Investigating runoff, infiltration and sediment discharge using mini portable pressure head type rainfall simulator

小型圧力水頭型降雨装置を用いた表面流出，浸透および土砂流出の解析

JIRARATCHWARO Charoen[1], SUZUKI Yutaka[1], SAHO Norihide[1],
SIAW Onwona-Agyeman[1] and WATANABE Hirozumi[1]
ジララーッチャワロー　ジャレン[1]，鈴木豊[1]，佐保典英[1]，
スィアウ　オンウォナーアジマン[1]，渡邊裕純[1]

Introduction：Rainfall simulator is a tool which has the ability to take many measurements within a short time instead of experiments under natural rain. The desirable features of a rainfall simulator are (a) accurate reproduction of natural rainfall drop sizes and energies; (b) nearly continuous, uniform application over an area of 1 m^2 or larger; (c) the ability to apply rainfall of varying durations and intensities of interest; and (d) portability and low cost.

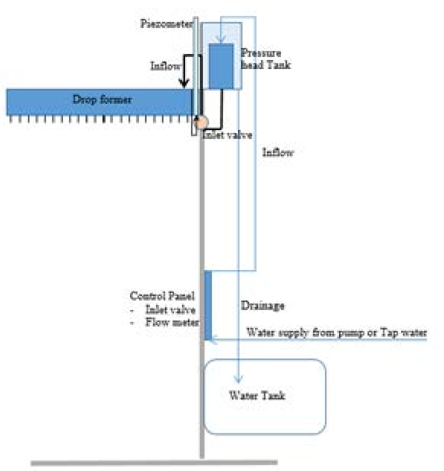

Fig. 1 Diagram of the Mini Portable Pressure Head type rainfall simulator (MPPH)

Surface runoff is water from rainfall, snowmelt or other sources that flows over the land surface. It occurs when soil moisture exceeds a soil's infiltration capacity and the excess rainfall turns into overland flow. Soil particles transported by runoff water are referred to as sediment and become a part of the erosion process.

The objectives of this study were to investigate the runoff, infiltration and sediment discharge using the mini portable pressure head type rainfall simulator under laboratory conditions.

Materials and methods： The Mini Portable Pressure Head type rainfall simulator (MPPH) having a variable pressure head unit was used in this experiment (**Fig. 1**). Its other components consist of the frame, drop former, needles and water supply system. The catchment area of the experimental lysimeter surface was 0.33 m by 0.48 m (0.1584 m^2). The calibration was performed by using 9 of 200 ml beakers placed 1.85 m below the drop former for 2 minutes. The rainfall intensities were calculated from the amount of water collected. The randomized distribution of raindrop was determined by uniformity coefficient developed by Christiansen. Amounts of raindrop water were measured for the calculation of uniformity coefficient.

The study of runoff, sediment and infiltration using the MPPH rainfall simulator used Andosol soil which brought from the field of Tokyo University of Agriculture and Technology, Koganei campus. The soil was examined for the field capacity. The field soil sample was transferred to a laboratory and packed in lysimeter. The soil packing in the lysimeter was performed following procedure. First, 2 cm of glass beads (diameter of 1.5 mm to 2.5 mm) layer covered with 500 micron opening stainless mesh (33 cm x 48 cm) was set on the bottom of the lysimeter. Next, 1 cm thick soil layer, then 8 layers of 1.5 cm thick soil layers were packed layer by layer. During the soil packing, soil layers were compressed to achieve the designed dry bulk

所属：[1] 東京農工大学；Affiliation：[1]Tokyo University of Agriculture and Technology
Key words：*Rainfall simulator, Runoff, Infiltration, Sediment, Soil erosion, Andosol soil*

density of 0.58 g/cm^3 which was measured in the field. The rainfall intensity of 70 mm/hr was manually calibrated by collected amount of water in the plastic tray in 2 minutes. The runoff and infiltration outflow samples were collected by using glass bottles placed under the runoff collector and infiltration outflow outlet of lysimeter, respectively. The time step for replacing the new bottle was every 10 minutes for 100 minutes after the runoff initiated. The weights of all samples were measured after sampling. The runoff samples was filtered to separate the sediment from the runoff water by using the Whatman glass microfiber filter ϕ60mm with pore size 1.6 micrometer. The mass of sediment in the runoff water samples were recorded.

