends on the net primary productivity (NPP) of the ecosystem.

Temperate and boreal forests of the Northern Hemisphere have recently been identified as important carbon sinks. Accurate calculation of forest carbon budgets and appraisal of the temporal variations of net forest carbon fluxes are important topics when trying to elucidate the “missing sink” question and to follow the changing carbon dynamics in the forest. Forest vegetation and soils contain about 1240 Pg of C (Dixon et al., 1994). This amount varies with latitude and in temperate forest the average SOC stock was calculated at 96 Mg C/ha in plants and 122 Mg C/ha in soil by Prentice (2001).

Net primary productivity (NPP) is a key component of the terrestrial carbon cycle. It can be defined as the net amount of new carbon absorbed by plants per unit of space and time (Chen et al., 1999), and is directly related to the rate of atmospheric CO2 uptake by vegetation through the process of net photosynthesis minus dark respiration. This parameter plays an important role in calculating the amounts of organic carbon in the ecosystems. However, on large spatial scales, direct estimation of NPP is not possible and remote sensing appears to be the most appropriate tool for making estimations about this environmental variable (Ricotta et al.,1999).

In this sense, computer based ecosystem process models are the only feasible means for accurately estimating NPP in a large area. Potsdam Institute of Climate Impact Research (PIK) in June 1994 and July 1995 carried out an intercomparison of 17 global terrestrial NPP models. Results showed that models agreed on basic features of the biosphere and the input data used. One method used to evaluate the NPP from satellite images is the maximum-value composite procedure (MVC). This method is based on the NDVI, which is the normalised ratio of near-infrared and red surface reflectance. Extensive research (Rouse et al, 1973; Carlson and Ripley, 1997) has shown that NDVI has a strong relationship with certain physical properties of vegetation, such as the amount of absorbed photosynthetically active radiation (fAPAR), leaf area index (LAI), fractional vegetation cover, and biomass (Chilar et al., 1991).

This work aims to assess the effects of wildfires on the organic carbon budget of sandy and acid soils which develop under wet climate conditions (Cantabrian Range, NW of Spain). In order to discover the effects of wildfires on soil carbon density, two similar hydrographic river basins were selected: 1- non-burned basin, Muniellos (268 ha) 2- burned basin, Combo (122 ha) which has suffered a high frequency of fires. Despite the fact that these basins are geographically very close and similar in terms of climate, geology, vegetal communities and relief pattern, they do differ in terms of their frequency of forest fires. The PPN of ecosystems was approached using NDVI; fAPAR and LAI indexes.

2. Materials and methods

The study area (Figure 1) is part of the Cantabrian Mountain Range (NW of Spain). In this area, the bedrock is almost exclusively formed by an Ordovician sequence of sandstone, quartzite and slate, giving rise to a high degree of lithological homogeneity. A large part of this substratum, 53%, is covered by coarse grain-supported deposits. Over these substrata there are aid soils with stony frameworks and discontinuous organic horizons.

Regarding land use in this sector of the Cantabrian Range, traditional livestock farming has given rise to the repeated burning of extensive sectors. This use of fire has caused severe degradation as far as the surface vegetation and soil are concerned (Fernández et al, 2005). At present, a large part of the area is deforested, alternating gorse-briar scrubland with stony areas in which the soil has completely disappeared. The natural wooded formations have been reduced to different types of oak groves at certain especially shady valley bottoms. Only Muniellos Natural Reserve has not experienced fires over the last decades.

2.1. Soil carbon density measurements

In order to measure soil carbon density, four soil erosion statuses have been defined and mapped in both river basins (burned and unburned). Outcrops, talus scree, soils with discontinuous and stony A horizons and soils with continuous A horizons were mapped. Oak and birch forest, scrubland, meadows and chasmophytic vegetation have also been mapped at 1:10,000 scales.

