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Effect of soil erosion on seasonal evolution of soil respiration

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Résumé
La respiration basale du sol est considérée comme un paramètre très utile pour la quantification de l'activité biologique et la qualité des sols. On a évalué l'évolution saisonnière de la respiration basale sur deux positions topographiques d'une parcelle avec une forte pente, considérées représentatifs des endroits d'érosion et de déposition durant une période d'une année. La respiration basale des échantillons individuelles prises dans des successives dates était plutôt modérée, avec une oscillation entre 0.019 et 0.104 mg $C0_2$ g^{-1} d^{-1}. La respiration du sol était significativement plus faible dans la zone d'érosion que dans la zone de déposition. L'évolution saisonnière de la respiration basale était relatée avec la température et l'état hydrique du sol.

Introduction
In situ and laboratory measurements of soil basal respiration, (BR) give information about soil organic matter reserves and microbiological activity. Soil basal respiration is also considered as a fundamental parameter for assessing soil quality. It is a measure of background microbial respiration and is commonly regarded as a parameter giving information about the overall decomposition of organic material (Hernandez and García, 2003). Temporal oscillations of soil respiration should reflect mainly the impact of climate and season, whereas spatial oscillations may be due to soil factors, i. e. physical-chemical properties. In agricultural land, temporal and spatial oscillations are also related to management practices leading to changes in soil organic matter and changes in nutrient recycling. Higher BR values are positive if combined with high biomass content and decreased values can indicate physical or chemical degradation and deterioration of the functions a soil should fulfil.
Erosion removes and redistributed topsoil, the layer of soil with the greatest amount of organic matter, biological activity and nutrients. Soil organic matter and nutrients eroded from a field area may contribute to resource accumulation in another area. Removal of organic matter and nutrients from the soil surface by erosion reduces populations of soil organisms, with consequent reductions in biological activity and fertility, thus aggregation and rooting depth. Soil erosion usually degrades soil quality and a potential effect of soil erosion is declining microbiological activity (Klik, 2002).
The objective of this study was to compare the temporal evolution of soil basal respiration at the upper and lower slope of a eroded field conventionally tilled.

Material and methods
The studied site is located at A Zapateira, a periurban area of La Coruña (Spain). The experimental field, over granite bedrock has an important slope (16.81%) and it is conventionally tilled following the common rotation system in the region. Since 1997, concentrated erosion has been monitored in this hillslope (Valcárcel et al., 2003). Long term mean annual temperature and rainfall figures are 14.4 ºC and 1008 mm,

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respectively. Yearly rainfall distribution is uneven with water surplus in the winter month and water deficits in summer.
Duplicate soil samples were taken on 19 successive dates between April 2004 and April 2005. Two different depths were sampled (0-5 and 5-10 cm) in the upper and lower side of the hillslope. Thus, a total of 152 individual samples were analyzed over the study period. Soil general properties, i.e. soil texture, pH, organic carbon content and nitrogen content were determined by routine methods (Guitián and Carballas, 1976). Soil water content was measured gravimetrically.
Soil respiration was determined by static incubation (Guitián and Carballas, 1976). The CO_2 produced during a 4-day period by 50 g soil samples incubated at field moisture content at 28 ºC was collected in 10 mL of a 0.1 M NaOH solution. Once the incubation had finished, a volumetric analysis with HCl 0.1N was performed. Biological activity was determined using three repetitions per individual sample. Results are expressed as mg CO_2-C g^{-1} soil d^{-1}, i.e. as the average daily rate of CO_2 production during the whole 4 day incubation period.
The study topsoil is sandy-loam textured; the sand content varied between 56.33% and 64.72% and the silt content was between 17.30% and 21.01%. For individual samples taken along the study period pH (H_2O) oscillated between 4.30 and 5.54 whereas pH (KCl) varied between 3.59 and 4.87. Carbon and nitrogen contents as well as carbon/nitrogen ratio also showed important oscillations when all the 152 soil samples were considered. In the upper hillslope zone, the organic carbon content oscillated between 0.78 and 3.81% whereas in the deposition zone it varied between 1.51 and 4.53%. A wide range of soil water content, between 2.41 and 34.90 g/100g was measured during the study period. (Mirás et al., 2005).

Results and discussion

Basal respiration differences between the two study soil depths were not significant according to an ANOVA test, even if it was slightly higher at 0-5 than 5-10 cm depth. Highest basal respiration values in the surface layer would be an expected result due to better aeration and high temperatures.
Differences of the investigated parameter between the uppermost erosive parts of the hillslope and its basal deposition zone were significant (Table 1). Soil basal respiration was 6 out of 19 times higher in the erosion than in the deposition zone and this in spite of the significantly mean greatest values in this later topographical position (Figure 1). In this work basal respiration at the 0-10 cm depth will be taken into account for assessing differences between the erosion and deposition sites.

Table 1 Rainfall, number of sampled dates per period and mean values of soil respiration, for the whole year and for successive periods.

Period	Rainfall (mm)	N	Erosion zone (mg C-CO_2 g^{-1} d^{-1})	Deposition zone (mg C-CO_2 g^{-1} d^{-1})
Apr 2004- Apr 2005	875,8	19	0.062	0.071
Apr 2004-July 2004	174.3	8	0.057	0.070
Aug 2004-Oct 2004	347.6	4	0.052	0.062
Nov 2004-Jan 2005	154.2	4	0.081	0.090
Feb 2005-Apr 2005	199.7	3	0.080	0.080

Taken into account different periods along the year differences between seasons were also observed, which are significant according to an ANOVA test. However the

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interaction between season and soil depth for soil basal respiration was not significantly different.

