Erosion, water availability and plant characteristics control plant colonisation on semiarid eroded slopes.

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ABSTRACT

The objective of this study was to understand the mechanisms that control spontaneous plant colonisation on severely eroded slopes in a semiarid badland area of East Spain. More specifically, we aimed at (1) determining topographic thresholds for plant colonisation, (2) identifying the soil properties that limit plant establishment and (3) identifying plant traits that enable colonising species to cope with these limitations.

We used slope angle and aspect as surrogates of erosion rate and water availability respectively. Since soil erosion and water availability can limit plant establishment and both interact in the landscape, we analysed variations in colonisation success with slope angle and aspect. Vegetation success was measured in terms of total vegetation cover on 156 different slopes. After determining slope angle thresholds for plant colonisation, soil was sampled on slopes just above and just below the threshold values for soil analysis in order to test for differences in soil properties related to plant establishment and development. Plant traits related to plant colonising capacity were analysed in two different groups of species: the group of species colonising the steep slopes near the threshold and the group of non-colonising species present on more gentle slopes but unable to colonise the slopes just below the threshold.

The identified slope angle threshold values for plant colonisation clearly decreased from North to South. No differences were found in soil properties neither among slope aspects at the slope angle threshold values nor between slope positions (just below and above the threshold) within slope aspect classes. Long-distance dispersal mechanisms and ability of seeds to segregate mucilage in contact with water were more frequent characteristics in colonising species than in non-colonising ones.
It is concluded that water availability for plants which, in turn, is controlled by the solar radiation can explain the differences in the slope angle threshold values for plant colonisation among slope aspect classes. Some important implications of these results in the context of ecological restoration of these severely eroded areas are also discussed.

Keywords: erosion – vegetation – slope angle – slope aspect – water stress – plant traits

INTRODUCTION

Vegetation and erosion interact actively in severely eroded areas of semiarid Mediterranean regions. The positive effects of vegetation on erosion control have been largely described for a wide range of vegetation types and environmental conditions (Thornes, 1990; Gyssels et al. 2005), whereas the interest for the influence of erosion as an ecological driver that shapes the vegetation is increasing in the last decade (Guerrero-Campo and Montserrat-Martí, 2000;

Puigdefrabregas, 2005; García-Fayos and Bochet, 2009). The objective of this study was to better understand the mechanisms that control spontaneous plant colonisation on severely eroded slopes in a semiarid badland area of East Spain. More specifically, we aimed at:

1. determining topographic thresholds for plant colonisation,
2. identifying the soil properties that limit plant establishment,
3. identifying plant traits that enable colonising species to cope with these limitations.

MATERIALS AND METHODS

Study area

The study area is located in the basin of the Alfambra River (Teruel, East Spain). The lithology consists of severely eroded limestones of Tertiary origin, calcareous marls and sands, resulting in a landscape of active badlands and an overall low vegetation cover dominated by shrubby and herbaceous plants. The vegetation pattern in the area changes continuously from one facet to another. The climate is semiarid with mean annual precipitation and air temperature of 373 mm and 11.8ºC respectively. Soils are loamy to sandy-loamy, poorly developed, calcareous and non-saline.

Vegetation establishment success

We analysed variations in plant colonisation success, in terms of vegetation cover, with slope angle as a function of slope aspect. Slope angle and aspect were chosen as surrogates of erosion and water availability respectively. Vegetation surveys were made in 2x2 m plots, on 156 slopes that accounted for slope angle (11 classes at every 5º intervals, from 20º to 75º) and aspect (4 classes: N, E, S, W).

Soil analyses

After determining slope angle thresholds for plant colonisation, topsoils were sampled near the threshold values to test for differences in soil properties related to plant establishment and development among slope aspect classes and between slope positions (just below and just above the threshold values). Total Nitrogen, total phosphorous, carbonate content and water holding capacity were determined by standard methods of soil analyses.

Plant traits

Twelve plant traits related to the plant colonising, persisting and competing capacities were measured both in the pool of species colonising the steep slopes just below the threshold values –hereafter colonising species- and in the pool of species inhabiting the more gentle slopes and absent from the steeper slopes just below the threshold –hereafter non-colonising species. Species surveyed were described in terms of lifeform, seed production, seed mass, seed appendages, dispersal mode, propagule shape, propagule mass, mucilage production, root architecture, sprouting capacity, specific leaf area, woodiness.

