SOIL ERODIBILITY VARIATION IN RELATION TO ENVIRONMENTAL FACTORS IN VOLCANIC SOILS OF THE CANARY ISLANDS (SPAIN)

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Abstract
A study of the variation in soil sensitivity toward erosion has been carried out in the geographical context of the Canary Islands, characterized by a high environmental diversity. The validity of aggregate stability tests versus the theoretical estimation of erodibility (K factor of USLE) has been tested. The lithology, the altitudinal climatic variation and the degree of vegetation disturbance have been shown to be mainly responsible for erodibility of the soils in the area.

Additional Keywords: aggregate stability, toposequences, plant succession

Introduction
The Canary Islands present high soil diversity, mainly due to a wide variety of mesoclimates. The influence of wet northeasterly trade winds and the barrier effect of mountainous regions in the higher islands result in the presence of several bioclimatic layers with marked differences between the leeward and windward slopes. The soil distribution in altitudinal sequences in the Canary Islands has been studied by several authors (Fernandez Caldas *et al*., 1982; Rodriguez Rodríguez *et al*., 1993). The aim of this work is to describe the different sensitivity to erosion of soils as a result of their distribution along environmental gradients on Tenerife Island.

Material and Methods
This study was carried out on Tenerife, the largest ((2034 km^2) and highest (3.718m, Pico Teide) of the Canary Islands. The study area is in the southeast of the island (Figure 1), leeward from the trade winds. The most relevant environmental characteristics of the area are recorded in Table 1.

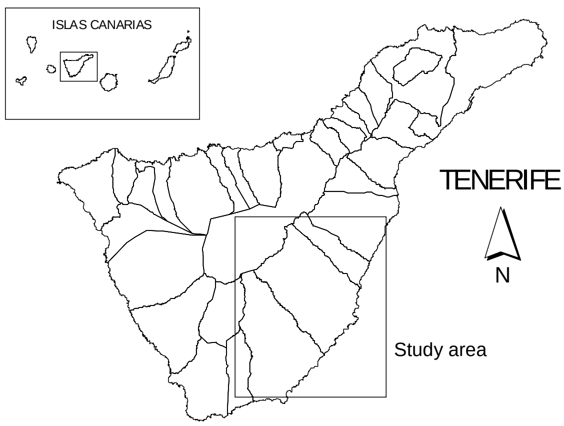

Figure 1. Situation of the study area

A total of 56 plots were studied with different degrees of plant colonization and anthropological, lithological and topographical influence at altitudes ranging from 45 to 1550 m a.s.l.. In each plot, the terrain was described and a surface soil sample was collected for analysis (the sample was composed of three subsamples randomly collected from each sampling site).

For each sample, erodibility was calculated according to the K factor of USLE from analytical data and field descriptions, using the equation of Wischmeier *et al*. (1971). Also, soil resistance to particle separation was demonstrated experimentally by two aggregate stability tests:

- Wet-sieving test (Bartoli *et al*., 1991). This determines slaking of the soil structure by dilation and breaking up of the aggregates in humectation. In this test, samples of aggregates are placed in partially submerged sieves with a 0.2 mm mesh oscillating at a constant rhythm until a maximum disaggregation level is reached. The aggregate fraction larger than 0.2 mm is quantified gravimetrically.
- TDI test (Imeson and Vis, 1984). This test estimates losses due to splash and rupture of aggregates under the direct impact of raindrops. This is done by submitting aggregates to the impact of 10 raindrops in

controlled conditions (1 drop of deionized water per second, with a mean weight of 0.1 g from a height of 1 m), and making a gravimetric measurement of material losses in the aggregates.

