Agriculture, Ecosystems and Environment 142 (2011) 280–290

Contents lists available at ScienceDirect

Agriculture, Ecosystems and Environment

journal homepage: www.elsevier.com/locate/agee

Differential influence of land use/cover change on topsoil carbon and microbial activity in low-latitude temperate forests

Ana María Gamboa, Leopoldo Galicia*

Departamento de Geografía Física, Instituto de Geografía, Universidad Nacional Autónoma de México, Circuito Exterior S/N, Ciudad Universitaria, México, D.F., C.P. 04510, Mexico

ARTICLE INFO

Article history:
Received 18 October 2010
Received in revised form 18 May 2011
Accepted 23 May 2011
Available online 16 June 2011

Keywords:
Soil carbon
Land use/cover change
Andosols
Microbial biomass carbon
Soil enzymatic activity
Basal soil respiration

ABSTRACT

Land use/cover change (LUCC) is one of the main factors that control the terrestrial carbon (C) cycle. We examined the effect of LUCC on topsoil C, microbial biomass C (MBC) and microbes mediated processes related to C circulation and their relationship with other soil properties in low-latitude mountain temperate forests. We selected three sites in the northwest of Cofre de Perote volcano (Mexico) in an altitudinal gradient (piedmont, lower mountain slope and mid slope). At each site we selected three land use/cover units as a chronosequence: (1) reference forest, (2) agriculture, and (3) regeneration/reforestation. At each of the nine land use/cover units we collected five soil samples (0–10 cm) for determination of total soil C (C_T), MBC, basal soil respiration, metabolic quotient and enzymatic activity (β-glucosidase and dehydrogenase activities, and fluorescein diacetate hydrolysis). Forest conversion to agriculture diminished the C_T concentration in the three sites (72%, 20% and 61% on piedmont and lower and mid slopes, respectively); however, C_T content only decreased at piedmont soils. The vulnerability of piedmont soils to C loss due to this LUCC is higher than in mountain slope Andosols. Furthermore, this LUCC differentially affected absolute MBC (i.e. on dry soil base) and specific MBC (i.e. on C_T base). Specific site environmental conditions and MBC reference levels seem to determine the sensitivity of MBC to LUCC. Forest recovery after agricultural use only caused an increase of C_T concentration (55%) in piedmont soils. There are different controls of soil C storage and circulation in the altitudinal gradient studied. At piedmont and mid mountain slope soils MBC, its activity, nutrient availability and physical soil properties play an important role; meanwhile, at lower mountain slope Andosols mineralogical properties, specifically the Al–humus complexes exerts the main control.

© 2011 Elsevier B.V. All rights reserved.

1. Introduction

The global carbon (C) balance is affected by land use/cover change (LUCC) (Amundson, 2001). It has been suggested that, at scales of decades to centuries, LUCC is the main factor determining soil organic carbon (SOC) storage (Scott et al., 2002). The CO_2 emissions linked to LUCC are the second-largest anthropogenic CO_2 source (1.5 ± 0.7 Pg C yr^{-1} for the period 1990–2005; Le Quéré et al., 2009). Soil is the largest C pool in terrestrial ecosystems, and SOC is estimated to be 1462–1548 Pg in the upper 1 m (Batjes, 1996). The C pool of temperate forest soils is 153 Pg, which is 22% of the soil C pool in the soils of the forest zones of the world (Prentice, 2001).

The conversion of forests to croplands causes a depletion of soil C pools by ~22% (Murty et al., 2002). However, these losses could be in part reversed through regrowth of secondary vegetation or reforestation (Guo and Gifford, 2002). This reduction of soil C has been related to increases in the rates of soil organic matter (SOM) mineralization, modification of the amount and quality of organic residues and their redistribution, changes in soil structure and increases in erosive processes (Post and Kwon, 2000; Guo and Gifford, 2002; Murty et al., 2002). Since the high decomposition rate of microbial biomass C (MBC), it is regarded as good indicator of the impacts of LUCC (Gregorich et al., 1997). Furthermore, the processes related to SOC circulation (e.g. mineralization and enzymatic activity) have been also suggested as indicators of the effects of LUCC on biological activity and soil quality because of their fast response to changes of use and management (Bandick and Dick, 1999; Haynes, 2005).

