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Soil surface roughness decay as affected by residue cover

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Résumé
Les résidus de récolte sont très utilisés dans les systèmes de conservation du sol. La rugosité de la surface des sols agricoles influence la infiltration, la détention superficielle et le ruissellement. L'objectif de ce travail était l'analyse de la influence de l'adition de résidus sur la rugosité de la surface du sol. Un rugosimètre à aiguilles a été utilisé pour l'acquisition des bases de données d'une surface avec des quantités de paille de maïs entre 0 et 8 t/ha. Des mesures on été effectues a l'état initial et après des pluies cumulatives de l'ordre de 146 mm. Les indices de rugosité les suivantes on été calculées: rugosité aléatoire (RR), tortuosité (T), différence limite (LD), pente limite (LS) dimension fractal (D) et distance d'intersection. Les différences antre l'état initial et final de la valeur des indices RR, T et LD montrait une diminution en fonction de la quantité de résidu ajouté à la surface du sol.

Introduction

The use of culture residues to conserve soil and water is becoming worldwide more and more important. Residues left over the soil ameliorate soil physical condition by protecting the soil from raindrop impact and also by increasing soil structural stability.
The concept of soil surface roughness is central in the context of scientific description of runoff generation and sediment production (Kamphorst et al., 2000; Merril et al., 2001; Vidal Vázquez et al., 2005). On agricultural fields, one may expect a disordered roughness initiated by the random disposition of structural units, aggregates and clods, which currently is superimposed by periodic effects induced by cultivation. Soil surface roughness has been demonstrated to influence water infiltration, overland flow, runoff velocity and erosion. This parameter is known to depend mainly on tillage, crop stage and previous amount and intensity of rainfall. It is important also to know the interaction between soil microrelief and other important erosion factors such as plant cover and the percentage of soil surface covered with residues.
The objective of this work was to investigate the effect of crop residue addition on soil surface roughness

Material and methods

The data used for this paper were obtained from a field experiment located in Lóngora, near Coruña (Spain) under natural rain. The study was conducted between April 25 and August 1 2005 on an Umbrisol according to the FAO classification system (FAO, 1994).
Microrelief data sets were obtained on small plots, 1 m^2 in size. A surface representing intermediate roughness conditions was artificially prepared and maize straw was added. Five different treatments with 0, 2, 4, 6 and 8 Mg ha^{-1} maize residues were studied. Each data set consisted of 400 point elevation measurements on a 3 cm grid. Measurements reported here were performed in two different dates, the first one just after surface preparation, before rain and the last one after 145.8 mm cumulative natural rain.

Different roughness indicators have been assessed after slope and tillage effects trend removal. The used indices were: random roughness (RR), tortuosity (T), limiting difference (LD) and limiting slope (LS). Random roughness is the predominant roughness measure in soil conservation and management studies and is defined as the standard error among heights, after effects of oriented roughness caused by tillage marks and land slope have been removed. Tortuosity index is based on the ratio of profile length and the length of its projection. Two surface microrelief indices based on geostatistics, i.e. the so-called limiting difference and limiting slope, were also computed. RR, T, LD and LS were calculated as per Vidal Vázquez (2002). In addition fractal dimension, D, describing how roughness changes with scale and crossover length, *l*, which specifies the variance at a reference scale were calculated from semivariogram analysis (Vidal Vázquez et al., 2005).

Results and discussion

Initial values for random roughness, RR, ranged from 23.30 to 15.96 mm, whereas final values after 145.8 mm rain were between 16.32 and 14.10 mm, indicating that the manually prepared microrelief was intermediate between very rough (40 mm) and smooth (1mm) conditions (Vidal Vázquez, 2002). An unexpected result was that the highest initial values of RR, LD, T and *l* were calculated for the plot with no soil cover, whereas the plot with 8 Mg ha^{-1} maize straw showed the lowest values of RR, LD and T. Thus, the differences in initial roughness between plots are not only due to the effect of different residue cover but also indicate that the manually prepared plots, thought to be more or less homogeneous from visual assessment, in fact presented an important heterogeneity. Due to this fact, the effect of soil residue addition on microrelief decay, rather than on the absolute values of roughness indices is presented and discussed in this work.