Table 1. General characteristics of the study area

Elevation a.s.l.	Parent material	Bioclimate	Vegetation	Soil moisture regime	Soils
0-400m	Basaltic and trachybasaltic lava flows, beds of phnolitic pumice tuffs	Desertic infra-mediterranean- arid xerophytic	*Euphorbia* formations , fruticose and grassy halonitrophilous communities	Thermic, aridic	Calcids, Cambids, Argids, Orthents, Arents
400-800m		Xerophytic termomediterranean upper semiarid	Rockrose scrub, nitrophilous brush, ruderal pasture	Thermic, ustic	Ustepts, Orthents, Arents
800-1900m		Mesophytic mesomediterranean dry	Canary pine forest, rockrose scrub, ruderal pasture	Thermic, ustic-udic	Ustepts, Udepts, Orthents, Arents

Results and Discussion

The kinetics of disaggregation show that the maximum level of disaggregation in humectation of these soils is reached after 6 hours constant shaking in wet conditions (Figure 2). This period is unusually long in comparison with other natural and cultivated soils on the archipelago that reach maximum disaggregation after shaking for 1 hour (Vargas Chávez, 2001; Bordón González, 2003), and is similar to that measured for Andic soils, characterized by their high stability (Rodriguez Rodriguez *et al*., 2002).

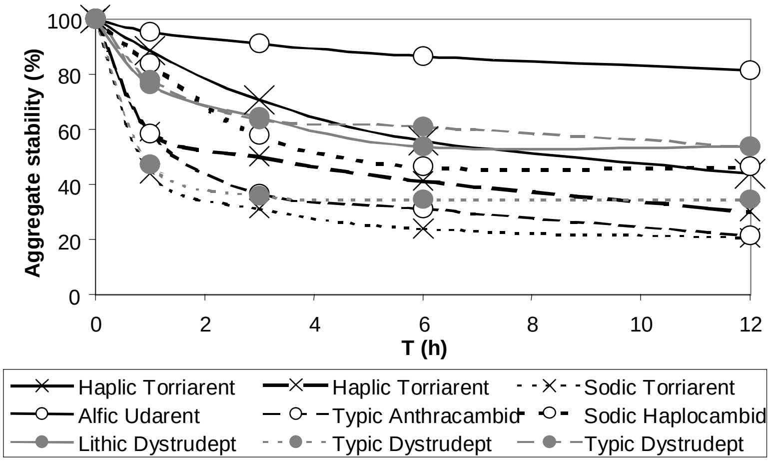

Figure 2. Disaggregation kinetics

The stability values of the aggregates according to two disaggregation mechanisms (humectation and drop impact) show significant correlations between them but not with the erodibility estimated by K of the USLE (Table 2). The altitudinal gradient (Table 2) shows a significant positive association with the stability of aggregates to impact, mainly due to the aridity of lower zones and the low organic matter contents of its soils.

Table 2. Pearson's correlation between the different measurements of erodibility and with altitude

	K-USLE	Stability to slaking (wet-sieving test)	Water-drop test TDI
Stability to slaking (wet-sieving test)	0.159	-	-
Water-drop test TDI	0.249	0.467*	-
Elevation a.s.l.	0.139	-0.029	0.428*

* Significant correlation at level ≤ 0,05

The soils developed on phonolythic ashes present a much higher stability to humectation than soils developed from basalts or trachibasalts (Table 3) in which the proportion of aggregates stable to humectation never exceeds 60% (Figure 3). Phonolythic ashes are characterized by having a microstructure with a high porosity (Vera Gómez, 1985), which could favor fine interlocking of the organic matter in the aggregates resulting in small aggregates highly stable to water.

Table 3. Mean value of erodibility in soils developed on different lithologies, soil types and successional plant states.

