SOIL CHEMICAL ATTRIBUTES AS AFFECTED BY VEGETAL COVER AND SEABIRDS IN PUNTA HENNEQUIN, ANTARCTICA

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Abstract: This study had the purpose of evaluating the effect of soil cover by vegetation on soil chemical attributes in a skua (*Catharacta maccormicki*) field at Punta Hennequin, Shetland Island, Antarctica. Four locals along a transect were sampled, involving soils with 5 and 100% of vegetal cover (L1 and L2, respectively) with *Deschampsia*+*Colobanthus*; bare alluvium soil (L3); and poor-drained moss (*Sanionia uncinata*) carpet with 100% soil cover (L4). Soil samples obtained from three layers and three replicates were submitted to chemical and physical analysis. Although both L1 and L2 are in the same nesting field, the more abundant vegetation at L2 promoted significantly larger ($P < 0.05$) total organic C (TOC) stocks in the soil than at L1 (43.08 and 9.03 Mg C ha⁻¹, respectively, at the 0-40 cm layer). Total N stocks increased from 2.60 to 6.54 Mg ha⁻¹ for L1 and L2, respectively. Although the presence of seabirds represents an important transfer of organic material from marine to the terrestrial environment, the differences evidence the importance of vegetation in order to raise the soil organic matter levels. Soil pH was consistently lower in L2 than L1 - about 1.0 unit for the soil layers herein evaluated, which is probably linked to the soil organic matter accumulation. Contrary to the distribution of TOC and TN contents, exchangeable P and K had no gradient along the soil profile, evidencing that most of the P and K is native from the parent material and their input by seabirds to the soil is negligible.

Keywords: organic carbon, total nitrogen, seabird field

Introduction

Soil chemical and physical attributes affect and are affected by the type and abundance of vegetal plants growing in the locality in a dynamic interaction. In ice-free regions of maritime Antarctica, such interaction is usually influenced by the presence of seabird colonies and by the heterogeneity of soil parent material (Navas *et al.*, 2008; Simas *et al.*, 2008), resulting in complex systems that are not fully understood (Ugolini & Bockheim, 2008; Vieira *et al.*, 2012). For this reason, the purpose of the study was to evaluate the effect of soil cover by vegetation on the changes of soil chemical

attributes in a skua field at Punta Hennequin, Shetland Island, Antarctica.

Materials and Methods

The study was performed in February 2011 in Punta Hennequin, Shetland Island, Antarctica (58° 23' 21" W and 62° 7' 41" S). Four locations along a transect were sampled: L1 and L2 consisted of a skua (*Catharacta maccormicki*) field with 5 and 100% of vegetal cover, respectively, distant from each other about 50 m, in the same moraine (same

level and parent material); vegetation was mainly composed by higher plant species, mostly of *Deschampsia antarctica* Desv. (Poaceae) and *Colobanthus quitensis* (Kunth) Bartl. (Caryophyllaceae); L3 was a poor-drained bare alluvium soil; and L4 was a poorly-drained moss (*Sanionia uncinata*) carpet with 100% soil cover, around a lake shore. Soil samples were obtained from three layers (0-10, 10-20 and 20-40 cm depth) at three replicates per locality, air-dried, ground and sieved (2 mm). Soil bulk density samples were taken by the core method. Soil contents of sand, clay, silt, exchangeable P and K, total N and soil pH were determined according to Tedesco *et al.* (1995). Total organic C (TOC) contents were determined by dry combustion using a total organic C analyzer (Shimadzu TOC-VCSH, Shimadzu Corp., Kyoto, Japan). Chemical attributes were submitted to one-way ANOVA, with Tukey test ($p < 0.05$) to separate means in each soil layer. Physical attributes are reported with standard deviations ($n = 3$).

Results

Clay contents were relatively similar among the soils of the four areas (Table 1). However, silt content was consistently greater for the soil in the moraine (L1 and L2) than for the other soils, which is likely due to the fact that the soil of the moraine is more autochthonous and stable than the others. Lower soil bulk density was observed for L2 than for the other soils up to 20 cm soil layer, which is presumably credited to the plant roots effect on soil structure.

Although both L1 and L2 are in a nesting/breeding field of skuas, the more abundant vegetation at the L2 promoted soil TOC stocks about five times larger than L1 (9.03 and 43.08 Mg C ha⁻¹, respectively, at the 0-40 cm layer), achieving the largest contents in all soil layers herein evaluated (Figure 1a). Moss vegetation (L3) also promoted larger soil TOC contents, but this effect was restricted to the surface soil layer and was not significantly different from the others. Relatively similar behavior was observed for total nitrogen contents in the soil profile. Total N stocks increased from 2.60 to 6.54 Mg N ha⁻¹ for L1 and L2, respectively (Figure 1b).

The bare alluvium soil and the moss soil had larger exchangeable K and smaller P contents than L1 and L2 (Figure 2). Contrarily to the distribution of TOC and TN contents, exchangeable P and K had no gradient along the soil profile. No significant effect of vegetation cover between L1 and L2 was observed for exchangeable P and K contents, but the soil pH was consistently lower in L2 than L1 - about 1.0 unit for the soil layers herein evaluated, which is probably linked to the soil organic matter accumulation.