Soil C pool and turnover depend on the interaction of numerous factors including climate, parent material, topography and vegetation, as well as physical, chemical and biological soil properties (Post and Kwon, 2000; Tan et al., 2004). Soil types differ in their C storage and Andosols, pertinent to the present study, have the second largest C pool (31 kg m^{-2}; Eswaran et al., 1993) after Histosols. The high C storage of Andosols has been attributed to enhanced SOM stabilization due to the formation of organometallic complexes with short-range-order minerals (Shoji et al., 1993). Andosols organic matter residence time is high and the cir-

* Corresponding author. Tel.: +52 55 56230222x45505; fax: +52 55 56162145.
E-mail address: lgalicia@igg.unam.mx (L. Galicia).

0167-8809/$ – see front matter © 2011 Elsevier B.V. All rights reserved.
doi:10.1016/j.agee.2011.05.025

culation rate very slow. It has been suggested that these soils could be used in sustainable ways from the point of view of soil C conservation (Parfitt et al., 1997). In Mexico, more than half of the area occupied by Andosols is covered by temperate forests (12 444 km^2; Palacio Prieto et al., 2000).

Mexican temperate forests occupy 323 305 km^2 which represents 17% of the country, however, ~40% of the areas occupied originally by these ecosystems have been transformed to other land uses such as crops and cattle pastures (Challenger, 1998). In Latin America and the Caribbean, Mexico is the second highest emitter of greenhouse gases derived from land use change and the forestry sector; 27% of the total emissions of the country come from this sector (UNFCCC, 2005). The effects of LUCC on soil C in temperate forests have been studied at mid latitudes, but seldom at low latitudes (e.g. Mendoza-Vega et al., 2003; Campos, 2004; Campos et al., 2007; Prado et al., 2007). Likewise, little is known about the effects of forest conversion to agriculture and forest recovery on C dynamics and stabilization in Andosols (Lal et al., 1998). Differences in SOC pools and climatic properties between mid-latitude and low-latitude temperate forests make it necessary to carry out research on the latter. The aim of this study was to evaluate the effect of LUCC on topsoil C, MBC and microbes mediated processes related to the C cycle in low-latitude mountain temperate forest and to analyze the relation between topsoil C changes and physico-chemical soil properties. The results may help in planning sustainable soil C management based on specific local and environmental properties.

2. Materials and methods

2.1. Study area

The study was realized on the northwest slope of the Cofre de Perote volcano (Veracruz, Mexico), along an altitudinal gradient between 2550 and 3500 masl (Table 1). Cofre de Perote, at 19°20′–19°40′N and 97°00′–97°15′W, is part of the Trans-Mexican Volcanic Belt. The volcano peaks at 4282 masl and is mainly composed of andesitic to dacitic lava flows (Carrasco-Núñez et al., 2010). Soils in the study area are Andosols and Cambisols (Table 1). The climate is semi-cold, with mean annual temperature <12 °C and summer rain.

Since the early 20th century, Cofre de Perote volcano has been intensively deforested to establish croplands and pastures with mature temperate forests now covering only 146 km^2, which represents 34% of their original area (García-Romero et al., 2010). Between 2200 and 3100 masl on the western slope (i.e. leeward), there are dense forests (74 km^2) dominated by *Pinus patula*, *P. teocote*, *P. montezumae* and *P. pseudostrobus*; fir forest (*Abies religiosa*) has a discontinuous distribution, covering 4% of the area in the range of 2900–3600 m (García-Romero et al., 2010). Crops and pastures cover the largest area of the volcano (162 km^2). Since the 1980s some croplands have been abandoned and reoccupied by secondary forest and reforestation programs. During 1976–2003, the area occupied by mature temperate forest decreased by 22%, the secondary forest cover increased by 18%, and rainfed crops and pastures increased by 15% (García-Romero et al., 2010).

