IMPACT OF ROOT ARCHITECTURE, SOIL AND FLOW CHARACTERISTICS ON THE EROSION-REDUCING POTENTIAL OF ROOTS DURING CONCENTRATED FLOW

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1. Introduction

Many studies focus on the effects of vegetation cover on water erosion rates, whereas little attention has been given to the effects of the below ground biomass. However, few studies (e.g. De Baets et al., 2006, Gyssels et al., 2003, Gyssels et al., 2005, Li et al., 1991, Mamo and Bubenzer, 2001a, 2001b, Zhou and Shangguan, 2005) indicate that roots can reduce concentrated flow erosion rates significantly. Nevertheless, the impact of roots on water erosion rates might become very important when the above ground biomass disappears because of grazing or surface fire and when concentrated flow occurs. Especially in semi-arid environments, where vegetation cover can be restricted and shoots can temporally disappear, roots can play a crucial role. In order to predict this root effect more accurately, this research aims to gain more insight into the influence of root morphology, soil and flow characteristics on the erosion-reducing effect of plant roots during concentrated flow. Although not experimentally investigated, Wischmeier already assumed in 1975 that plant species with contrasting root morphologies have a different reducing effect on soil losses by interrill and rill erosion (Fig. 1).

2. Objectives

In this study, the effects of roots of different root morphologies (tap roots vs. fine-branched roots) on concentrated flow erosion rates are studied experimentally. The impact of soil type, soil moisture conditions (saturated vs. dry topsoil samples) and flow shear stress on the erosion reducing effect of roots is also considered.

3. Materials and methods

Treatments were (1) bare, (2) grass (simulating fine-branched roots) and (3) carrots (simulating taproots). The soils used were a sandy loam and a silt loam, under saturated and dry conditions. Next, laboratory experiments during which concentrated flow was simulated in a flume were conducted (Fig. 2). Slope, flow discharge, mean velocity, water temperature and sediment concentration were measured. Root density (RD) and root length density (RLD) values were assessed. Relative soil detachment rates (SDR) and mean flow shear stresses were calculated.

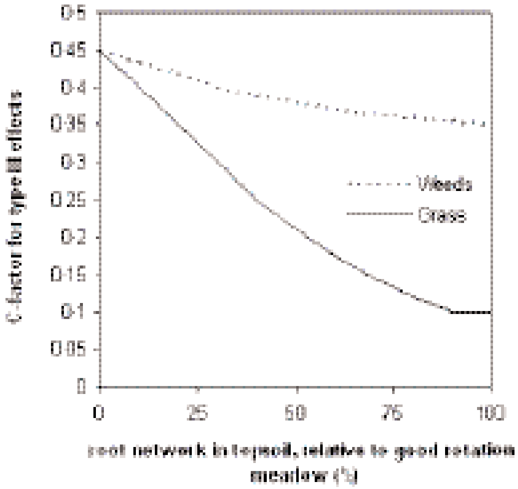

Fig. 1. Type-III effects (i.e. below soil surface effects of vegetation) of undisturbed land on the RUSLE C-factor (i.e. cover and management factor) depending on the development of a root network in the topsoil (after Wisschmeier, 1975).

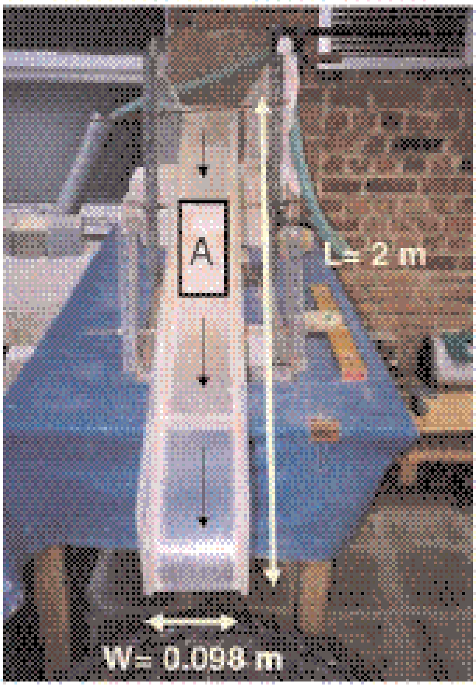

Fig. 2. Hydraulic flume used to measure detachment rated on bare and root permeated topsoil samples. A indicates test section, arrows indicate flow direction.

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4. Results

Roots play an important role in increasing the topsoil resistance against erosion by concentrated flow. Relative soil detachment rate (*SDR*) decreases to very low values (from 1 to 0.001 for grass roots and to 0.03 for carrot roots) for a silt loam topsoil with increasing root density (*RD*) from 0 to 2 kg m^{-3} only. *SDR* for a sandy loam soil decreases from 1 to 0.18 for carrots and to 0.10 for grasses with increasing *RD* from 0 to 2 kg m^{-3}. The results indicate that tap roots reduce the erosion rates to a lesser extent compared to fine-branched roots. Different relationships linking relative soil detachment rate with root density could be established for different root diameter classes (Fig.3). Carrots with very fine roots (*D*<5 mm) show a similar negative exponential relationship between root density and relative soil detachment rate as grass roots. With increasing root diameter (5<*D*<15 mm) the erosion-reducing effect of carrot type roots becomes less pronounced. Additionally, an equation estimating the erosion-reducing potential of root systems containing both tap roots and fine-branched roots could be established (1).

$$SDR = e^{-1{,}45RD_{1<D<5\,mm}}\ e^{-0{,}47RD_{5<D<15\,mm}} \qquad (1)$$

Equation 1 can be used to predict the erosion-reducing effect of plant species having roots of different diameters. Moreover, the erosion-reducing potential of grass roots is less pronounced for a sandy loam soil compared to a silt loam soil and a larger erosion-reducing potential for both grass and carrot roots was found for initially wet soils. For carrots grown on a sandy loam soil, the erosion-reducing effect of roots decreases with increasing flow shear stress. This can be explained by the occurrence of local turbulence and vortex erosion scars around individual carrot roots, which form an obstacle to the flow and increase the detachment rate. For grasses, grown on both soil types, no significant differences could be found according to flow shear stress. The erosion-reducing effect of roots during concentrated flow is much more pronounced than suggested in previous studies dealing with interrill and rill erosion. Root density and root diameter explain the observed erosion rates during concentrated flow well for the different soil types tested.

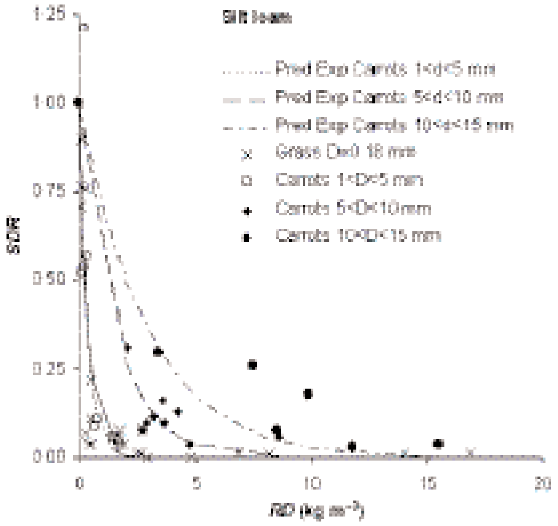

Fig. 3. Relationship between root density (*RD*) and relative soil detachment rate (*SDR*) for topsoils with grass and carrot roots for different root diameter classes. D is mean root diameter. Pred Exp is predicted values obtained with the exponential model (De Baets et al, in press).

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