Mean yearly values of basal respiration at the 0-10 cm dept were 0.071 and 0.062 mg C-CO_2 g^{-1} soil d^{-1}, in the erosion and deposition field topographical positions, respectively (Table 1). The range of basal respiration values for individual soil samples taken at two depths oscillated from 0.010 to 0.15 mg C-CO_2 g^{-1} soil d^{-1}. Mean values at the 0-10 cm depth were between 0.019 and 0.104 mg C-CO_2 g^{-1} d^{-1} for the 19 successive study dates (Figure 1). The lowest soil basal respiration values, below 0.040 mg C-CO_2 g^{-1} d^{-1} were recorded on 24 May, 26 July and 5 October 2004. The highest soil basal respiration was measured by the end October and the first decade of November 2004. Relatively high values of soil basal respiration were recorded between December and February, the coldest study months.

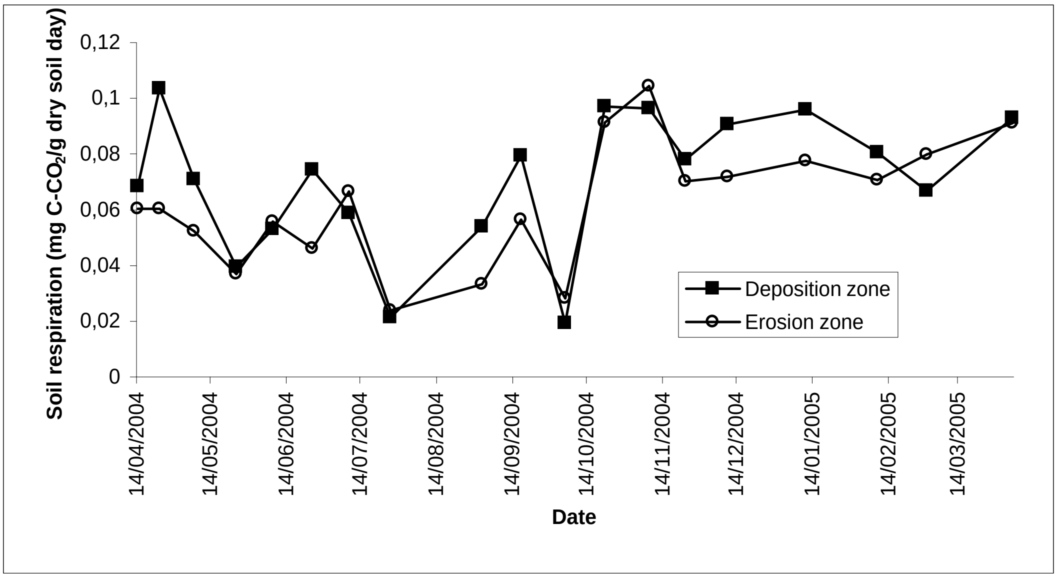

Figure 1. Yearly evolution of soil basal respiration on a hillslope at 0-10 cm depth as a function of topographical position.

Results in Table 1 and Figure 1 also indicate a trend to decreased soil basal respiration values as soil water deficits developed. Total precipitation along the 13 month period from 1 April 2004 to 30 April 2005 was 875.8 mm, much lower than the long-term average for the study site. The lowest values of soil basal respiration in spring, summer and autumn 2004 are related to low soil water contents. An increase in soil water content during summer month leads to increasing soil basal respiration. In fact a very significant relationship was found between soil water content and basal respiration (Mirás et al., 2005). On the other hand relatively high respiration values during winter months are the consequence of soil water content near saturation and mild temperatures, which is illustrated by the fact that mean temperatures between December and February were above 10 ºC and average minimum montly temperatures were above 7ºC.

Mean values of basal respiration measured in the studied hillslope were lower than figures for this parameter reported in soils supporting natural vegetation of the region (Leirós et al., 2000). On the other hand basal respiration assessed by García and Hernández (1997) on degraded soils for arid climatic conditions was between 0.023 and 0.055 mg C-CO_2 $soil^{-1}$ day^{-1}. This is a consistent result taking into account that soil organic matter content in our temperate climate conditions is higher that those in the arid climate conditions of García and Hernández (1997). Soil respiration was studied in

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the period between March and October 2001 by Klik et al. (2002) in the topsoil of three soils with different tillage systems: conventional tillage, conservation tillage and no till in Austria. Soil respiration values ranged between 0.07 and 0.26 mg C-CO_2 $soil^{-1}$ day^{-1} depending mainly on soil type. No significant differences between treatments compared to conventional tillage were found. The above results from the literature allow rating our site as a filed with moderate to low soil biological activity. Thus, conventional tillage leads to a biological degradation of the study soil and soil conservation practices are recommended to protect and restore soil quality.

Conclusions

On a yearly basis, soil basal respiration was highest in the deposition than in the erosion zone of a conventionally tilled hillslope. However soil respiration during some of the sampling dates was higher in the erosion zone. Significant differences in basal respiration values along the seasons of the year were found, in accordance with temperature and soil water content oscillations.

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