2.2. Land use/cover units and study design

We selected three sites that represent a range of climatic conditions, landscape positions and land use/covers in the region (Table 1): Perote at the piedmont (2550 masl), Los Pescados on the lower mountain slope (3350 masl), and El Conejo at mid mountain slope (3500 masl). At each site we selected three land use/cover units: (1) reference forest, (2) agriculture, and (3) regeneration or regeneration/reforestation. We analyzed these three land use cover units as a chronosequence that represents the deforestation and agricultural use, the subsequent abandonment and the recovery of vegetation. The main assumption of this method is that there are only age differences between covers and that the biotic and abiotic components of each cover have followed the same history (Johnson and Miyanishi, 2008). In this study, the land use/cover history was reconstructed by interviewing the farm owners. Also, we made use of data from concurrent studies on dendrochronology (Ponce, 2008) and LUCC dynamics (Montoya, 2008) to verify the land use history. Because of the historical use of forests at Cofre de Perote, mature undisturbed forests are not present at the altitudinal positions we studied (Montoya, 2008; García-Romero et al., 2010). Consequently we had this limitation to select forests representative of reference forest cover before agricultural use. We selected a pine reforestation at Perote piedmont site and regenerated forests at mountain slope sites (i.e. Los Pescados and El Conejo) and compared those with agricultural units. In our study we do not imply that the "reference forest" is equivalent to an undisturbed mature forest. Nevertheless, reforestations and regenerated forest covers at the study area have at least structural properties similar to those of mature natural forests (Montoya, 2008). Hence we use these reference forests for comparison purposes, as they represent the closest analog available to natural forests.

Soils within each study site have similar characteristics. At the mountain slope sites (i.e. Los Pescados and El Conejo) soils are in all cases silandic Andosols. At the piedmont site (i.e. Perote) they are vitric Andosols at reference forest and haplic Cambisols at the agricultural and regeneration/reforestation units. Based on our field observations, we interpret the differences between the soil types at the piedmont site as a result of the land use history since they share the same set of forming factors. In particular we think that the Cambisols result from the truncation by sheet erosion of former Andosols, whose remnants can be found only under reference forest.

At Perote, forests were felled more than 50 years ago and subsequently have been under agriculture. Since agricultural use caused erosion and loss of soil fertility, forest management and reforestation programs have been implemented. As a consequence most pine forests on the piedmonts of the study area correspond to reforestations (Montoya, 2008). At Perote site the following land use units were selected: (1) a *P. patula* reforestation (30 years; reference forest unit), (2) a maize crop area that has been used for 50 years, and (3) a regeneration/reforestation area of 15 years (Table 1). At Los Pescados we selected: (1) a reference regenerated forest in an area with no agricultural historical use and dominated by *P. montezumae* and *A. religiosa* (~40 years), (2) a potato crop area that has been cultivated for 45 years, and (3) a 20-year-old regeneration cover, dominated by *Pinus montezumae* and *Abies religiosa* in the tree layer and *Baccharis conferta* in the shrub layer. At El Conejo the units were (1) a reference regenerated forest of 75 years dominated by *Abies religiosa*, which is located in an area that has never been used for agriculture, (2) a 42-year-old potato crop area, and (3) regeneration cover (12 years) dominated by herbaceous vegetation (*Senecio* spp. and *Lupinus montanus*).

Agriculture at all sites is rainfed. At Perote (piedmont site) maize (*Zea mays* L.) is planted in May; additionally oat (*Avena sativa* L.) or broad bean (*Vicia fava* L.) is planted in February as forage when winter moisture is favorable. Reversible plough pulled by mules is applied. Yearly before maize sowing, one fertilization is applied, 170 kg N-urea ha^{-1} and organic fertilizer (~6–12 m^3 ha^{-1} of manure). Crop residues are removed from the field and used as forage. At mountain slope sites (i.e. Los Pescados and El Conejo) potato (*Solanum tuberosum* L.) is planted between March and May and harvested around October. Oat or broad bean is planted in moist winters. Reversible plough is used and soil is fertilized with diammonium phosphate equivalent to 90 kg N ha^{-1} and

Download English Version:

https://daneshyari.com/en/article/2414675

Download Persian Version:

https://daneshyari.com/article/2414675

Daneshyari.com