Catena 165 (2018) 516–519

Contents lists available at ScienceDirect

Catena

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

Technical report of a rainfall temperature control system for rainfall simulators

Eyal Sachs, Pariente Sarah*

Laboratory of Geomorphology and Soil, Department of Geography and Environment, Bar-Ilan University, Ramat Gan, Israel

ARTICLE INFO

Keywords:
Erosion
Raindrop temperature control system
Rainfall simulator experiments
Runoff

ABSTRACT

Rainfall Simulators are widely used in studies on soil erosion. Most of the rainfall simulators use water with tap or ambiance temperature. However, previous studies showed that soil erosion may increase or decrease by up to three times while raindrops temperature varied from 2 °C to 20 °C. Therefore, it is of great importance to use a temperature control system in rainfall simulators.

This paper describes the design of a temperature control system suitable for a rotating disk rainfall simulator at the Soil and Geomorphology Laboratory in Bar-Ilan University.

The rain temperature is continually monitored by thermocouples, located very close to the disk. IR remote sensing results showed that the real temperature of the drops hitting on the ground surface differed from that measured with thermocouples by maximum 1° for the coldest simulated rain (2 °C), and −3° for the hottest one (35 °C), hence the continually monitoring temperature error is negligible.

1. Introduction

Rainfall Simulators are more and more used to study soil erosion processes, and the use of rainfall simulators is widely accepted (Iserloh et al., 2013; Lassu et al., 2015; Martínez-Murillo et al., 2013).

Raindrops temperature affects hydraulic conductivity (Constantz, 1982; Constantz and Murphy, 1991; Gao and Shao, 2015; Hopmans and Dane, 1986; Levy et al., 1989; Nimmo and Miller, 1986; Romero et al., 2001), soil structure stability (Blair, 2010; Bruce-Okine and Lal, 1975; Kemper and Koch, 1966) and raindrops impact, thus it may affect surface flow and soil erosion (Sachs and Sarah, 2017a, 2017b). The latter studies have found that soil erosion has changed threefold under different rainfall temperatures. This finding raises the importance of controlling and measuring rainfall temperature in simulated rain experiments.

Rainfall temperature significantly affects soil erosion, therefore it is necessary to control and measure rainfall temperature in rain simulation experiments. These have been neglected in previous studies. In recent years, we have conducted rainfall experiments at various water temperatures with a stationary rotating disk rainfall simulator system at the Soil and Geomorphology Laboratory in Bar-Ilan University. In these experiments, for the first time, we used a water temperature control facility. The present paper describes the design characteristics of the temperature control system of the above simulator. We hope that this detailed description will help other researchers in designing and constructing a temperature control system that will improve the features of the rain simulators. In this system, the rainfall temperature is continually monitored by thermocouples located very close to the disk. We asked how much this close to disk water temperature represents the temperature of the droplets while reaching the ground.

2. Materials, methods and results

2.1. The rainfall simulator

The rainfall simulator at the Soil and Geomorphology Laboratory in Bar-Ilan University comprises a rotating disk with a tilted nozzle. It is a non-portable simulator, based on the field simulator model built by Morin in Arizona (Cerda and Lavee, 1999; Morin and Cluff, 1980). The simulated rainfall is driven by 1.5 kW pump (Hmax = 25.5 m, Qmax = 500 l min^{-1}) using a Spraying Systems Fulljet 2H30 nuzzle, which was excentre rotated 10° from the vertical. The mean distance between the nozzle and the soil surface was 215 cm. The simulator reliably simulates the energy of natural precipitation (Morin and Cluff, 1980). The simulated rain had a Christiansen's uniformity coefficient (Christiansen, 1941) of 0.89. The rain intensity applied in the present experiments was 21 mm h^{-1}. Other properties of this simulator are described at the paper of Morin and Cluff (1980).

* Corresponding author.
E-mail address: Sarah.Pariente@biu.ac.il (P. Sarah).

https://doi.org/10.1016/j.catena.2018.03.006
Received 24 September 2017; Received in revised form 30 January 2018; Accepted 5 March 2018
Available online 10 March 2018
0341-8162/ © 2018 Elsevier B.V. All rights reserved.

2.2. Requirements

The requirements from the system were: 1. To supply water with a stable temperature as close as possible to the freezing point. Previous results showed that applying rainfall simulation experiments with water at temperature of 10 °C and extrapolating the results to lower temperature may lead to false conclusions (Sachs and Sarah, 2017a); 2. To supply hot water up to 35 °C; 3. To prevent impact of the temperature control system on the rainfall chemical composition. Technically the easiest way to design such a system is to install cupper pipe spiral inside the supply water reservoir of the rainfall simulator. In order to check if there is a significant dripping of cupper cations to the water, a 50 m cupper pipe spiral was immersed into a 150 l barrel with distilled water. The concentration of Cu^{++} ions in the water was measured with an atomic absorption spectrophotometer (Perkin-Elmer Model 560, Norwalk, USA), after 2 days and 30 days, and found to be 0.5 and 1 ppm, respectively. In order to check the effect of such concentration on soil chemical composition, 30 mm (90 min) of simulated rainfall water with cupper concentration of 1 ppm was applied to Rhodoxeralf clayey soil (Terra Rossa). The mean Cu^{++} concentration in the runoff and in the drainage water was 0.04–0.06 ppm, which means that almost all the Cu^{++} ions were trapped in the soil. One ppm of Cu^{++} is equal to 0.03 meq l^{-1}. This concentration can be ignored if the average accumulation of Cu^{++} is equally distributed in the soil section. But if we take into consideration the option that all the Cu^{++} ions are trapped in the upper millimeter of the soil, then, after 60 mm of sprinkling, the Cu^{++} concentration can reach 1.8 meq l^{-1}. This may affect the exchangeable sodium percentage (ESP), and thus it can't be ignored. Therefore, we preferred not to insert a cupper pipe into the rainfall simulator water barrel, and instead we used a polyethylene coated metal pipe, as describe below.