RESULTS AND DISCUSSION

The identified slope angle threshold values for plant colonisation – in terms of vegetation cover- clearly decreased from North to South. A similar trend with similar threshold values was described for the species richness in the same area by Bochet et al. (2009). These results indicate that vegetation is able to establish on steeper slopes on northern-facing slopes than on southern-facing ones (Fig.1).

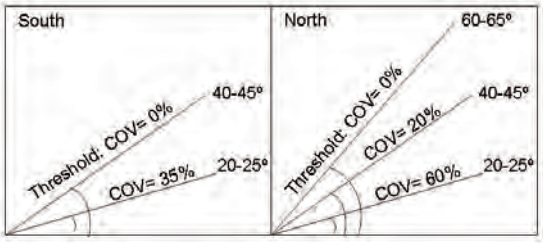
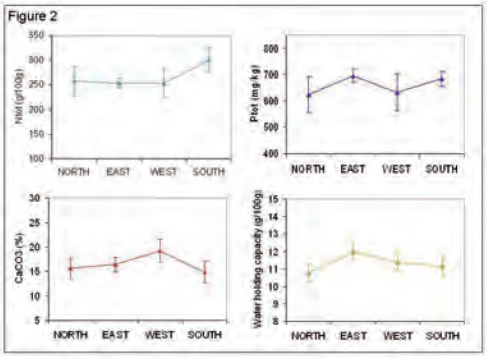
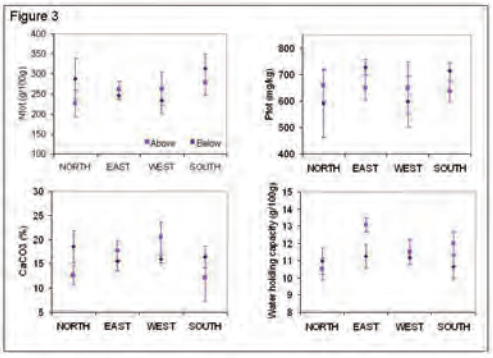


Figure 1. Slope angle thresholds for plant colonisation in North- and South-facing slopes. COV= mean vegetation cover for a given slope angle interval. (After Bochet et al. 2009).

No differences were found in soil properties neither among slope aspects at the slope angle threshold values nor between slope positions (just below and above the threshold) within slope aspect classes, indicating similar degrees of soil evolution among the different levels of both factors (Figs. 2 and 3).





Figures 2 and 3. Variation in soil properties according to slope aspect (Fig.2, 4 classes: North, East, West, South) and position with respect to the slope angle threshold within each slope aspect category (Fig.3, 2 positions: just below and above the threshold). (After Bochet et al. 2009).

Long-distance dispersal and mucilage production were over-represented in the group of colonising species, whereas sprouters and species with higher specific leaf area were over-represented in the non-colonising group of species (Figure 4). These results provide evidence that colonising species preferably devote their resources to the production of high-performing seeds in the first step of plant succession, whereas non-colonising species capable to persist and compete in later stages of plant succession devote their resources to the below-ground organs.

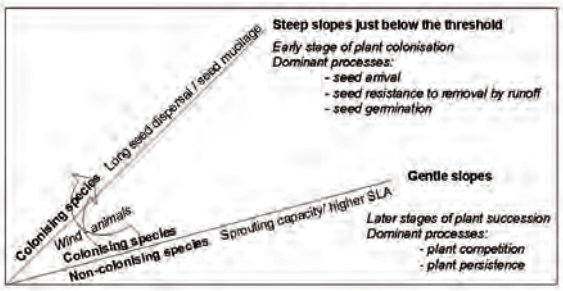


Figure 4. Description of the traits over-represented (a) in the group of colonising species able to colonise the steep slopes near the threshold for plant colonisation from the surrounding more gentle slopes at later stages of succession (see arrow) and (b) in the non-colonising group of species inhabiting the more gentle slopes but absent from the steep slopes near the threshold. SLA= specific leaf area. (After Bochet et al. 2009).

CONCLUSIONS

Differences in water availability, caused by differences in solar radiation and not due to differences in soil properties, are responsible for the variations in the threshold values for plant colonisation among slope aspects. The identification of thresholds for plant colonisation and the identification of specific plant traits associated with the plant ability to colonise steep eroded slopes are important issues that should be taken into consideration in the field of ecological restoration of semiarid eroded areas.

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