Results and discussion : The raindrop diameter was 2.86 mm. The rain drop velocity for the MPPH rainfall simulator obtained graphically from van Boxel (1998) was about 5.2 m/s. The calibration showed the MPPH rainfall simulator had ability to produce rainfall intensity from 50 mm/hr to 110 mm/hr with R^2 of 0.997 The CU values showed that the uniformities of rainfall distribution were increased from 64.8% of without fan to 84.3% of with fans

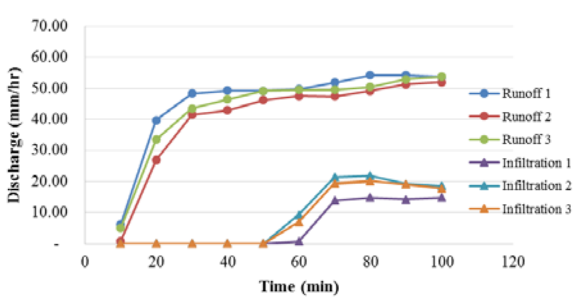

Fig. 2 Results of runoff and Infiltration discharge

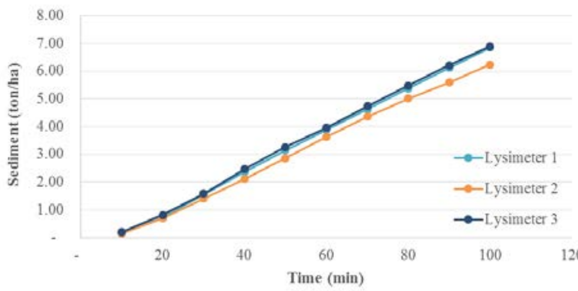

Fig. 3 Results of cumulative sediment

The trend of runoff rate increased rapidly until 20 minutes and gradually became constant around 52 mm/hr after 30 minutes. In this experiment, the infiltration outflow occurred at 50 minutes after the rainfall simulation was started. After, the average of infiltration rate gradually increased to 17 mm/hr (40.8 cm/day) and became relatively stable after 70 minutes. The total average discharge was about 69 mm/hr while the rainfall intensity was 70mm/hr. The average value of cumulative sediment losses which showed in **Fig. 3** was about 3.81 ton/ha/hr, while Khonesavanh et al., (2016) reported that the cumulative sediment loss from rainfall simulator experiment for rainfall intensity of 70 mm/hr was about 0.49 kg/m^2 (4.9 ton/ha/hr)

Conclusions : For the rainfall-runoff simulation, the average time for runoff initiation was at about 98 seconds after the rainfall simulation started. The trend of runoff rate increased rapidly until 20 minutes and gradually became constant around 52 mm/hr after 30 minutes. The infiltration outflow occurred at 50 minutes after the rainfall simulation was started. The average of infiltration rate gradually increased to 17 mm/hr and became relatively stable after 70 minutes. The average cumulative sediment loss was about 3.81 ton/ha/hr.

Finally, the MPPH rainfall simulator demonstrated the capabilities to use in rainfall-runoff experiments and produced useful data sets for runoff, infiltration and sediment discharge.

Reference: Van Boxel, J. (1998): Numerical model for the fall speed of raindrops in a rainfall simulator, *I.C.E. Special Report*, **1**, 77-85.

Khonesavanh, V., Noriyuki, Y., Ishikura, R. (2016): Rainfall-induced soil erosion and sediment sizes of a residual soil under 1D and 2D rainfall experiments, *Procedia - Social and Behavioral Sciences*, **218**, 171 – 180