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Phosphorus content in five representative landscape units of the Lomas de Arequipa (Atacama Desert-Peru)

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Abstract

Phosphorus forms and content were studied in soils of the Lomas de Arequipa (Atacama desert, Peru) using a fractionation method. These Lomas are small hills periodically submitted to the El Niño-Southern Oscillation (ENSO) which causes heavy rainfall. Sample soils were randomly selected in five landscape types characterized by vegetation: cactaceae (Cac), cactaceae and herbaceous (CacHerb), shrubs (Shr), trees with cover <60% (Tree) and shrubs or trees with cover >60%) (ShrTree). All the soils were strongly acidic and classified as loamy sand, sandy loam or silt loam. Organic carbon content was under 1% in Cac or CacHerb, then increased strongly in ShrTree (6.50%). Considering phosphorus, all the forms (labile as well resistant forms) increased markedly from Cac soils to ShrTree soils. In all the soils, the labile forms (Resin-P: range 45–105 μg g^{-1}; NaHCO3-Pi: 23–123 μg g^{-1}; or NaHCO3-Po: 10–122 μg g^{-1}) were very high. These high phosphorus contents were attributed to the specific climatic conditions of the Lomas that feature a long period of vegetation dormancy (very dry period) and a short period of growth, following ENSO-associated precipitation. We suggested that during the dry period, plant decay and microbial cells death lead to release and accumulation of labile P in the soil, the rainfall wetting the soil, permitting vegetation growth. In this respect, the Lomas climatic conditions contribute to soil fertility, especially as labile forms of phosphorus are chiefly concerned.

Keywords: Soils; Phosphorus fractionation; Lomas; Peru; ENSO; Atacama desert

1. Introduction

Coastal deserts such as Atacama (Coastal Peruvian desert continued by the Northern Chilean desert) present specific characteristics: a) they are the driest among all deserts; b) the general climate is mild and uniform; c) the temperature is fairly evenly distributed throughout the year; d) they are subject to winter fogs. These climatic conditions impart to coastal arid regions unique characteristics compared to arid regions characterised by high mean and large amplitude temperature. The aridity results from several combined factors, especially the permanent high pressure area over the Pacific Ocean and atmospheric stability induced by the cold northward flowing Humboldt Current. This cold current makes the air become cool or cold but dry and very stable overall, unable to produce precipitation. At the same time, there is very little evaporation and humidity is confined to a low level, giving persistent haze. Whereas mist may occur any time throughout the year, there are some particularly foggy periods, generally at the end of the austral winter and in early spring (Zavala Yupanqui, 1993). Along the Chilean and Peruvian coasts, elevations between 600 and 1000 m are the most favourable for fog formation (Osses McIntyre, 1996).

The Atacama desert is strongly affected by El Niño (disruption of the ocean–atmosphere system in the Tropical Pacific with consequences for weather around the globe) which generates abundant rainfall. El Niño-Southern Oscillation (ENSO) is a coupled ocean-atmosphere phenomena that has a worldwide impact on climate.

ENSO, which seems to occur with a cyclic rhythm in coastal Peru (every 10 years on average) induces exceptional rainfall in these regions. However, since the nineties, ENSO has occurred every 2 to 7 years. The last very rainy

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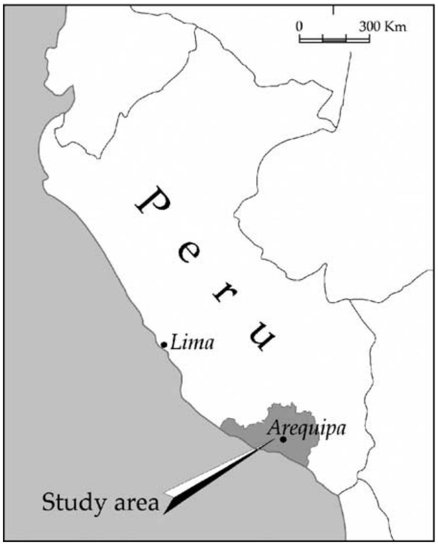

Fig. 1. Study site location.

periods occurred in 1982, 1992 and 1997–1998. In several parts of the Atacama desert as in the Arequipa region (South Peru), the coast is dominated by low hills (elevation varying from some hundred to about 1200 m) termed "Lomas" in Spanish (geomorphological sense). The same term refers to the fog caught on these hills (climatic sense) and to the vegetation arising during the foggy season (phytological sense). In the following text, the term Lomas is used in the global sense, comprising all three of these notions.