	K-USLE ($t\ yr^{-1} MJ^{-1} mm^{-1}$)	Stability to slaking (wet-sieving test) (%)	Water-drop test TDI (%)
Statistical test of comparison*	**T-Student**	**T-Student**	**U Mann-Whitney**
Basalts and trachybasalts lava flows	0.11 ± 0.03 a	39.5 ± 9.9 a	47.7 ± 27.0 a
Pumice tuffs	0.12 ± 0.03 a	51.0 ± 15.8 b	56.9 ± 21.0 a
Statistical test of comparison*	**Kruskal-Wallis**	**ANOVA, Tukey**	**Kruskal-Wallis, U**
Entisols	0.13 ± 0.04 a	53.9 ± 17.7 a	62.8 ± 17.2 a
Aridisols	0.09 ± 0.03 a	40.8 ± 11.3 b	37.7 ± 17.2 b
Inceptisols	0.11 ± 0.02 a	43.8 ± 10.9 b	63.0 ± 28.8 a
Statistical test of comparison*	**ANOVA**	**ANOVA**	**ANOVA, Tukey**
Climax community	0.11 ± 0.02 a	50.9 ± 18.5 a	68.1 ± 23.5 a
Substitution brush	0.13 ± 0.04 a	50.3 ± 13.6 a	56.5 ± 24.7 ab
Substitution grassland	0.11 ± 0.03 a	42.2 ± 13.3 a	46.5 ± 21.9 b

*Values followed by the same character do not exhibit significant differences according the statistical-test used ($p \leq 0.05$).

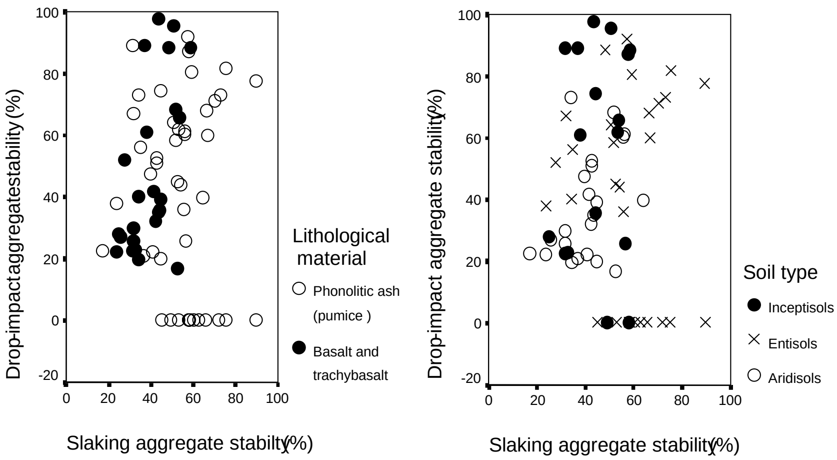

Figure 3. Aggregate stability in relation to the material of origin and soil type

The combined influence of lithological and altitudinal factors confer characteristic erodibility values to the different soil types (Table 3, Figure 3). Aridisols present very low values of structural stability because they are found in lower more arid zones. Similarly, Inceptisols and especially the Udepts show a high stability to drop impact. The Entisols studied mainly develop on phonolythic ashes and include soils with greater stability to humectation.

To this natural variability, the influence of man on the natural environment must also be taken into account. Degradation of plant cover coincides with a gradual degradation of the structure that manifests in a reduced resistance to drop impact (Table 3, Figure 4).

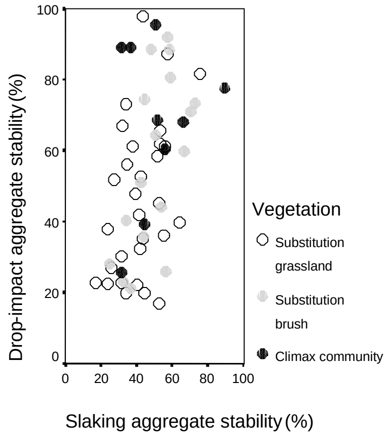

Figure 4. Aggregate stability in relation to the degree of vegetation maturity.

Conclusions

The K factor values of USLE do not appear to be related with experimental measurements of disaggregation or with the main gradients or environmental factors of the area and have little validity for the soils studied here. Aggregate stability tests, especially the drop impact test, was a quick and reliable way to estimate soil sensitivity to erosion in this area. Disaggregation in humectation is a slow process and its magnitude is determined by the nature of the material of origin. Resistance to drop impact shows a high sensitivity to climatic gradients and to human disturbance and is a good indicator of changes in erodibility associated with these factors.

Acknowledgments

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