NATURAL AND ACQUIRED SOIL QUALITY ALONG ENVIRONMENTAL GRADIENTS (TENERIFE, CANARY ISLANDS, SPAIN)

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Abstract
Tenerife Island, has a wide environmental diversity due to its altitude (3718m at its highest point) and to the climatic differences between its windward and leeward slopes. This work studies the changes in the natural soil quality along environmental gradients on the Tenerife Island and how this natural quality is modified by man's effect on the ecosystem. For this purpose, a total of 320 plots in the Southeast of Tenerife Island were studied at altitudes ranging from sea level to 2400 m a.s.l. In each plot, the physicochemical properties of the soils were studied, the ecological characteristics of the environment, the composition and structure of the vegetation and the maturity of the ecosystem. The main environmental gradients and edaphic processes are identified by multivariant statistical techniques. The results show that the *natural quality* of the soils of Tenerife Island is conditioned by the abrupt topography, the influence of the sea, the recent parent materials, the aridity and the extreme temperatures in coastal and mountain regions. Additional factors include the intense human pressure on the land, resulting in degradation processes such as accelerated erosion, degradation of the structure, biological degradation and alkalinization/salinization.

Additional Keywords: environmental gradients, vegetation communities, soil degradation

Introduction
We understand soil quality as its capacity to fulfill certain functions: agricultural or woodland productivity, environmental regulation, to sustain the biodiversity etc. Soil quality is determined both by natural soil characteristics and by human alterations of the soil. It is, therefore possible to distinguish two components in soil quality: a *natural quality*, conditioned by the intensity and nature of the characteristic edaphogenetic processes of the ecosystem in which the soil originates; and an *acquired quality*, resulting from man's management of the land that either improves or degenerates its properties. The aim of this work is to establish the importance of natural and acquired components in soil quality in an area of Tenerife Island (the Canary Islands, Spain).

Material and Methods
Field Sites
The natural quality of the soils on Tenerife Island is limited by the young age of the geological materials, the abrupt topography or the aridity of some areas. However, soil diversity is very high, as demonstrated by the occurrence of 17 WRB soil units. This diversity results from the high altitude (3718m in its highest point) and the differences in precipitation on the leeward and windward slopes of the island (Rodríguez Rodríguez and Mora, 2000).

On the other hand, the diversity and intensity of current land uses (agricultural, urban, tourism) affect the soils in Tenerife where degradation is a serious problem with multiple manifestations: historical deforestation, erosion and physical degradation of the soil, salinization of agricultural soils, the abandonment of crop land, loss of water resources etc. (Rodríguez Rodríguez *et al*.,1998).

The present work was carried out in the southeastern region of Tenerife Island at heights ranging from sea level to 24000 m.a.s.l.. Natural ecosystems of the area are distributed in altitudinal layers according to the following sequence: xerophytic shrubland between sea-level and 500 m.a.s.l.; open juniper forest from 500 to 800 m.a.s.l.; Canarian pine woods from 800 to 2000 m.a.s.l. and high mountain leguminous shrubland above 2000 m.a.s.l. The vegetation has undergone a severe transformation in the last five centuries and has been replaced, to a variable, extent by substitution shrubland and grassland. Only the high mountain vegetation currently presents a good degree of conservation (Rivas-Martínez *et al*.,1993).

Analysis
The characteristic layers of vegetation on the island are taken as the basic working units. Together, a total of 320 sites are studied: 155 in the lower zone, 60 in the intermediate zone, 75 in the high zone and 30 in the peak zone, including well conserved ecosystems and those with different degrees of degradation. At each site, a sample was

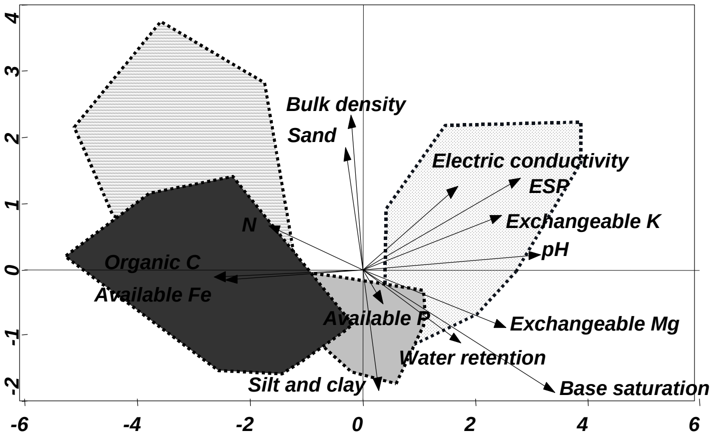
taken from the first 30-35cm of soil. Also, the degree of human intervention was described (previous cultivation of the land, forest fires, the timing of these events) and the floristic composition was studied by listing the percentage cover of the different plant species.

