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Soil phosphorus forms as quality indicators of soils under different vegetation covers

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Abstract

The type of vegetation cover determines the physicochemical and biological properties of the soil over which they are developing. The objective of this study was to determine the effect of different vegetation covers on the forms of soil phosphorus, in order to know which of these forms can be used as a soil quality indicator. The experimental area was located on the acidic plateau at the North of Palencia (North Spain), where an area was selected vegetation covers very close to each other: pine (*Pinus sylvestris*), oak (*Quercus pyrenaica*), and three different shrub species (*Arctostaphylos uva-ursi*, *Erica australis* and *Halimium alyssoides*). The Ah horizon was sampled and pH, total organic C (C_{org}), total N (N), cationic exchange capacity (CEC), sum of bases (S) and P forms by a sequential fractionation were analysed. Results showed that oak and *A. uva-ursi* improve the considered soil parameters (pH, C_{org}/N ratio, CEC, and S) and provide soils of better quality. Inorganic soil P forms were influenced in greater extent by the vegetation cover than were P organic forms. Labile inorganic P forms could be used as indicators of soil quality. The organic P forms were less sensitive than inorganic ones to the indicated improvements.

Keywords: Soil phosphorus; Vegetation covers; Land use; Sequential fractionation of P; Soil quality

1. Introduction

In the acidic plateau formation at the North of Palencia (North Spain) human activity has played a very important role in the shape of the landscape, due to previous burning and ploughing of the original forest (dense formation of oak, *Quercus pyrenaica*) over a long period of its history. During times of great poverty, practically all the surface was dedicated to agricultural uses. At the moment some territories of agricultural use have been left and they are in a process of degradation, showing a new landscape integrated by different land use systems.

The nature and dynamics of soil organic matter (OM) and associated nutrients, including P, in the soil is different under different land use (Turrión et al., 2001). Therefore, knowledge of soil properties under different vegetative cover is the base to predict the modifications that land use change can cause on soil quality and to determine the limitations that could arise when establishing new uses. Consensus does not exist about concrete indicators that must be used to evaluate the soil quality (Karlen et al., 1997).

Distribution of P in different organic and inorganic forms reflects the history and actual structure and function of an ecosystem (Magid et al., 1996). The fractionation of Tiessen and Moir (1993) removes the more labile inorganic P (Pi) and organic P (Po) forms first, followed by more stable P forms. In this manner

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the chemically less resistant fractions, which are thought to have greater bioavailability and to have more active turnover in the soil system, are separated from more stable Pi and Po forms. This fractionation provide information about short- and long-term P availability by quantifying organic and inorganic P fractions of varying degrees of availability to plants, but not on the structural composition of the P forms in soil (Turrión et al., 2001).

The aim of this study was to determine the effect of different vegetation covers on the dynamics of soil phosphorus, with the purpose of knowing if this can be used as a quality indicator of the studied soils.

2. Material and methods

The study was carried out in Palencia, North of Spain, on what is commonly referred as acidic plateau, more exactly around the coordinates 42° 46′30″N; 04° 47′20″ W. Geomorphologically it is a wide platform with slope <1% divided into a series of tentacles by the erosive action of the current fluvial net. The climate can be classified as Humid Temperate Mediterranean with an annual rainfall of 1017 mm. The soils can be classified as Ultisols. Potential climax vegetation corresponds to oak formation (*Q. pyrenaica*). Nevertheless, man's action has created a new landscape integrated by different vegetation formations such as pine afforestations (*Pinus sylvestris*, *Pinus nigra*, *Pinus pinaster*), oak masses (*Q. pyrenaica*), areas with degradation shrub, and cultivated areas.

For the present study an area was selected in which different vegetation covers are close to one another. The following vegetation covers were selected:

Pinegrove: monospecific mass of *P. sylvestris* around 30 years old, with diameters around 20–25 cm and a dominant height of 15 m.

