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Variability of particle size distributions of upward/downward splashed materials in different rainfall intensities and slopes

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ABSTRACT

The particle size distribution (PSD) of the splashed sediment is expected to vary depending on rainfall intensity, slope steepness and slope position. This study therefore discusses the results of analysis of laboratorial experiments to compare PSDs of splashed materials in upward and downward directions of splash cup with original soil PSDs before runoff initiation from different parts of an erosion plot under different rainfall intensities at various slope gradients. To achieve the objectives, a set of laboratorial experiments were conducted using rainfall simulator at erosion plots scale. The rainfall intensities of 30, 60, and 90 mm h^{-1} were applied at 5, 15 and 25% plot slopes for a soil collected from Kojour rangeland watershed in the Alborz Mountains, northern Iran. Besides very oft-reported results of more splashed material in downward direction and positive effects of rainfall intensities ($P > 0.05$) on rate of splashed materials, it was found that there were significant differences between clay, silt and sand contents of original soil and upward and downward splashed materials on slopes of 5 and 15% in all study rainfall intensities. In general, comparison of D_{10}, D_{50} and D_{90} of splashed materials in upward and downward splash cups were larger than those of original soil. Furthermore, the sorting of splashed materials in upward and downward of splash cups with respective amounts of 4.84–6.62 μm and 5.13–6.54 μm under different rainfall intensities and slopes were less than that of the original soil (8.12 μm).

1. Introduction

Soil erosion involves detachment of particles from the soil surface followed by subsequent transport of the detached soil material away from the detachment site. Water erosion results from the expenditure of the energy of falling raindrops and/or flowing water on soil surface. This is therefore obvious that no erosion occurs unless detachment takes place first either by raindrop or runoff. The Raindrop-Impact-Induced Erosion (RIIE) occurs when detachment results by raindrop energy (Kinnell, 2005). Raindrop impact detaches soil particles from the surface layer of the soil matrix. It produces detached material that can be transported by splash and/or flowing water. The splash process can be divided into two sub-processes of aggregate breakdown physical mechanisms (Le Bissonnais, 1996) and transport of breakdown products (Sharma et al., 1991; Legout et al., 2005). The transport process can be controlled by the availability of kinetic energy of the raindrops comparable to the weight and size of the detachment fragments.

Numerous studies have investigated the various aspects of splash erosion process. The effects of rainfall intensity and slope steepness on splash rate have already been extensively studied (Fan and Wu, 2001; Zhang et al., 2002; Fu et al., 2011; Iserloh et al., 2012; Liu et al., 2015; Grismer, 2012; Khalili Moghadam et al., 2015; Mahmoodabadi and Sajjadi, 2016). The splash rate in lateral, downward and upward directions also has been studied (Sutherland et al., 1996; Van Dijk et al., 2003; Fu et al., 2011; Liu et al., 2015; Saedi et al., 2016). However, few studies (e.g., Sutherland et al., 1996; Legout et al., 2005; Wei et al., 2015) have examined the particle size distribution of splashed materials. In this respect, Leguédois et al. (2005) reported the splash projection distance for aggregated soils and showed that the splashed particle sizes of 50 to 2000 μm were transported as single airborne particles and particle size less than of 50 μm were transported in groups. In this regard, the size selectivity of splash processes in comparison with the original soil has been reported (Poesen and Savat, 1981; Parsons et al., 1992; Sutherland et al., 1996; Wan and El-Swaify, 1998). In addition, the relationship between the size selectivity of splash erosion with soil aggregate strength (Misra and Rose, 1995; Mouzai and Bouhadef, 2011; Ma et al., 2014) and soil particle size distribution (Legout et al., 2005; Wei et al., 2015) have been generally disseminated. Only some studies investigated splash erosion caused by raindrops impact (Van Dijk et al., 2002; Kinnell, 2005; Legout et al., 2005). Legout et al. (2005) found that the size distribution of splashed particles depends indirectly on the size distribution of aggregate breakdown products and

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directly on the size selectivity of the initiation of movement. Boix-Fayos et al. (2005), Yan et al. (2008) and Aksoy et al. (2016) pointed out that better understanding of soil erosion mechanisms is greatly helpful for soil conservation, soil erosion control and development of dynamic soil erosion prediction models.

Securitizing available literatures shows that despite of many reports on different soil erosion processes; no comparative study has been conducted on PSDs of original soil and splashed sediment before runoff initiation from different parts of an erosion plot under different rainfall intensities at various slope gradients. Accordingly, the present study was designed to comprehensively compare the PSDs of original soil placed in large sized plots and splashed sediment in upward and downward directions at the splash cups. The effects of rainfall intensity and plots slope were also studied for better understanding of the processes. It was therefore hypothesized that not only there is a significant different between PSDs of the origin soil and splashed soil, but also PSD components are also different in upward and downward directions.

