Evaluation of Mediterranean plants for controlling gully erosion

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ABSTRACT

In Mediterranean environments, gullies are responsible for large soil losses causing loss of fertile cropland soil, reservoir sedimentation and flooding. To limit soil loss and sediment export it is important to prevent the initiation of rills and to stabilise gullies. This can be done by establishing vegetation at vulnerable places in the landscape. Although in the past, the effects of vegetation on soil erosion rates were usually predicted using above-ground biomass characteristics only, plant roots also play an important role in protecting the soil against erosion by concentrated runoff. Especially in conditions where the above-ground biomass becomes very scarce (e.g. due to drought, harvest, overgrazing or fire) the effects of vegetation will be underestimated when only above-ground plant characteristics are taken into account. Unfortunately, information on dryland vegetation characteristics, especially on their root characteristics and their suitability for gully erosion control is often lacking. A methodological framework to evaluate plant traits for this purpose is absent as well. Therefore this paper presents a methodology to assess the suitability of plants for erosion control and its application to 25 plant species, representative for a semi-arid Mediterranean landscape in SE Spain. In this analysis determination of suitable plants for gully erosion control is based on a multi-criteria analysis where both above- and below-ground plant characteristics were taken into account. The scores for the indicators were represented on amoeba diagrams, indicating the beneficial and the weak plant traits, regarding to erosion control. The methodology developed in this study can be applied to other plant species in areas suffering from gully erosion in order to select suitable species for restoration purposes.

Keywords: methodological framework, ecological restoration, root, suitable plants, concentrated flow erosion

INTRODUCTION

In semi-arid environments, water erosion is one of the main soil degradation processes (Poesen, 1995). Several studies indicate that in Mediterranean areas gully erosion may be held responsible for more than 80% of total soil losses due to water erosion, whereas this process only operates on less than 5% of the land area (Poesen et al., 2003). Human impacts, such as geomorphic smoothening of the topography by land levelling, highly industrialised farming or the lack of maintenance of agricultural terraces are leading to a high risk for gullying, increasing runoff and sediment connectivity (Hooke, 2006). Gullies can act as effective links, connecting highlands to lowlands and transferring runoff and sediment from the hillslopes to the river system. This causes severe on- and off site effects, such as loss of fertile cropland soil, reservoir sedimentation and flooding (Poesen et al., 2003).
To limit soil loss and sediment export it is important to prevent the initiation of rills and to stabilise gullies. This can be done by promoting vegetation at vulnerable places in the landscape. Many studies attribute the effects of vegetation in reducing soil erosion rates to the effects of the above-ground biomass (e.g. Thornes, 1990). The effects of roots on topsoil

resistance to concentrated flow erosion are much less studied, but are shown to be important as well for preventing concentrated flow erosion (e.g. De Baets et al., 2008). Especially in a Mediterranean context, the above-ground biomass can temporarily disappear because of fire, drought or overgrazing, and when concentrated flow erosion occurs, roots play an important role in controlling soil erosion rates. Unfortunately, information on Mediterranean plant characteristics, especially root characteristics, growing on semi-natural lands, and knowledge of their suitability for gully erosion control is often lacking. A methodological framework to evaluate plant traits for this purpose is absent as well. This research therefore presents a methodology to assess the suitability of plants for gully erosion control and its application to 25 plant species, representative for a semi-arid Mediterranean landscape in SE Spain.

METHODS

Study area and selected plants

The measurements of stem and root properties of 25 Mediterranean plant species were conducted in the Cárcavo catchment (1°34’-1°27’ E.L., 38°09’-38°14’N.W.), located about 40 km northwest of the city of Murcia in Southeast Spain, near the town of Cieza. A set of 25 native typical Mediterranean plant species, growing on marls and Quaternary loamy deposits, was preselected based on assessment of abundance. The preselected species were present in three habitats that are very prone to concentrated flow erosion phenomena, i.e. a) ephemeral channels and gully bottoms, b) steep badland slopes and c) abandoned fields. 5 medium-sized plants per species were analysed.

Methodological framework

In this analysis determination of suitable plants for gully erosion control is based on a multi-criteria analysis (Fig. 1), using mechanical and architectural plant properties.

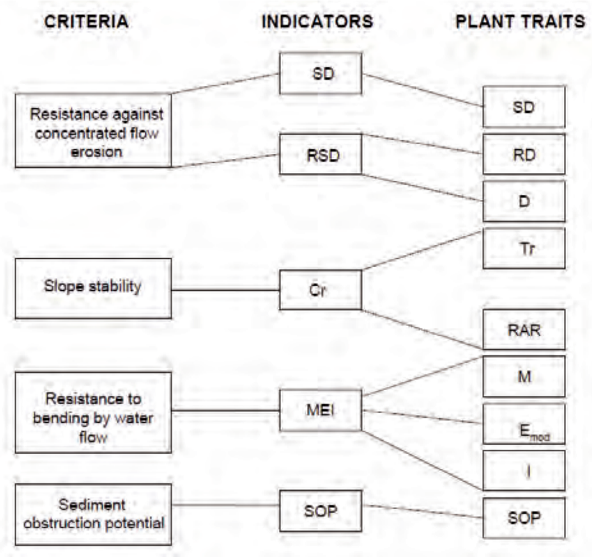

Figure 1 Multi-criteria approach for selecting plant species to control rill and gully erosion. C_r (kPa) is root cohesion at 0.3-0.4 m soil depth, MEI (N) is index of stiffness, SD (m^2 m^{-2}) is stem density, RSD (dimensionless) is topsoil erosion-reducing potential of plant roots during concentrated flow erosion, SOP (m m^{-1}) is sediment obstruction potential, T_r (kPa) is mean root tensile strength, RAR (m^2 m^{-2}) is root area ratio, M (m^{-2}) is stem density, E_{mod} (Pa) is modulus of elasticity, I (m^4) is second moment of inertia, RD (kg m^{-3}) is root density is and D (m) is mean root diameter.

