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The kinetic energy of rain measured with an optical disdrometer: An application to splash erosion

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ABSTRACT

The present paper describes the procedures used to measure and compute the kinetic energy and various other rainfall characteristics as well as the concurrent splash erosion rates in a recently terraced forest plantation in Soutelo, north-central Portugal, from May to September 2007. This involved the use of an optical disdrometer, a standard automated rain gauge and two types of splash erosion measurement devices (i.e. 10 cups and 10 funnels). In the computation of the kinetic energy, the raindrops exceeding a specific threshold size were considered to not have a spherical shape. Without this correction for the shape of the bigger raindrops, the kinetic energy can be overestimated by 50% of its real value. A meteorological analysis indicated that four weather types with a western component produced more precipitation and kinetic energy, and, thus, a higher erosive power. The relationship between splash erosion and various rainfall characteristics set was analyzed in an exploratory manner, since the splash data only concern nine sampling periods. It showed well-defined relationships of increasing splash erosion with, amongst others, increasing total rainfall as well as total kinetic energy but these relationships require further analysis using additional data. The splash erosion figures obtained with the two types of devices showed a strong agreement but appeared to corroborate that the funnels are a more effective design than the cups.

1. Introduction

Modern-day societies are increasingly aware of the occurrence of extreme weather events and their potential impacts. They seem to occur with increasing frequency and to cause increasing damages. In the case of extreme precipitation events, soil erosion plays a major role in provoking environmental as well as socio-economic damages. The rainfall-erosion relationship has received much attention (see e.g. Morgan 2005) but under field conditions there has been a strong focus on easily-measurable or widely-available parameters, in particular rainfall total and various intensities. The role of parameters like drop size distribution and measured kinetic energy is less well-studied.

The kinetic energy with which raindrops impact the soil surface and provoke compaction or detachment of soil particles depends on their velocity and mass or size. If a drop velocity can be assumed equal to the terminal velocity, it can be computed as a function of the drop size only and, consequently, so can the drop kinetic energy. A complicating factor, however, is that the shape of raindrops varies with their size, typically becoming non-spherical if their diameter exceeds 1 mm.

The first attempts at measuring the size of raindrops involved the use of filter paper and of trays with flour (Best, 1950). These two methods continue being used because they are cheap and straightforward to (Jayawardena and Rezaur, 2000). Nonetheless, there are now more technologically-advanced methods using disdrometers that are based on

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either the transfer of moment or on the interruption of laser beams. For a more exhaustive review of measuring methods, the reader is referred to van Dijk et al. (2002a).

Splash erosion has long been recognized as a key process in soil erosion, representing the first stage of erosion by water (Ellison, 1944). The impact of raindrops not only modifies the characteristics of the soil surface (Moss, 1991) but also causes the detachment of particles from the soil matrix and their subsequent re-deposition at short distances or export by surface runoff (Moss and Green, 1983). Erosion by rainsplash under field conditions has been relatively well-studied with respect to rainfall intensity, not only intensity itself but also derived variables (Van Dijk et al., 2002b). A good example of the latter is the rainfall erosivity factor of the Universal Soil Loss Equation (USLE; e.g. Wischmeier, 1978). The importance of the underlying characteristics and, in particular, kinetic energy and moment, and average drop size is generally recognized (Fornis et al., 2005). However, this type of information is not (yet) widely available from standard climate data sources nor it is collected in the bulk of the scientific studies.

Besides rainfall properties, also the characteristics of the soil itself and of its surface cover are important factors in determining splash erosion (Kinnell, 1991; Sharma et al., 1991; Legout et al., 2005; Morgan, 2005). Wildfires can substantially alter splash erosion through the effects of changes to the soil and of (partial) removal of the vegetation and litter layer, especially during the first one to two years following fire (Shakesby and Doerr, 2006). In a post-fire setting, however, these direct effects can be still be considerably enhanced by management practices like rip-ploughing. The present study is intended as a contribution to the EROSFIRE and EROSFIRE-II projects, which aim at predicting soil erosion hazard in recently burnt forest areas for the purpose of identifying adequate scenarios of post-fire land management. The study's original plan was to compare splash erosion for different fire severities but logging activities obliged to cancel the field experiments almost immediately,

