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Land use change and soil nutrient transformations in the Los Haitises region of the Dominican Republic

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Abstract

We characterized soil cation, carbon (C) and nitrogen (N) transformations within a variety of land use types in the karst region of the northeastern Dominican Republic. We examined a range of soil pools and fluxes during the wet and dry seasons in undisturbed forest, regenerating forest and active agricultural sites within and directly adjacent to Los Haitises National Park. Soil moisture, soil organic matter (SOM), soil cations, leaf litter C and pH were significantly greater in regenerating forest sites than agricultural sites, while bulk density was greater in active agricultural sites. Potential denitrification, microbial biomass C and N, and microbial respiration g^{-1} dry soil were significantly greater in the regenerating forest sites than in the active agricultural sites. However, net mineralization, net nitrification, microbial biomass C, and microbial respiration were all significantly greater in the agricultural sites on g^{-1} SOM basis. These results suggest that land use is indirectly affecting microbial activity and C storage through its effect on SOM quality and quantity. While agriculture can significantly decrease soil fertility, it appears that the trend can begin to rapidly reverse with the abandonment of agriculture and the subsequent regeneration of forest. The regenerating forest soils were taken out of agricultural use only 5–7 years before our study and already have soil properties and processes similar to an undisturbed old forest site. Compared to undisturbed mogote forest sites, regenerating sites had smaller amounts of SOM and microbial biomass N, as well as lower rates of microbial respiration, mineralization and nitrification g^{-1} SOM. Initial recovery of soil pools and processes appeared to be rapid, but additional research must be done to address the long-term rate of recovery in these forest stands.

Keywords: Land use; Forest regeneration; Nutrient transformations; Dominican Republic

1. Introduction

Tropical land use change has important implications for biogeochemical cycles both regionally and globally (Scholes and Van Breemen, 1997). Much work has focused on the effects of forest conversion to cropland or pasture on C storage (Fisher et al., 1994; Nepstad et al., 1994; Van Noordwijk et al., 1997) and soil nutrient availability (Ewel et al., 1991; Keller et al., 1993; Reiners et al., 1994; Fernandes and Sanford, 1995; Neill et al., 1995, 1997; Henrot and Robertson, 1994; Groffman et al., 2001). Often, C storage and soil nutrient availability are greater in forested land than pastures that replace them. Forest conversion to pasture can decrease soil C storage as natural vegetation is cut and decomposes, burnt, or replaced by crops that support lower C contents in the soil or aboveground plant biomass (Houghton, 1990). However, in some cases land converted to pasture may have amounts of stored C that equal or exceed the forest that preceded it (Moraes et al., 1996). There is some evidence that the abandonment of agriculture and the subsequent regeneration of forest may return C storage to pre-agricultural amounts, although the rate of recovery depends on the time frame one considers and whether the previous land-use was cropland or pasture (Post and Kwon, 2000; Guo and Gifford, 2002). Despite the fact that some studies have addressed C dynamics following

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reforestation in the tropics, it is not easy to predict the effects of tropical land use change on soil C transformations.

In addition to effects on C transformations, land use can have profound implications for soil N cycling in tropical systems. There is a consistent finding that intact tropical forests have higher rates of N mineralization and nitrification than agricultural sites (Piccolo et al., 1994; Reiners et al., 1994; Neill et al., 1995, 1997), suggesting that N availability is greater (Nadelhoffer et al., 1983) where there is less human disturbance. However, soil stocks of inorganic N can be higher in agricultural sites than forest sites because of lower plant uptake (Neill et al., 1995). Moreover, converting forests to pastures can influence how much N_2O is emitted to the atmosphere through denitrification (Keller et al., 1993; Neill et al., 1997; Verchot et al., 1999). It is important to understand patterns of N_2O loss because it is both a greenhouse gas and a contributor to stratospheric ozone destruction. In tropical soils, N is often emitted to the atmosphere through denitrification rather than being taken up by plant biomass because N is often in high supply relative to other essential nutrients (Vitousek and Sanford, 1986; Vitousek and Matson, 1988; Vitousek and Farrington, 1997). Unlike net mineralization and nitrification rates, the pattern of N emissions with land use change is not well understood or reliably predicted (Erikson and Keller, 1997). Research suggests that there is sometimes a transient increase in N emissions from soils once forests are cut, but that over time older pastures can have lower N emissions than intact forests (Keller and Reiners, 1994; Verchot et al., 1999).