Table 1 shows the decline of roughness, i.e. the change of roughness as measured before and after rainfall according to four different indices, RR, LD, T and *l*. In all these cases microrelief decay was highest when maize straw was not added and lowest with the highest soil cover, i.e. 8 Mg ha^{-1}. However the decreasing trend of roughness decay as the residue cover increased was not similar for the different study indices.

	0 Mg/ ha	2 Mg/ ha	4 Mg/ ha	6 Mg/ ha	8 Mg/ ha
RR decay (mm)	6.98	5.63	5.16	3.64	1.87
LD decay (mm)	9.96	7.03	7.04	3.25	1.47
T decay	0.136	0.085	0.108	0.088	0.069
l decay (mm)	5.96	5.25	4.63	5.57	3.67
D decay	0	0.028	0	0.087	0.069
LS decay	0.060	0.054	0.006	0.070	0.113

Table 1. Decay of random roughness, RR, limiting difference, LD, tortuosity, T, crossover length, *l*, fractal dimension, D, and limiting slope, LS, for increasing corn straw addition.

RR decay varied between 6.98 mm, in the plot without residues, and 1.87 mm in the plot with the highest soil cover by corn straw. This means a decline of surface roughness of 42.8% and 13.3% in the former and the later plot, respectively. Moreover, the decline of roughness as a function of soil cover followed a very regular trend. Determination coefficients between roughness decay and residue dose fitted by lineal and second order polynomic decreasing functions were r^2 = 0.96 and r^2 = 0.99, respectively. Thus, microrelief degradation clearly is reduced as surface cover increase. The main reason for this behavior is the expected decrease of the rain impact energy as the added corn residue increases.

Likewise, LD decay values showed in Table 1 and represented in Figure 1 clearly indicates the effect of increased crop residue in diminishing microrelief breakdown. LD decay ranged between 9.96 and 1.17 mm without and with the highest soil cover by straw, respectively. This indicates that LD index was somewhat more sensitive than RR index in describing the effect of surface cover on microrelief breakdown by cumulative rain. However, determination coefficients of the relationship between LD decay and soil cover, were r^2 = 0.92 and r^2 = 0.93 for a decreasing lineal and second order polynomial fitting, respectively. This means that changes in microrelief breakdown are best described by the random roughness index.