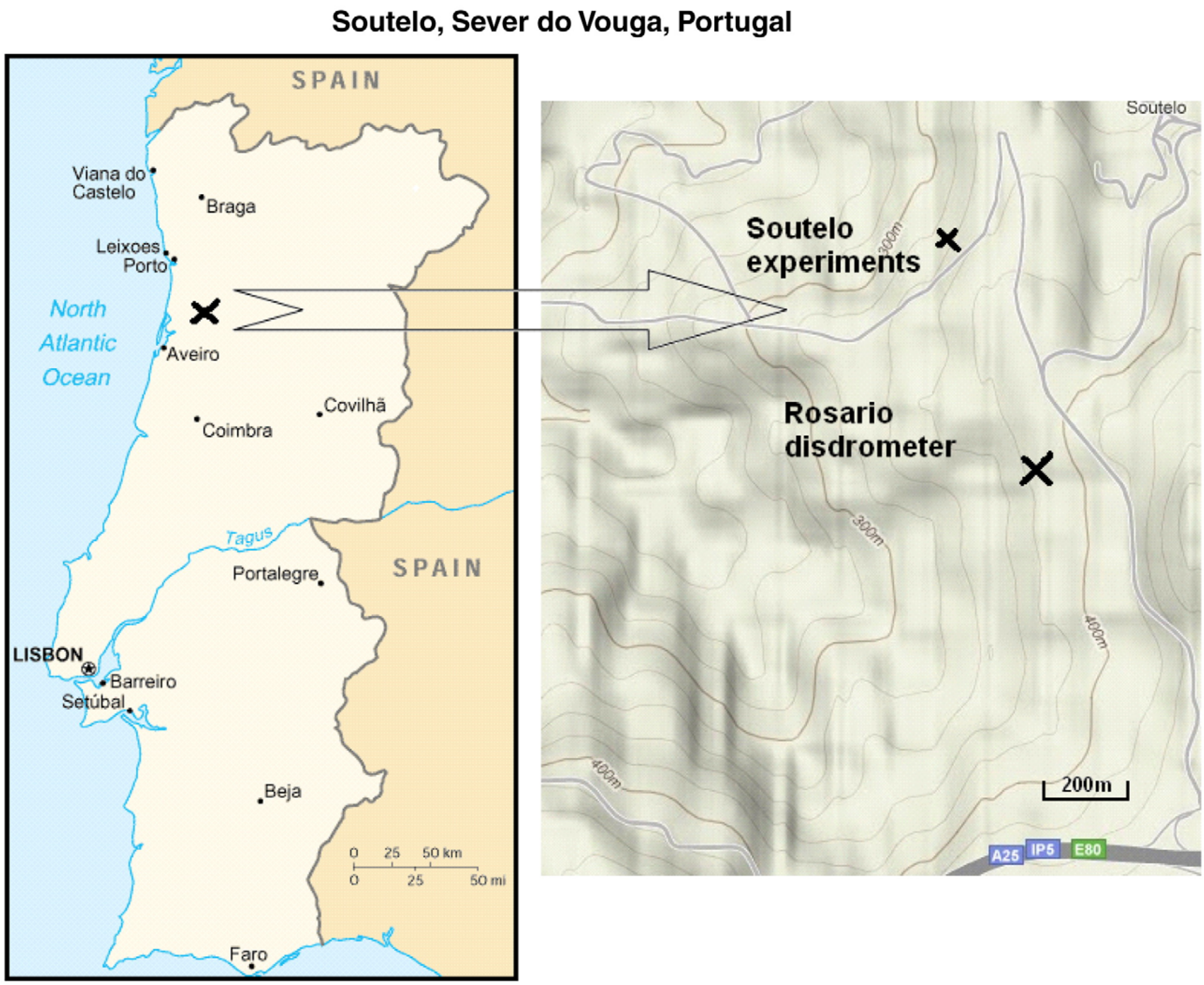

Fig. 1. Location of the study area in north-central Portugal, and of the study sites with the disdrometer and automated rain gauge ("Rosario disdrometer"), and the splash erosion devices ("Soutelo experiments").