Oakwood: open oakwood of *Q. pyrenaica*, the biggest specimens reach heights of up to 7 m, with diameters of 15 cm in the areas with a continuity of patches.

Degradation shrub: The species compete for the space, forming small monospecific bushes. The selected shrubs were: *Arctostaphylos uva-ursi*, *Erica australis*, and *Halimium alyssoides*.

For each one of the five selected types of vegetation, (*P. sylvestris*, *Q. pyrenaica*, *A. uva-ursi*, *E. australis*, and *H. alyssoides*) five randomized samples from the Ah horizon (0–8 cm) were taken.

2.1. Chemical analysis

The pH of the soils was measured in a 1:2.5 soil: water suspension using a glass electrode. The organic C (C_{org}) and total N were determined with a LECO CHN 2000 analyzer. The cationic exchange capacity and exchange cations were determined using 1 M ammonium acetate.

A sequential extraction following the Tiessen and Moir (1993) procedure was applied to distinguish between different soil P pools. Briefly, soils were extracted at first step by using an anion exchange membrane (AEM) and sequentially adding 0.5 M $NaHCO_3$, 0.1 M NaOH, and 1 M HCl shaking for 16 h each addition. Then concentrated HCl was added and samples were heated for 10 min at 80 °C. From each extract an aliquot was used for Pi determination according to a modified molybdenum-blue method of Murphy and Riley (1962), after precipitating the OM. Total P in these extracts was determined after digestion with persulphate. The Po in the alkaline extracts was calculated as the difference between total P and Pi.

2.2. Statistical analysis

A one-way ANOVA was conducted to determine the influence of the vegetation type on each one of the studied parameters. In cases of positive result, a LSD test was applied.

3. Results and discussion

Significantly lower pH values were observed in soils under *P. sylvestris*, *H. alyssoides* and *E. australis* than under *Q. pyrenaica* and *A. uva-ursi* (Table 1).

The highest C_{org} values were found in soils under *A. uva-ursi* and the lowest under oak (Table 1), with

Table 1
Chemical parameters determined in the soils under the different vegetable covers

Soils under	pH	C_{org} (%)	N (%)	C_{org}/N	CEC ($cmol_c\ kg^{-1}$)	S ($cmol_c\ kg^{-1}$)
P. sylvestris	4.66 b	4.15 b	0.128 b	32.4	15.4b	3.9 c
H. alyssoides	4.84 ab	4.63 b	0.166 b	27.9	14.1b	3.6 c
E. australis	4.55 b	4.58 b	0.161 b	28.4	13.7b	3.5 c
A. uva-ursi	5.09 a	6.41a	0.263 a	24.4	21.0a	9.0 a
Q. pyrenaica	5.16 a	3.01 c	0.160 b	18.8	18.3a	5.7 b

Note: C_{org}: organic C; N: total N; CEC: cation exchangeable capacity; S: sum of bases. Different letters in the same column indicate significant differences $p<0.05$.

Table 2
Concentrations in the forms of P extracted according to the procedure of Tiessen and Moir (1993) for soils under the compared types of vegetation

Soils under	P-AEM	Pi-$NaHCO_3$	Po-$NaHCO_3$	Pi-NaOH	Po-NaOH	P-HCl_{dil}	P-HCl_{conc}
	(mg P kg^{-1} soil)						
P. sylvestris	4.49 c	1.64 c	12.22 a	11.38 b	51.05 b	1.48 c	30.02 a
H. alyssoides	5.98 bc	2.25 abc	9.22 a	8.98 bc	76.85 ab	1.88 bc	18.12 b
E. australis	7.69 ba	2.19 bc	10.60 a	6.66 c	73.17 ab	2.02 bc	12.01 b
A. uva-ursi	8.25 a	3.22 ab	9.57 a	13.44 ab	73.20 ab	2.80 b	27.47 a
Q. pyrenaica	9.80 a	3.69 a	14.57 a	17.25 a	91.43 a	7.81 a	29.77a