First, four main criteria were determined, i.e (1) the potential of plants to prevent incision by concentrated flow erosion, (2) the potential to improve slope stability, (3) the resistance to bending by water flow and (4) the ability to trap sediments and organic debris. In total, five indicators were selected to assess the scores for the four criteria, i.e. additional root cohesion (C_r, kPa), plant stiffness (MEI, N), stem density (m^2 m^{-2}), the erosion-reducing potential during concentrated flow (RSD, dimensionless) and the sediment and organic debris obstruction potential (m^1 m^{-1}). Both above- and below-ground plant characteristics were taken into account and measured to assess the scores for the five indicators, i.e. stem density, sediment and organic debris obstruction potential, modulus of elasticity of the stems, moment of inertia of the stems, root density, root diameter distribution, root area ratio and root tensile strength. The scores for the indicators were represented on amoeba diagrams, indicating the beneficial and the weak plant traits, regarding to erosion control (Fig. 2).

Plant trait measurements

A more detailed description of formulas used to quantify the selected above-ground and below-ground plant traits and of how scores were given can be found in De Baets et al., 2009.

RESULTS AND DISCUSSION

Table 1 shows the suitability of all studied plant species for gully erosion control. The grass *Helictotrichon filifolium,* the rush *Juncus acutus* and the shrub *Salsola genistoides* amongst others, were selected as very suitable plant species for gully erosion control. *Stipa tenacissima* can be used to re-vegetate abandoned terraces as this species is adapted to drought and offers a good protection to concentrated flow erosion and shallow mass movements. *Lygeum spartum* or *Juncus acutus* can be used to vegetate concentrated flow zones or to obstruct sediment inflow to channels at gully outlets. *Stipa tenacissima* and *Salsola genistoides* can be used to stabilize steep south-facing slopes.

Plant species name	Vegetation type	Resistance to erosion	Slope stabilization	Resistance to bending	Ability to trap sediments	Overall
Tamarix canariensis	tree	++	++++	++++	+	+++
Anthyllis cytisoides	shrub	+++	++++	++	+	+++
Artemisia barrelieri	shrub	++	0	++	0	+
Atriplex halimus	shrub	++	+++	++++	0	++
Dittrichia viscosa	shrub	+++	++	++	0	++
Dorycnium pentaphyllum	shrub	++	++	+++	+	++
Fumana thymifolia	shrub	+	0	+	0	+
Nerium oleander	shrub	++	+	++++	++	++
Ononis tridentata	shrub	++	++	++++	+	++
Retama sphaerocarpa	shrub	++	++++	++++	+	+++
Rosmarinus officinalis	shrub	+++	+	++++	+++	+++
Salsola genistoides	shrub	++	++++	++++	+	+++
Teucrium capitatum	shrub	+	0	+	0	+
Thymelaea hirsuta	shrub	+	++	+++	0	++
Thymus zygis	shrub	++	0	+++	+	++
Juncus acutus	rush	++++	+++	++	+++	+++
Phragmites australis	reed	+	++++	++	++++	+++
Avenula bromoides	grass	+++	0	+	++	++
Brachypodium retusum	grass	++	0	0	+++	+
Helictotrichon filifolium	grass	++++	0	++	++++	+++
Lygeum spartum	grass	+++	0	+	+	+
Piptatherum miliaceum	grass	+++	0	++	+	++
Stipa tenacissima	grass	++	++	+	0	+
Limonium supinum	forb	++	0	0	++++	++
Plantago albicans	forb	++++	0	0	++++	++

Table 1 Suitability of plant species for gully erosion control, depending on the 4 main criteria (++++= very high, +++= high, ++=medium, +=low, 0=very low suitability)

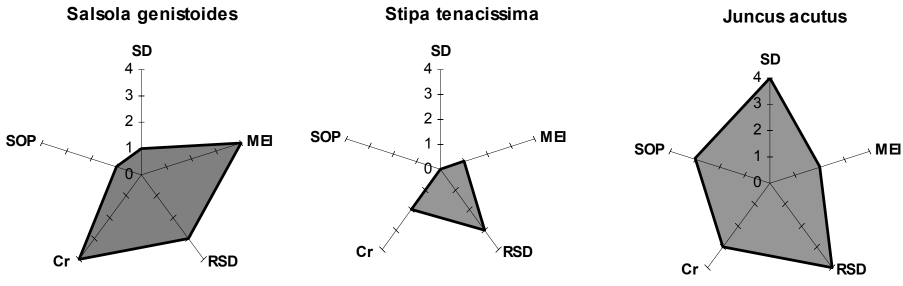

Figure 2 Amoebe diagrams of some species suitable for gully erosion control

CONCLUSIONS

The selection of suitable plant species depends on the process of interest. The methodology developed in this study can be applied to other plant species in areas suffering from rill and gully erosion. A combination of species (e.g. on the one hand a grass having a high potential to resist concentrated flow erosion and a high ability to trap sediments and on the other hand a shrub with a high resistance to bending by water flow and a high potential to improve slope stability) or the allocation of species to specific target areas (e.g. grasses in concentrated flow zones and on terrace walls, deep-rooted species to stabilize gully walls) is recommended.

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