In the laboratory, several physicochemical properties of the soil were studied related with its capacity to sustain plant productivity, associated with different soil degradation processes, or with diagnostic value in the main reference systems used for soil classification.

In each altitudinal layer, the main types of vegetation present were defined using multivariant statistical techniques -cluster analysis, DCA (M.O. Hill and H.G. Gausch-1980)-. The study of anthropological disturbances and, especially, the chronology of these, permitted each of these communities to be placed in the process of ecological succession. A Canonical Correspondence Analysis -CCA- (C.J. Ter Braak-1986) permitted the relationship to be studied between the soil properties and floristic composition and to identify edaphic processes associated with degradation/regeneration of the ecosystem.

Results and Discussion

Figures 1-4 show the results of the CCA. Although all the variables were studied, these diagrams only represent a minimum set of variables with maximum non-redundant explanatory power of the variance. These variables were selected by the *stepwise* procedure using a Montecarlo test with 1000 repetitions and a significance of $p \leq 0.05$. This procedure excludes variables with little explanatory power from the model and those with a high explanatory power but strongly correlated with other variables previously included in the model (Ter Braak and Šmilauer, 1998). The shaded boxes in the diagrams correspond to 95% of the plots of the type of vegetation indicated.



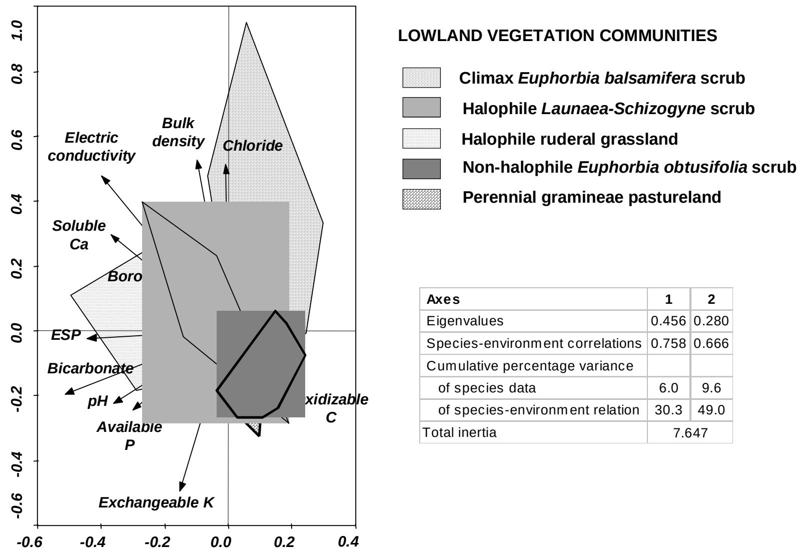
Axes	1	2
Eigenvalues	0.756	0.444
Species-environment correlations	0.911	0.733
Cumulative percentage variance		
of species data	3.6	5.8
of species-environment relation	28.2	44.7
Total inertia	20.804	

Figure 1. Relationship between vegetation and the soil properties

Figure 1 represents the relationship between the vegetation and the soil properties in all the plots studied. It can be observed how the soil properties associated with the vegetation follow a strong altitudinal gradient, which is deformed by the typical arching of the representation of long slopes in the correspondence analysis. In the positive semiaxis of axis 1, variables associated with aridity can be found and with proximity of the sea: sodicity, alkalinity, salinity, etc. while variables related positively with a wetter climate, such as nitrogen and organic carbon, are found around the negative semiaxis. At this scale, changes in soil properties associated with human intervention cannot be observed, but instead the main ecological gradients that determine the natural quality of the island soils.