2.3. Preliminary check

A preliminary test was conducted in order to estimate the required power of the cooling system. The water supply barrel was filled with water in equilibrium with ice, and the temperature inside it was measured while applying rain for half an hour.

Linear regression between time and water temperature showed that heating caused by the pump and friction was 2300 kcal h^{-1}, equal to 9100 BTU h^{-1}. The water consumption of the rainfall simulator is 75 l h^{-1} (for rain intensity of 21 mm h^{-1}). Assuming that the difference between the tap temperature and the required temperature is 20 °C, then 1480 kcal h^{-1}, equal to 5850 BTU h^{-1}, are needed in order to compensate for this.

2.4. Design

The rain temperature control system comprises components as fallow: Two 17,000 BTU h^{-1} air-condition compression units; A Dotech model FX3D-dual temperature control unit, two 10 Ampere contactors, temperature sensor; A 50 m polyethylene coated metal pipe 16 mm in diameter, was inserted inside the 150 l water-storage barrel of the rainfall simulator, and connected to the compression units (Fig. 1). The cooling capacity declared by manufacturers of the compression units is suited for a temperature of 20 °C, while the efficiency dramatically decreases with temperature decrease. Therefore, we made some trials until we found that 35,000 BTU h^{-1} compression units are needed to keep a constant temperature of 2 °C while the simulator works. Less than a half of this power is needed to keep the water at 35 °C, because of two reasons: heat exchange systems are more efficient while heating than while cooling, and, the simulator pump contributes a lot of energy to the water, most of it is converted to heat. The reason for using two small compression units instead of one of 35,000 BTU h^{-1} was because we couldn't find such a unit without internal controlling circuits that dramatically reduced its effectivity. A 1 kW pump connected to 32 mm diameter plastic pipe, was used to circulate the water inside the barrel while achieving the temperature required to start an experiment, in order to prevent an ice development. One can use the rainfall simulator pump for the circulation, if the disk is switched to blocking position. In this case the high energy contribution of this pump will cause an increase in both temperature achieving time and energy consumption.

The controller was set to have a delay of 3 min before it connects to one unit, and of 4 min before it connects to the other one. In such setting, the two units do not rest simultaneously, so the water temperature is kept stable. A manual switch located on each of the compression units was used to switch its valve from cooling to heating.

2.5. Failed designs

In this section, we describe some failed trials that we made, in order to prevent others from doing them. We first cooled 1 m^3 water tank with a cupper pipe spiral. Automotive antifreeze liquid was added to the water to reduce its temperature below 0 °C. A plastic pipe, 300 m in length and 32 mm in diameter, was inserted into this tank and was connected to the simulator supply barrel with 1 kW circulating pump. In such a way, the simulator reservoir contained 300 l, half inside the barrel and half in the pipe. Unfortunately, we found that in order to keep water temperature at 2 °C while the simulator is working, the temperature of the water inside that pipe must be below 0 °C. This means that the water froze and caused the circulation to stop. A trial to circulate the antifreeze water inside the polyethylene coated metal pipes also failed, because the antifreeze water was much warmer than the air conditioning gas.

2.6. Temperature monitoring

Three thermocouples measured the water temperature inside the barrel at 1 s intervals and two thermocouples measured the water temperature close to the disk, to ensure that it did not vary throughout the experiment. The thermocouples were connected to CSI CR10X datalogger with AM416 multiplexer, and were calibrated with Brannan mercury thermometer.

2.7. Raindrops temperature while hitting surface

The thermocouples measure the temperature of the returned water from the disk to the barrel, very near to the disk. Yet after the raindrops left the disk toward the surface they can be affected by friction with air, by loss of latent heat due to evaporation, and by transformation of kinetic energy to heat. A Flir model ThermoVision 320 thermal camera was used to determine the difference between the water temperature measured by the thermocouples near the disk, and the raindrops temperature when hitting the surface, as described below.

2.7.1. Thermal camera calibration

Four factors affect the temperature measurement in the thermal infra-red range: emissivity, ambient temperature, relative humidity and distance of sensing. The emissivity of water is 0.96–0.98, of wet soil is 0.95 and dry soil is 0.92.

The thermal camera was calibrated by sensing water surface in a dish vs. two mercury thermometers. During the measurements, the water was mixed to prevent errors caused by a thermal stratification of the water, results from heat exchange between the water surface and the atmosphere and cooling of water surface because of latent heat loss.

2.7.2. Sensing raindrops temperature while hitting on the surface

Remote sensing with thermal camera or IR remote sensors, allows sensing only the droplet surface temperature but not its internal one. Therefore, some experiments have been made to sense the temperature of the drop while it smashes on the surface. Several factors may affect the temperature of the drops when it smashes: heat transfer to the

Download English Version:

https://daneshyari.com/en/article/8893631

Download Persian Version:

https://daneshyari.com/article/8893631

Daneshyari.com