Catena 156 (2017) 401–404

Contents lists available at ScienceDirect

Catena

journal homepage: www.elsevier.com/locate/catena

Comment on: Evaluation of kinetic energy and erosivity potential of simulated rainfall using laser precipitation monitor, by Meshesha et al. (2016)

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ARTICLE INFO

Keywords:
Drop size distribution
Kinetic energy
Rainfall simulator
Soil erosion

ABSTRACT

Characterization of simulated rainfall at macro- and micro-structural levels represents a major research task in order to realistically extrapolate laboratory results to the field scale. Different rainfall simulation systems produce different erosivity relationships. However, Meshesha et al. (2016) identified additional new sources of variation, which are poor simulator maintenance and the simulator's experimental settings, and showed that these factors may give rise to disagreements and conflicts in experimental results. Understanding raindrop generation under certain simulated conditions in the laboratory is key for attribution of simulated raindrops characteristics to different simulator designs. In this comment, issues related to the attribution of kinetic energy and drop size to rainfall simulator design are discussed, in order to shed further light on Meshesha et al.'s (2016) work, and its wider context.

1. Introduction

Evaluation of simulated rainfall in order to compare results from the laboratory to natural rainfall at the field scale is highly welcome, and is of clear interest to different experimental and applied disciplines. Our interest in the recent study on rainfall simulation by Meshesha et al. (2016) is based on (1) previous experience in using the simulator that has been applied in this study, and (2) the fact that the sensor used in this study represents one of the most sophisticated methodological approaches to evaluate rain microstructure and erosivity at experimental scales that can simulate real environmental conditions.

2. Attribution of Meshesha et al. (2016) results to rainfall simulator design

Meshesha et al.'s (2016) study used a dripper-type rainfall simulator located at the Arid Land Research Center, Tottori University, Japan. This is a high-performance rainfall simulator controlled by computer and able to mimic natural rainfall events in a form of fluctuating and fixed intensities of rainfall in an experimental setting. According to Wang and Pruppacher (1977), the simulator height is sufficient for 99% of the generated drops > 7 mm in diameter to reach their terminal velocity. The rainfall intensity of the system is controlled by a positive-displacement pump (piston pump). Increasing and decreasing the rainfall intensity is achieved by adjusting the pump rotational speed (number of revolutions per minute; rpm). The raindrops are generated using fixed size hypodermic needles connected to disc-type water distributors (Fig. 1).

However, the simulator has some limitations. The major limitation is that, to increase rainfall intensity, an increase in flow rate is needed, which increases the pressure at the hypodermic needle point (0.4 mm diameter) and leads to small droplets being generated. Thus, high-intensity rain events with large droplet sizes are not well captured in this experimental setup, even though such large droplets are found in nature (e.g., Brandt, 1989; Cerdà, 1997). For this reason, an oscillation mesh below the needles has been introduced to enhance the drop size distribution.

Considering these experimental limitations, the results presented by Meshesha et al. (2016) can be discussed in detail. The basis for this discussion is that Meshesha et al. (2016) used the same rainfall simulator equipment and the same experimental design as previous work by Abd Elbasit et al. (2010). However, Meshesha et al.'s (2016) results are different to those by Abd Elbasit et al. (2010). Here, we explore the reasons why.

The D_{50} data reported by Meshesha et al. (2016), their Table 1 show a linear increase in median drop size with increased flow rate (Fig. 2a)

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http://dx.doi.org/10.1016/j.catena.2017.04.021
Received 8 November 2016; Received in revised form 26 March 2017; Accepted 19 April 2017