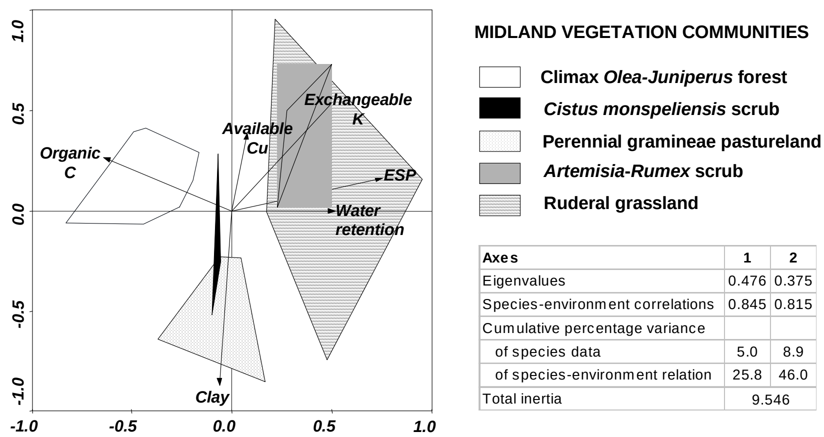
In coastal areas (Figure 2), substitution of the climax vegetation coincides with an alkalinization process, attributable to the uptake of salts through the capillaries after disturbance of the soil surface. Also, a decrease in the organic carbon contents has been observed due to the smaller input of plant matter and less protection offered by the dispersed substitution vegetation and a rise in assimilable phosphorus related with growing crops on the land. Another important edaphic gradient for vegetation is related with salinity and sodicity, natural phenomena in the area due to its proximity to the sea. Salinity and sodicity do not seem to limit development of the mature vegetation but they do condition the composition of the substitution vegetation.

In the middle zones (Figure 3), degradation of the original woodland is accompanied by a drastic reduction in the organic carbon content. Here, the composition of the substitution vegetation depends basically on the nature of the parent material, which can be made up of phonolitic ashes (sandy, base-saturated and with a high water retention capacity) or basalt (more clayey and desaturated).



Axes	1	2
Eigenvalues	0.456	0.280
Species-environment correlations	0.758	0.666
Cumulative percentage variance		
of species data	6.0	9.6
of species-environment relation	30.3	49.0
Total inertia	7.647	

Figure 2



Axes	1	2
Eigenvalues	0.476	0.375
Species-environment correlations	0.845	0.815
Cumulative percentage variance		
of species data	5.0	8.9
of species-environment relation	25.8	46.0
Total inertia	9.546	

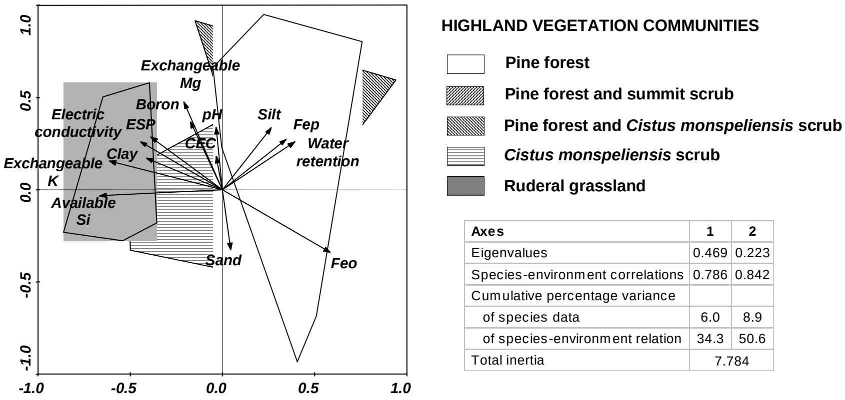
Figure 3

In the high zone (Figure 4), the composition of the mature woodland is also influenced by the geology. On phonolitic ashes, soils are silty, alkaline and base-saturated; on basaltic pyroclasts they typically have a sandy texture and exhibit andic character. In both cases, substitution of the arboreal plant cover by shrubs and grassland coincides with severe losses of organic carbon and degradation of the humified organic matter and reduced water retention capacity.