The vegetation is composed of numerous ephemeral but also of perennial species, ligneous plants and cactaceae. Some studies have been published on the Peruvian Lomas (Péfaur, 1982; Ferreyra, 1993).

The Lomas are utilized for forage and to gather woody species for fuelwood (Ferreyra, 1977). They are periodically used for grazing livestock (cattle, sheep and goats), especially during ENSO events, and possibly as grazing land during seasonal livestock migration during the Spanish period.

Considering the soils of deserts, studies are scarce and mainly concern hot deserts or arid ecosystems (Lajtha, 1988; Lajtha and Schlesinger, 1988; Cross and Schlesinger, 2001). At the moment, no information exists on the soil characteristics of the Atacama desert or of the Lomas. In this paper we consider some general soil characteristics and we emphasize the different forms of phosphorus in soils of five representative vegetation types (Lomas types) of Lomas de Arequipa (South Peru, Fig. 1). Hypothesis of a close relationship between labile phosphorus content in the soils and ENSO events inducing exceptional rainfall is discussed.

2. Materials and methods

2.1. Study site

The study site was situated near the town of Mollendo, in the Arequipa region, on the south Peruvian coast (72°10–71°40′ W; 16°90′–17°40 S). In this region, average annual precipitation is only <50 mm below 500 m alt. and several years may pass without rainfall. The driest period occurs from January–February to April. From May to October, heavy fog (relative air humidity near 75%) permits vegetation growth. The average annual temperature is around 18 °C and the annual variation in temperature is small with a minimum of 9–12 °C in July and a maximum of 25 °C in January–February (Zavala Yupanqui, 1993).

When the coastal topography is flat, the seasonal fog dissipates inland but where isolated hills (150 to 1000 m) intercept the fog, a fog zone appears allowing the development of rich vegetation termed "Lomas formations" separated by areas without vegetation. In Peru, around 40 Lomas formations exist, among them the Lomas de Mollendo.

The bedrock is acid igneous (granodiorite) with local clastic sediments (sand, clay, sandstone or conglomerates). The non-consolidated parent material (particles <2 mm) pertains to the loamy or sandy texture groups. The soils are in the Aridisols class characterized by low organic carbon.

2.2. Soil sampling

Using SPOT images (SPOT 661–384; July 1995) and aerial photography, 8 different landscape types were identified in the Arequipa region. Five of them were retained in this study: cover dominated by cacti (Cac), by cacti and herbaceous (CacHerb), by shrubs (Shr), by trees with percentage cover <60% (Tree), and by shrubs and trees with percentage cover >60% (ShrTree). The distinction between these landscape types resulted from a site vegetation study (120 sample plots of vegetation statistically analysed using correspondence analysis). Some dominant species are listed in Table 1. In each type, 4 sampling areas were randomly selected using a grid. However, as in desert landscapes, the vegetation strongly influences soil nutrient content, soil samples were randomly selected, after eliminating nearness of vegetation patches. Soil samples were taken in the first 5 cm after discarding the litter when necessary. They were stoney, particularly in Cac and CacHerb. The soil samples were stored for grain size and chemical analysis. Sampling and vegetation studies were performed during September 1997, before a rainy period.

2.3. Chemical analyses

Soil samples were analysed for grain size, pH in water, organic carbon using CHN auto analyser, and different forms of phosphorus. Sand, silt and clay percentage were estimated using the pipette method and the soil texture classes were determined using the Soil Science Society of America chart.

Total phosphorus was fractionated using a sequential extraction method (Hedley et al., 1982). The sequential extraction removed inorganic P (Pi) and organic P (Po) of increasing chemical stability with different geochemical or ecological significance. First, the most labile inorganic