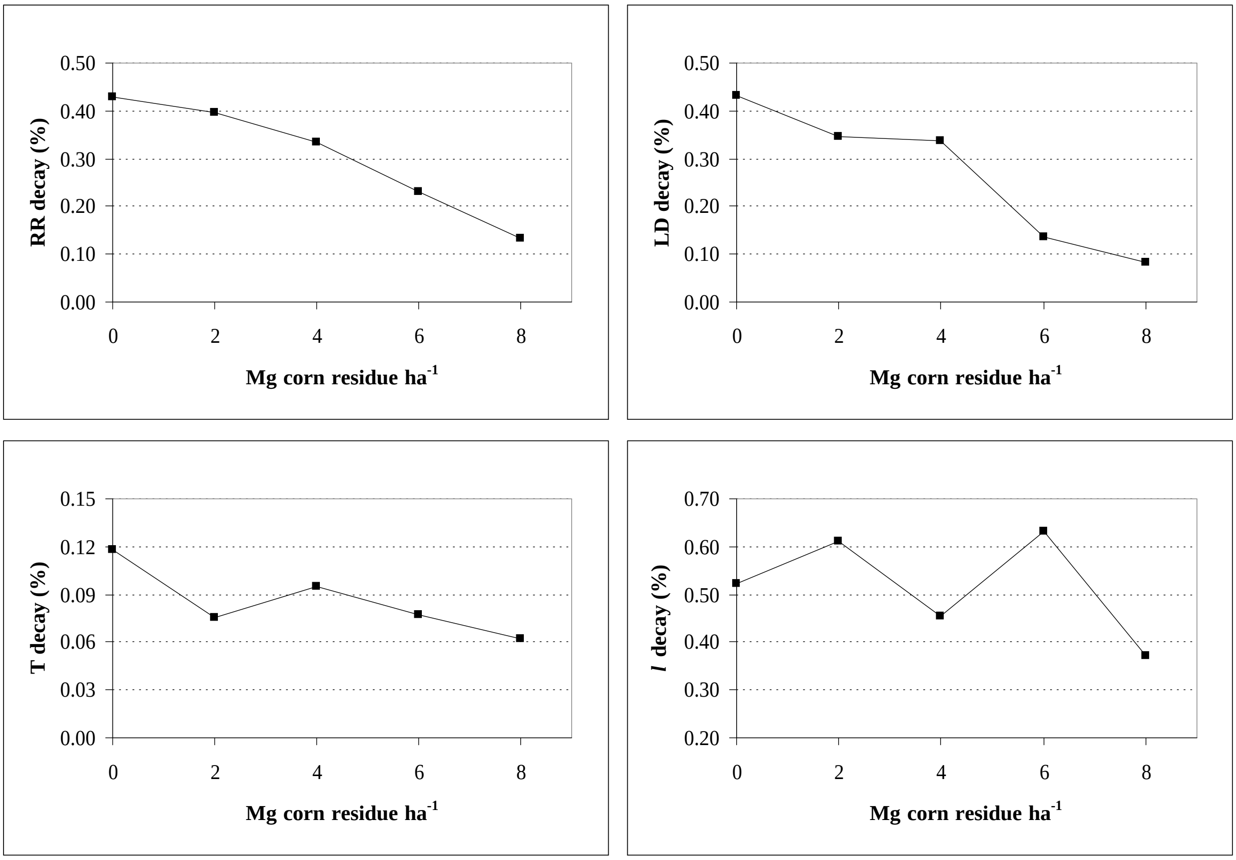

Figure 1. RR, LD and T decay versus increase residue cover.

Tortuosity, T, was also found adequate for describing the influence of soil cover on microrelief decay. However, T was less sensitive than RR and LD in assessing microrelief breakdown. This is illustrated by T decline between initial and final conditions, ranging from 11.8% in the plot without residues 7.6 % as 8 Mg h^{-1} were added.

The crossover length index, *l*, was somewhat ambiguous in describing the effect of crop residue addition on soil surface microrelief decay. Even if differences between plots with no residue and high dose (8 Mg h^{-1}) were consistent, the trend to microrelief breakdown as soil cover increases was obscured.

Fractal dimension, D, oscillated between 2.80 and 2.91 in the initial conditions, before rain and between 2.72 and 2.84 after rain. Thus, a general trend for decreasing fractal dimension with increasing rain was observed, which is consistent with previous findings (Vidal Vázquez et al., 2005). However this trend was not observed in all of the study plots. Note that differences of D values between plots, both in the initial (not degraded) and final (degraded) surface conditions are higher than differences in the D values before and after rainfall, again, this is an indication of the heterogeneity of the surface conditions of the study plots.

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The index LS has been interpreted as surface slope at small intervals (Linden and van Doren, 1986). LS values were between 0.152 and 0.248 in the initial surface, before rain and between 0.092 and 0.135 in the degraded soil surfaces after 145.8 mm rain. Limiting slope also decayed with increasing rain, but this decay tended to increase as the soil cover increased. This result may be due to the interaction between the effect of raindrop impact, diminishing the slope at small distances as soil surface degrades and the different decay velocity of soil surface and residue cover.

Conclusions

Soil microrelief breakdown was due to natural rain strongly influenced by soil cover. Roughness decay, as assessed by the microrelief indices RR, LD and T, decreased as maize straw cover increased.

Microrelief indices RR and LD were found to be more sensitive than T index in describing the influence of soil cover on microrelief breakdown by rain.

A general trend for decreasing fractal dimension with increasing rain was observed, but this trend was not assessed in all of the study plots.

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