Compared to the study of effects on N and C cycling caused by forest conversion to pastures, few studies have focused on the conversion to other agricultural uses (e.g. Ewel et al., 1991; Fernandes and Sanford, 1995). However, understanding the effects of a wide variety of agricultural activities on forest regeneration processes is very important because a significant amount of forest land in the tropics is converted to agricultural use other than pasture. Thus, the major objective of our study was to compare soil N and C cycling in a series of sites that have experienced different land use legacies.

Like many other tropical countries where deforestation is occurring at high rates, the Dominican Republic has a very high rate of land conversion to agriculture. Between 1930 and 1980, 60% of its original forest was cut (Bolay, 1997). Much of this land has been converted to farmland, including pastures, oil palm plantations, sugar cane and cacao. In 1968, the government of the Dominican Republic legally protected 208 km^2 of forest land in the northeastern region of the country (Bolay, 1997). This area became Los Haitises National Park in 1976 and was enlarged to 1600 km^2 in 1993 by presidential decree. An extensive amount of land was taken out of agriculture with the park expansion.

The abandonment of agriculture in 1993 within the park presented an opportunity to evaluate the effects of land use change in the Los Haitises region of the Dominican Republic. The park has been shown to have an extensive amount of floral (Rivera et al., 2000) and faunal diversity (Glor et al., 2001) that varies across the landscape with time since agricultural abandonment and topography (e.g. forests on hill tops of mogotes vs valley bottoms). To date, there have been few studies to examine how land use change affects soil nutrient and C transformations in Caribbean forest systems. We therefore sought to characterize a range of soil pools and fluxes during the wet and dry season across a variety of land use sites. Our objectives were (1) to compare patterns of C, N and cation availability and loss in a variety of active agriculture, regenerating and intact forest sites and (2) to explore the role of organic matter quality in influencing patterns of C and N storage and availability in this tropical landscape.

2. Materials and methods

2.1. Study area

This study took place in Los Haitises National Park (19°00′N, 69°40′E), located in the northeastern region of the Dominican Republic. We examined the effects of land use on soil N and C processes in the Trepada Alta region of the park and adjacent agricultural sites surrounding the park. The region is characterized by karst topography and mogotes, which are steep 'haystack hills' that are covered by distinct vegetation (Rivera et al., 2000) and rise approximately 50 m a.s.l. (Zanoni et al., 1990). Mogotes are composed of rocks that are Miocenic and Pleistocenic limestone and are characterized by relatively thin soils and shorter stature trees than the surrounding valleys (Zanoni et al., 1990). The soils of the valleys are red clays from the Los Haitises Association. We are not aware of publications that describe in greater detail the classification of soils within the park or the surrounding area. The area has an average annual temperature of 25.2 °C and receives approximately 2000 mm rain $year^{-1}$, mainly occurring from April to December (Bolay, 1997). Native vegetation is comprised of subtropical broadleaf forest (Zanoni et al., 1990).

Our experimental design compared four major land use classes: old forest, mogote forest, regenerating forest and active agriculture sites. Agricultural activities largely modified forests on the valley floor, but not on the hilltops within Los Haitises National Park. In general, the mogote tops of Los Haitises were disturbed less than the valley floors because of the very steep slopes leading up to them. However, fires or selective harvesting of trees have affected some mogote tops. Regenerating sites were either abandoned pasture or abandoned conuco mixed gardens containing species such as banana, coconut, beans, pineapple and citrus trees. Previous land uses were determined from oral histories communicated by park guards. The design was not completely balanced due to the uneven availability of habitat