At the peak, there is no clear edaphic process associated with degradation/regeneration of the ecosystem. Only two variables, pH and Fe extractable with ammonium oxalate (Figure 5), can explain 20% of the variance in floristic composition and the addition of other explanatory variables does not produce a significant increase in the variance explained. The change in these two properties is not associated with the anthropic influence but responds to natural gradients related with the material of origin and the topography. Therefore, soils of the peak ecosystem must be considered as not degraded, and their properties correspond to climax soils characteristic of the corresponding topography and material of origin.

Conclusions

On the whole, the natural quality of the soils of Tenerife Island is mainly conditioned by general ecological factors, especially by the coastal-peak climatic gradient. On a local scale, anthropic factors are important and constitute the main source of variation of soil properties associated with the composition of the ecosystem. The most important process is quantitative and qualitative degradation of the soil organic matter, with which other processes such as degradation of the structure and aridification of the edaphoclimate are associated. In the more arid zones, anthropic disturbance of the ecosystem can cause alterations in the saline dynamics of the soil profile and trigger salinization and alkalinization phenomena of the soil surface. Finally, in the high mountain zone, anthropic disturbances do not seem to cause the degradation and only natural edaphic gradients are involved in the functioning of the ecosystem



Axes	1	2
Eigenvalues	0.469	0.223
Species-environment correlations	0.786	0.842
Cumulative percentage variance		
of species data	6.0	8.9
of species-environment relation	34.3	50.6
Total inertia	7.784	

Figure 4

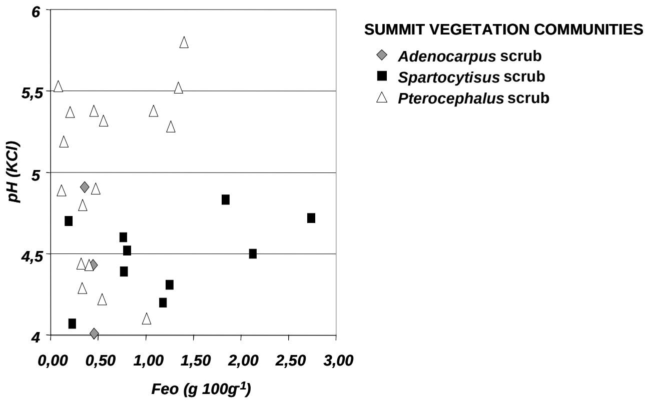


Figure 5

Acknowledgments

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References

Hill. M.O. and Gauch. H.G. 1980. Detrend Correspondence Analysis, an improved ordenation technique. *Vegetatio* 42: 47-58.

Rivas-Martínez S., Wildpret, W., Díaz, T.E., Pérez de Paz, P.L., del Arco, M. and Rodríguez, O. 1993. Excursion guide. Outline vegetation of Tenerife Island (Canary Islands). *Itinera Geobotanica* 7: 5-167.

Rodríguez Rodríguez A., Jiménez, C.C. and Tejedor, M.L. 1998. Soil degradation and desertification in the Canary Islands. In: A. Rodríguez Rodríguez et al. (Eds.) *The Soil as a Strategic Resource: Degradation Processes and Conservation Measures*. Geoforma Ediciones. Logroño, España. Pp. 13-22.

Rodríguez Rodríguez, A. and Mora Hernández, J.L. 2000. Los suelos. In: A. Concepción et al. (Eds.) *Gran Atlas Temático de Canarias*. Editorial Interinsular Canaria. Santa Cruz de Tenerife, España. Pp. 107-120.

Ter Braak C.J.F. 1986. Canonical Correspondence Analysis: a new eigenvector technique for multivariate direct gradient analysis. *Ecology* 67: 1167-1179.

Ter Braak C.J.F. and Šmilauer. P. 1998. *CANOCO Reference Manual and User's Guide to Canoco for Windows. Software for Canonical Community Ordination (version 4).* Microcomputer Power. Ithaca, NY, USA.

Northcote, K.H. (1979). A factual key for the recognition of Australian soils. Rellim Technical Publications Pty Ltd, Adelaide.

Shafique, M.S. and Skogerboe, G.V. (1983). Impact of seasonal infiltration function variation on furrow irrigation performance. In "Advances in Infiltration", *Proc. Nat. Conf. Advances in Infiltration*. p292-301. American Society of Agricultural Engineers, St Joseph.

Quirk, J.P. and Schofield, R.K. (1955). The effect of electrolyte concentration on soil permeability. *Journal of Soil Science* 6, 163-78.