Discussion

Although the presence of the seabirds represents an important transfer of organic material from marine to the terrestrial environment, the differences in TOC and NT contents between L1 and L2 evidence the importance of the high soil cover by higher plant species in order to raise

Table 1. Soil bulk density, clay and silt contents, and pH for the four locals of air sampling in a transect in Punta Hennequin, Shetland Island, Antarctica.

Soil attribute	Soil layer (cm)	Locality			
		L1	L2	L3	L4
Soil bulk density (g cm ⁻³)	0-10	1.34 ± 0.11	1.27 ± 0.14	1.43 ± 0.06	1.49 ± 0.02
	10-20	1.51 ± 0.09	1.29 ± 0.02	1.42 ± 0.02	1.49 ± 0.05
	20-40	1.55 ± 0.02	1.47 ± 0.14	1.47 ± 1.47	1.54 ± 0.05
Clay content (g kg ⁻¹)	0-10	17.2 ± 4.5	14.2 ± 1.3	8.6 ± 3.6	11.8 ± 0.9
	10-20	13.0 ± 2.8	11.9 ± 3.7	9.6 ± 4.0	4.9 ± 2.3
	20-40	4.2 ± 1.8	13.4 ± 7.3	7.6 ± 3.0	3.5 ± 0.9
Silt content (g kg ⁻¹)	0-10	162.2 ± 53.4	225.9 ± 103	149.3 ± 30.1	55.9 ± 16.1
	10-20	198.6 ± 31.2	173.7 ± 38.7	72.9 ± 8.9	3.1 ± 2.7
	20-40	266.1 ± 18.1	231.3 ± 38.2	199.2 ± 54.2	0.0 ± 0.0

L1: 5% soil cover with *Deschampsia* + *Colobanthus*; L2: 100% soil cover with *Deschampsia*+*Colobanthus*; L3: alluvium soil; L4: 100% soil cover with *Usnea*. Values are means ($n = 3$) ± standard deviations.

Figure 1. Soil contents of total organic carbon (a) and total nitrogen (b) in four areas in a transect in Punta Hennequin, Antarctica. L1: 5% soil cover with *Deschampsia* + *Colobanthus*; L2: 100% soil cover with *Deschampsia* + *Colobanthus*; L3: alluvium soil; L4: 100% soil cover with *Usnea*. Horizontal bars mean the minimum significant difference (MSD) by Tukey test at $P < 0.05$ ($n = 3$).

Figure 2. Soil contents of exchangeable P (a) and K (b) and soil pH (c) in four areas in a transect in Punta Hennequin, Antarctica. L1: 5% soil cover with *Deschampsia* + *Colobanthus*; L2: 100% soil cover with *Deschampsia* + *Colobanthus*; L3: alluvium soil; L4: 100% soil cover with *Usnea*. Horizontal bars mean the minimum significant difference (MSD) by Tukey test at $P < 0.05$ ($n = 3$).

the soil organic matter levels. The seabirds are crucial to enrich the soil with N, which in turn favors the increase of vegetal cover and, in consequence, more birds are attracted, completing a feedback looping. However, if we consider that TOC stock in L1 is basically derived from the presence of seabirds (as vegetation cover was low) and that the difference between L1 and L2 is primarily due to the occurrence of plants in the same field, we can infer that carbon accumulation in the soil was about 4.8 times larger in the “skuas+higher plants” condition than that of just skuas. In addition, we speculate that superior plant species have a larger potential to increase soil TOC and NT content not only due to their big biomass production rate (not evaluated), but also due to their important input of C and N in subsurface soil layers by their root system. This is supported by the greatest gradient of TOC contents in the soil profile under moss than under superior vegetal species, which is probably linked to the absence of root systems in the moss. However, such differences of TOC stocks between different vegetal species can be hidden if only a surface soil layer is taken into account (Cannone *et al.*, 2008).

Despite the relatively low annual rates of C and N input at the vegetated skua fields, TOC and TN stocks in such soils can be as high as those found in non-polar regions (Vieira *et al.*, 2009). Stocks of TOC of 40 Mg ha⁻¹ are difficult to sustain in agricultural soils of tropical and subtropical climate because of their larger decomposition rates (Vieira *et al.*, 2009). Therefore, in a scenario of expansion in the vegetated area in maritime Antarctic soils, the potential of C sink through soil organic matter accumulation is relatively high.

The prevalent absence of gradients for exchangeable P and K in the soil profile and the large differences among the

soils strongly evidences that most of the P and K is mostly driven by their content in the parent material, while their input by seabirds to the soil is negligible. The only exception is the exchangeable P content in soil with moss, which is slightly smaller in the soil surface layer. In all soils, the exchangeable P and K contents are very high (CQFS, 2004) and are similar to those reported by Simas *et al.* (2008) for ornithogenic and weakly ornithogenic soils of the region.

Conclusion

In the localities of the present study, the presence of soil cover by higher plant species contributes markedly to increase the contents of total organic carbon and total nitrogen, being more effective than the cover by moss and much more effective than the presence of seabirds without vegetal cover. The contents of exchangeable P and K in such soils are more attributed to their content in the soil parent material than to the presence of seabirds and vegetation.

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