Note: P-AEM and Pi $NaHCO_3$ are highly labile inorganic P, extracted with anion exchange membranes and by 0.5 M $NaHCO_3$, respectively; Po-$NaHCO_3$ is highly labile organic P extracted by 0.5 M $NaHCO_3$; Pi-NaOH and Po-NaOH are moderately labile inorganic P and stable organic P, respectively, extracted by 0.1 M NaOH; P-HCl_{dil} is primary inorganic P extracted by 1 M HCl and P-HCl_{conc} is highly recalcitrant P removed by concentrate HCl. Different letters in the same column indicate significant differences $p<0.05$.

significant differences occurring between both. The soils under *P. sylvestris*, *H. alyssoides* and *E. australis* showed a C_{org} concentration very similar among them and significantly different from the rest of the considered vegetation types. For total N significant differences were only observed for soils under *A. uva-ursi*, with higher values than the others (more than double that soil under *P. sylvestris*). The C_{org}/N ratio showed that soil under oak had better quality humus than the other soils. Also the soils under oak and *A. uva-ursi* presented higher values of CEC and S.

Among the studied vegetation covers, oak and *A. uva-ursi* improved the general soil parameters considered and provided better humus quality. Almendros et al. (2000) in their studies of decomposition of tree and shrub leaves for different typical species of Mediterranean ecosystems observed that the *A. uva-ursi* presented a high content in N and the lowest N loss in the course of their decomposition. This fact could explain the high concentrations of N found in the current study for soils under this species. Nevertheless, more studies should be carried out to determine if the improvement observed in the present work for soils under *A. uva-ursi* also occurs in soils with other characteristics, and to study the decomposition processes of different vegetation materials and its incorporation into soil.

As can be seen in Table 2, the NaOH extractable Po was the predominant fraction (represented around 55% of total P), which suggests that a high proportion of P is in stable organic forms, this result is in accordance with the indicated by other authors (Magid et al., 1996).

Soils under oak presented the highest values in all forms of P considered, except the highly stable Pi fraction (P-HCl_{conc}), while the soil under pine usually presented the lowest values in highly labile Pi fractions (P-AEM, and Pi-$NaHCO_3$), in the fraction generally considered as Ca associated phosphorus (Pi-HCl_{dil}), and in the stable Po (Po-NaOH). In these last four fractions and in Pi-NaOH the differences between the soils under oak and pine were statistically significant.

The soils under degradation shrubs presented similar values to each other for the different P forms and, generally, values were between those of oak and pine. Significant differences were only observed between those soils under *H. alyssoides* and *A. uva-ursi* for the P-AEM; and under *E. australis* and *A. uva-ursi* for the moderately labile Pi (Pi-NaOH), and for the highly stable Pi (P-HCl_{conc}) *A. uva-ursi* showed significant higher values than *H. alyssoides* and *E. australis*.

Soils under oak showed the highest P bioavailability followed by *A. uva-ursi*, the other two shrub species considered and the last position was occupied by the soils under pine.

The organic fraction extracted with $NaHCO_3$, considered as relatively labile fraction (rapid turnover Po) did not show significant differences among any of the compared soils. Stable Po fraction (Po-NaOH), that represents compounds affecting the long-term availability of P, only showed significant differences between soils under pine and oak.

4. Conclusions

The present study corroborated that vegetation covers produce differences in the soils developed under them and that they will therefore affect soil quality. Among the studied vegetation covers, oak and *A. uva-ursi*, improved the general soil parameters considered, enhancing soil quality. With regard to the forms of soil P, the inorganic forms better reflected the changes in vegetation cover. Inorganic labile forms (P-AEM and Pi-$NaHCO_3$) could be used as soil quality indicators due to their sensitivity to the vegetation cover type and their easy determination. The organic forms of P, however, are less sensitive than the inorganic ones to land use systems.

According to our results, in the studied area vegetal species as *A. uva-ursi* that improve qualitatively and quantitatively some characteristics of the soil could be used initially for land restoration and then tree species could be used for reforestation.

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