2. Materials and methods

2.1. Experimental design

In order to comprehend the effective sediment size distribution of upward and downward splashes with the original soil in RIIE, 27 sets of experiments were conducted on a silt loam soil collected from the top 20 cm of surface layer (Kukal and Sarkar, 2011; Gholami et al., 2013) of a rangeland in the Alborz Mountains, northern Iran located in latitude of 36° 24″, longitude of 51° 44″ (Fig. 1). The experiments were arranged at the Rainfall and Erosion Simulation Laboratory of the Faculty of Natural Resources of Tarbiat Modares University, Noor, Iran. The experiments were conducted at plot scale and laboratorial circumstances due to increase the accuracy and the number of high-quality measurements (Aksoy et al., 2016) using 6 × 1 m erosion plots with a depth of 0.5 m, slopes of 5, 15 and 25% and rainfall intensities of 30, 60 and 90 mm h^{-1}. The duration of the rainfall experiments was considered about 30, 15 and 10 min in accordance with the intensity-duration-frequency specification of the nearest meteorological station (Kojour) for a return period of <30 years.

2.2. Soil properties and preparation

The general characteristics of the soil used in the study have been given in Table 1. Soil was prepared for the experiments according to previously reported methods (Khaledi Darvishan et al., 2014; Kiani Harchegani et al., 2016). Particle size distribution of soils was determined by laser diffraction Malvern Mastersizer 2000, organic matter content (OM) through dichromate oxidation technique, Walkley–Black procedure (Nelson and Sommers, 1986), and calcium carbonate content measured through calcimetric method (Loeppert and Suarez, 1996).

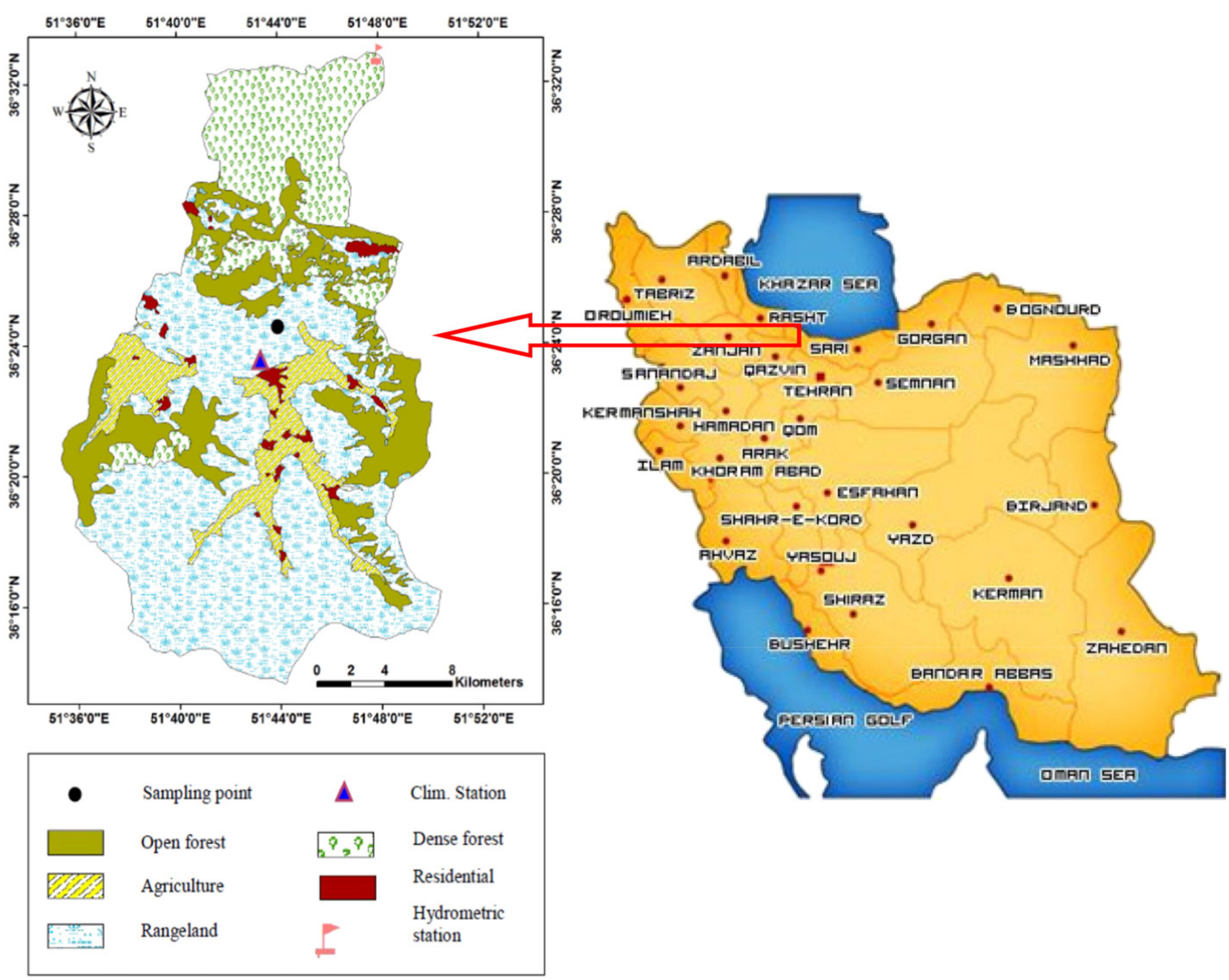

Fig. 1. Location of the study area and soil sampling.