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"Rainfall Simulations"

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RAINFALL SIMULATORS

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Rainfall simulators are instruments designed to apply water simulating natural rainstorms. They are used as research tools for many types of soil erosion and hydrologic studies, both under field and laboratory conditions. Much of the erosion research in the past fifty years has been done with rainfall simulators.

Infiltration of rainfall into the soil is one of the most important processes in hydrology, and the rainfall simulation type infiltrometers are the most useful and common means to measure this process. The best application of these measurements is the estimation of the parameters required in presently available physically-based hydrology models. The simple ponded-conditions ring infiltrometer is not an appropriate tool for that purpose.

Rainfall simulators used in estimating infiltration parameters must be selected on the basis of the input needed by the models. It is required to assess the nature, or at least the relative importance of precipitation characteristics-soil-cover interactions.

The research with rainfall simulators is more controlled, more adaptable, more efficient (from the standpoint of time and personnel), and provides more rapid results than research done under natural rainfall. Results from field plots relying on natural rainfall generally require many years to be conclusive, due to the variability of rainfall and soil conditions. Natural rainfall plots are also costly to establish and to operate.

The results obtained with simulated rainstorms would be more or less reliable depending on the proper simulation of rainfall characteristics, and if the results are interpreted taking into consideration the limitations of such simulation. The main disadvantages or limitations of the rainfall simulators may be in some cases the cost of the equipment, the small area covered, and the differences with natural rainfall in drop-size distribution, terminal velocity of drops, and rainfall intensity variation during a storm.

Rainfall simulators have different devices for forming raindrops, and for reaching energy levels and intensities simulating natural conditions. The size varies from small laboratory devices to simulators for field use covering more than one hundred square meters.

The simulators for field use are generally portable, and have a supply source of water, and cover a defined field plot. Their sprinkling or dropping systems have various degrees of control over water application rates and/or amounts. The field plots include devices for collecting and measuring the output.

The major techniques used to produce simulated raindrops can be grouped in two broad categories:

1) Those involving nozzles from which water is forced at a significant velocity by pressure.

The nozzles range from simple shower heads, and rotating irrigation sprinklers, to nozzles specifically designed for rainfall simulation. The higher intensities are reached pointing spray nozzles downward. Reduced intensities are reached where the spray is directed upward or horizontally, or by covering a much larger area than covered when stationary, or by intercepting part of the spray beneath the nozzles.

The rainfall simulators with nozzles have a much wider drop size distribution, but lower control of drop size and intensity than the drip type rainfall simulators. The drop size generally increases with larger nozzle orifices, and decreases with larger pressures.

2) Those where drips form and fall from a tip, starting at essentially zero velocity. The drops are formed in different ways, including small pieces of yarn hanging through holes on the bottom of a water container, polyethilene or glass capillary tubes, hypodermic needles, brass tubes, pieces of wire inside plastic pipes, etc.

Drip type rainfall simulators generally have a limited range of drop sizes and often consist of only one size. Successive drops that form on a tip are generally identical in size, although different types and sizes of tips produce different sized drips, usually between 2 and 5 mm diameter. Rate of drop formation is controlled by the length and diameter of tubes, or by the water level in the water container above the holes.

Since the drops begin their fall with no velocity, the drop former must be located quite high above the impact surface to reach near the drop's terminal velocity. The drip method is very difficult to use on areas larger than a few square meters. Intensity is controlled by drop size, rate of drop formation and space within drop formers. When the pressure on the water source to the drop former can be varied, flow control of resultant intensities can often be achieved over rather wide ranges without varying the number or size of the drop formers.

Different rainfall simulators have different characteristics because the research goals are different. Each researcher must identify those characteristics of greatest importance for his research situation. Given the fact that the nozzle or drop forming device will not give a complete simulation of natural rainfall, choices must be made among the rainfall parameters to simulate depending upon the nature of the research. Mean drop size, impact velocity, intensity and uniformity of coverage are generally the criteria used in the design or selection of simulators for a particular research. Parameters, such as Kinetic energy per unit rainfall, have been developed using those basic parameters. Since the most runoff is usually associated with high-intensity storms, most simulators have been designed to apply water at relatively high intensities.

Impact velocity, drop size and intensity are not independent of each other. In nature the three are interrelated in a complex manner. In simulation, reduction of intensity is reached through intermittent or reduced application, but neither the impact velocity nor the drop-size distribution is reduced at lower intensities as would occur in natural rainfall.

The limitations of rainfall simulators must be recognized and considered when designing experiments and analyzing and interpreting results. Although simulation should not be considered the panacea for all research in runoff, erosion and infiltration, in many cases there are no alternatives to rainfall simulation to the demand of rapid answers, when and where they are needed. The advantage of using rainfall simulators to obtain a large variety of data in a relatively short time and the value of these data usually far outwweigh any of the disadvantages or limitations. Good, usable data have become a critical need in many research required for implementation of soil and water conservation activities. As this need intensifies, rainfall simulators have to be used to obtain needed data. Therefore, simulated rainfall will probably grow in importance for future hydrologic and erosion research.

Bibliography

MEYER, L.D. 1988. Rainfall simulators for soil conservation research. In (R. Lal, ed.). Soil Erosion Research Methods. 75 - 95. SNCS - ISSS. Ankerry (U.S.A.)

NACCI, S. and PLA SENTIS, I. 1991. Tecnicas y equipos desarrollados en el pais para evaluar propiedades fisicas de los suelos. FONAIAP. Serie B, No.17. Maracay (Venezuela)

PLA SENTIS, I. 1981. Simuladores de lluvia para el estudio de relaciones suelo-agua bajo agricultura de secano en los tropicos. Rev. Fac. Agron. XII (1-2): 81 - 93. Maracay (Venezuela)

USDA - ARM - W. 1979. Rainfall Simulator Workshop Proc. Tucson (U.S.A.)