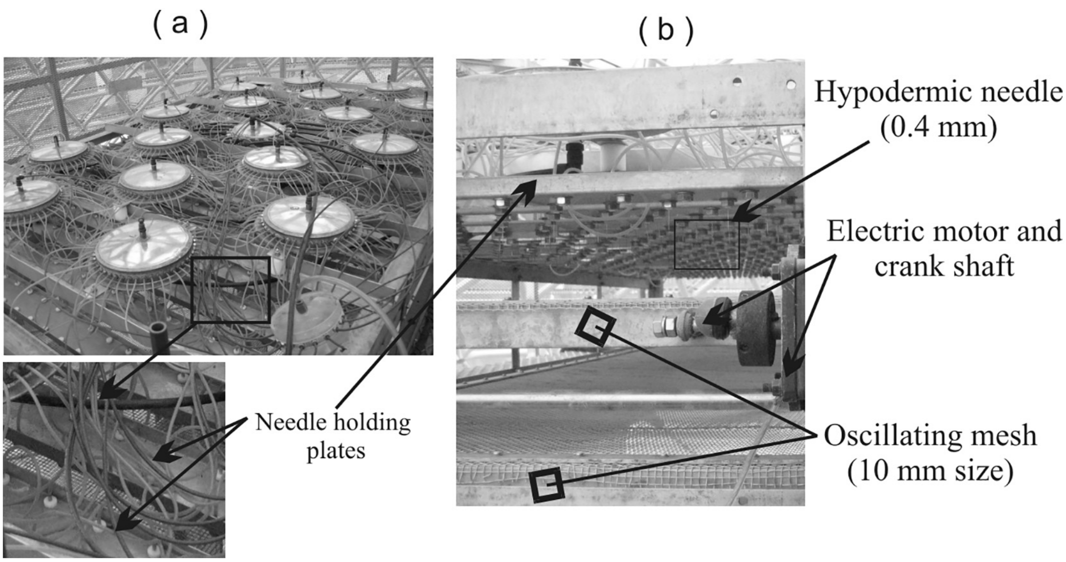

Fig. 1. Illustration of the experimental setup used by Meshesha et al. (2016). (a) Raindrop generation system and needles holding plates, and (b) hypodermic needles and oscillating screen.

and rainfall intensity (Fig. 2b). This relationship between rainfall intensity and median drop size is different to the power law relationship (Eq. (1)) that is commonly used, because individual raindrops cannot physically increase in size continuously due to hydrodynamic breakdown mechanisms. Thus the median drop size, after a certain threshold has been reached, will either stabilize at this level or decrease over time (due to collision and temporary coalescence breakdown processes). Although there is discussion on the validity of this power law relationship (e.g., Kostinski and Jameson, 1999), it can be characterized as:

$$D_{50} = \alpha\ R^{\beta} \tag{1}$$

where D_{50} is median drop size and R is rainfall intensity. The coefficients α and β are empirical factors related to rainfall type and environments. Under natural conditions, the value of α ranges between 0.8 and 1.28 and β ranges between 0.123 and 0.292 (van Dijk et al., 2002). However, there is still uncertainty on the physical processes within clouds that can affect raindrop size distributions, and the role of ambient environmental factors (e.g., Williams and Gage, 2009; Penide et al., 2013). Under simulated rainfall, changes in median drop size are mainly linked to the raindrop generation mechanism and to rainfall simulator design. For instance, pressurized rainfall simulators are not expected to generate large median drop sizes due to the fact that, to attain high intensity rainfall, an increase in the flow rate across the nozzle is needed, but which will in turn lead to smaller raindrop size ranges (Abd Elbasit et al., 2015).

Differences in droplet size and rainfall characteristics produced in the experiments reported in Meshesha et al. (2016) and Abd Elbasit et al. (2010) can be related to the following issues:

1) The characteristics of the rainfall simulator and its rainfall macro-structural parameters have been evaluated using a single data source (an optical disdrometer). The major issue is that all the rainfall parameters are calculated from the drop size distribution and raindrop speed measured by the optical sensor, and that it is not possible to cross-validate these values with another independent data source. In Abd Elbasit et al. (2010), the kinetic energy, rainfall depth and intensity, and drop size distribution were measured using separated sensors, and the net result was validated by the amount of sediment detachment.
2) The rainfall simulator used by Meshesha et al. (2016) was not recalibrated for uniformity and leakage. The fine hypodermic needles of the simulator can be easily blocked by algae, which affect the rainfall uniformity. Moreover, due to needle blockage, the

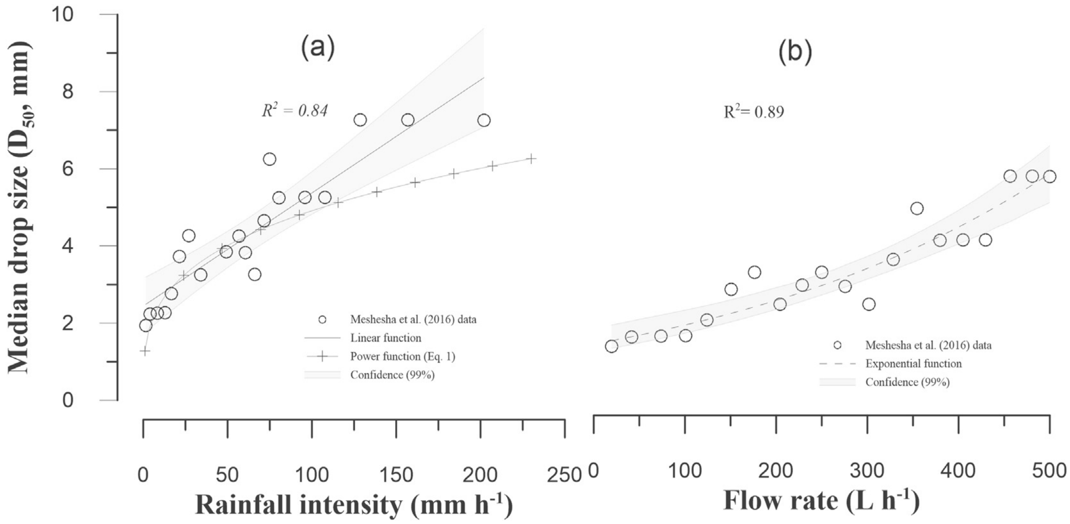

Fig. 2. Relationship between rainfall intensity and median drop size, based on Meshesha et al.'s (2016) published data (their Table 1).