At least five canopy types resulting from the combination of soil erosion status and vegetation units have been defined: outcrops and talus scree with vegetation (R), forest over discontinuous and stony A horizons (FS), forest over continuous A horizons (F), scrubs over discontinuous and stony A horizons (SS), and scrubs over continuous A horizons (S). In each canopy type ten soil profiles were sampled. Bulk density; thickness; textural fraction < 2mm; total carbon; oxidizable carbon; nitrogen and organic matter in A horizons were measured in order to estimate the soil oxidizable carbon budget (Mg ha $^{-1}$) of the different canopies in both basins.

2.2. Net primary productivity (NPP) approach

Vegetation indexes (NDVI, fAPAR, LAI) were calculated in both river basins using a QuickBird image of the area with 60 cm of spatial resolution. This image was taken in July (2005) during the optimum vegetative period and was georeferenced and atmospherically corrected.

In order to compare the vegetation index values in similar units, they were calculated for each of the canopies in both basins.

3. Results and discussions

The results of the soil analysis show that the frequently burned basin (Combo) contains higher stocks of oxidizable carbon (Mg C ha^{-1}) than not burned basin (FS: 21,8; F: 116,5 ; SS: 48,6; S: 263,7 in front of FS: 6,32; F: 42,5; S: 150,4). In SS canopy which is present only in the burned basin, around of 40 % of the SOC is mineralized carbon. The soil carbon density estimated for the forest in the burned river basin agrees with the 122 Mg C/ha amount estimated by Prentice (2001) as an average soil carbon budget under humid forest. But in no burned basin do the soils under forest canopies present low amounts of organic carbon. This phenomenon can be related to the soil characteristics in the area, derived from its substrata nature; low amounts of soil matrix; very stony frameworks; very low pHs, together with very steep slopes which cause thick soils with poorly developed profiles, which can explain the low amounts of carbon in these forest soils.

On the other hand, soils under scrubs in the burned basin contain the highest carbon amounts (S: 263.7 Mg C/ha), and they are opposite to the stony scrub soils of the same basin (SS) with 48.6 Mg C/ ha. The stony scrub canopy comes from the degradation of scrub, due to incidence of wildfires which burnt the soil organic horizons and caused the depletion of soil organic carbon (SOC). Also, the scrubs series are phases of forest vegetation series degradation which come from the land cover transformation by forest fires.

In general, results show a lower amount of soil organic carbon in non-burned basin soils. Nevertheless, when vegetation indexes are taken into account in the burned basin, the average data of the indexes show less photosynthetic activity and, related to this, lower percentages of forest cover. Vegetation index average values in Combo: NDVI 0,551 ± 0,119; fAPAR 0,857 ± 0,193; LAI -0, 202 ±0,381, and in Muniellos: NDVI

0,627 ± 0,102; fAPAR 0,979 ± 0,165; LAI 0, 085 ± 0,582. These results were derived from the same satellite image which covers all the study area.
In the same way, when canopies are compared using vegetation indexes, the forest canopies in the non-burned basin (SF and F) show higher mean values than the same canopies in the burned basin: 1- stony forest (SF) = 0.92, is the fAPAR value in the burned basin and 0.98 is the value of the same index in the non-burned basin. 2- forest (F) = 0.93 in the burned basin and 1.01 in the non-burned basin. The fAPAR index measures the amount of absorbed photosynthetically active radiation and this value is very high in the forest canopy of the non-burned basin. The tree species are the same (*Quercus Pirenayca*) in both areas, but the forest patterns are dissimilar due to the incidence of forest fires. Similar results were obtained with NDVI index and with LAI index. In this way LAI index shows negative values for the forest canopies of the burned basin (SF: -0.06; F:-0.08), which indicates that the forest cover is not very dense and the soil radiance is gathered by the satellite sensor.

4. Conclusions

All the collected data seems to indicate that forest fires have transferred organic carbon from vegetation to the soils in the burned basin, in which carbon stocks are nearly three times higher. Also, these transfers promote losses of soil carbon due to both physical erosion processes and release into the atmosphere. On the other hand, vegetation indexes show that the burned canopies have lower photosynthetic activity and therefore a lower carbon fixation capability.

Acknowledgments
Research has been partially supported by both the FICYT Project “Erosion processes on the hillslopes of the Cantabrian Mountain Range: wildfires relation”, contract no. PC04-17.

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