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Using meshes to change the characteristics of simulated rainfall produced by spray nozzles

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Abstract

Rainfall simulators have been used for many years contributing to the understanding of soil and water conservation processes. Nevertheless, rainfall simulators' design and operation might be rather demanding for achieving specific rainfall intensity distributions and drop characteristics and are still open for improvement. This study explores the potential of combining spray nozzle simulators with meshes to change rainfall characteristics, namely drop properties (drop diameters and fall speeds). A rainfall simulator laboratory set-up was prepared that enabled the incorporation of different wire meshes beneath the spray nozzles. The tests conducted in this exploratory work included different types of spray nozzles, mesh materials (plastic and steel), square apertures and wire thicknesses, and positions of the meshes in relation to the nozzles. Rainfall intensity and drop size distribution and fall speed were analysed. Results showed that the meshes combined with nozzles increased the mean rainfall intensity on the 1 m^2 control plot below the nozzle and altered the rain drops' properties, by increasing the mass-weighted mean drop diameter, for example.

Key Words: Rainfall simulators, Spray nozzle, meshes, Drop characteristics

1 Introduction

Rainfall simulation is a common tool that has been widely used in studies related to soil erosion, nutrient and pollutant transport, water conservation and agricultural management practices. One of the main advantages of rainfall simulation is the possibility to generate and replicate rainfall with a specific intensity and duration (e.g. de Lima and Singh, 2003; Potter et al., 2006; de Lima et al., 2013). In laboratory controlled conditions, it is also possible to reduce the effects of the variability of temperature, humidity and wind, as experienced in the field (e.g. de Lima et al., 2003; Fister et al., 2012). Nevertheless, rainfall simulators' design is demanding, raising questions on rainfall distribution and intensity, drop characteristics, manpower required, energy availability, costs and transportability.

In the literature, one finds many studies that have used rainfall simulators. These include studies by Mutchler and Hermsmeier (1965), de Ploey (1981), Bowyer-Bower and Burt (1989), and de Lima et al. (2003, 2008). However, the rainfall simulators' drop properties and spatial intensity distribution is often not discussed (e.g. Lascelles et al., 2000; Ries et al., 2009) although some studies report on the mean drop size of the simulated rain (e.g. Arnaez et al., 2007; Marques et al., 2007). In natural rain, large mean drop sizes are associated with high rain intensities, but in simulated rain the relationship between drop size and intensity may be different. For example, Parsons and Stone (2006) reported simulated intensities ranging from 59 to 170 mm h^{-1}, but the median drop size remained constant at 1.2 mm.

Rain simulators can be classified according to the way they produce drops. The two most common types of

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simulators are: (i) non-pressurized rainfall simulators or drop-former simulators which drip water from hypodermic needles and capillary tubes (e.g. Munn and Huntington, 1976; Kamphorst, 1987; Abd Elbasit et al., 2010); (ii) pressurized rainfall simulators, such as spray nozzles (e.g. Meyer and McCune, 1958; Esteves et al., 2000).

Non-pressurized rainfall simulators are less used in the laboratory; but they are a convenient technique for places experiencing difficult access and limitations in water supply (e.g. Humphry et al., 2002). The well-known disadvantage in these simulators is that they produce a narrow range of drop sizes (e.g. Tossell et al., 1987) and a small drop fall speed. Some non-pressurized rainfall simulators include meshes below the drop formers in order to break up water drops into a distribution of drop sizes closer to that of natural rainfall and to randomize drop landing positions (e.g. Holden and Burt, 2002; Clarke and Walsh, 2007; Fernández-Gálvez et al., 2008).

Pressurized rainfall simulators have an important advantage over the non-pressurized simulators: drops do not rely on gravity to reach terminal velocity, but are sprayed under pressure. For example, the hydraulic spray nozzles, which are commonly used in scientific and technical experiments on soil and water conservation, operate by discharging the water under pressure through an exit orifice with a small diameter. This leads to an increase in water velocity, causing instability in the nozzle exit and subsequent breakup into small drops; typically a spray nozzle provides a broader range of drop sizes compared to non-pressurized simulators (e.g. Battany and Grismer, 2000). Moreover, drop properties and hence the entire simulated event will depend on the pressure applied, the flow rate, and the nozzle design (e.g. Kincaid, 1996; Cerdà et al., 1997; Erpul et al., 1998).

To our knowledge, meshes have been combined with drop-former simulators but not with nozzle type simulators. However, Schindler Wildhaber et al. (2012) recently described a "field hybrid simulator", and claimed that the performance of the simulator improved in relation to the mean drop size and kinetic energy when a mesh grid (aperture size of 2 mm × 1.7 mm) was fixed at a distance of 0.5 m under a spray nozzle.

The objective of this study was to further explore the effect of meshes on spray nozzle rain simulations, namely on rain intensity, drop size and drop fall speed. In particular, we are interested in the raindrop properties which are important for calculating rainfall erosivity. These properties depend on the design and operation of rainfall simulators.

2 Materials and methods

2.1 *Laboratory set-up*

Fig. 1 shows a schematic representation of the laboratory set-up used in this study. The main components are: the rainfall simulator which includes a downward-oriented spray nozzle operating in a static position; a

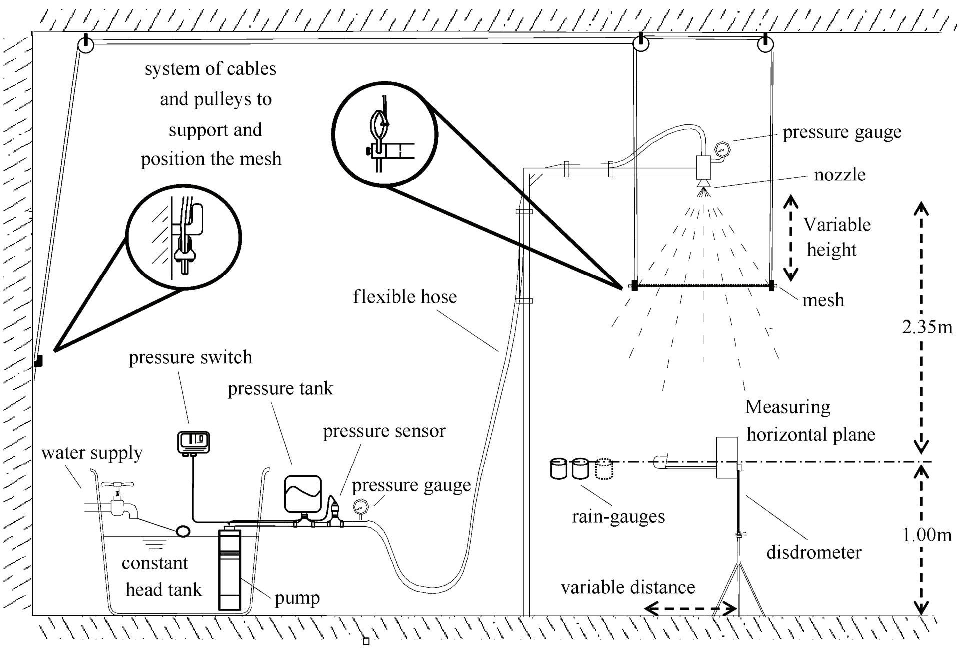

Fig. 1 Set-up of the laboratory experiments