Proceedings of the

Rainfall Simulator Workshop

Tucson, Arizona

March 7-9, 1979

U.S. Department of Agriculture
Science and Education Administration
Agricultural Reviews and Manuals • ARM-W-10/July 1979

INFILTRATION CONTROL RESEARCH AS EXPEDITED BY RAINFALL AND RAINWATER SIMULATION TECHNIQUES

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This is a brief summary of an ongoing research program directed to developing principles and practices for controlling infiltration for the purpose of increasing and stabilizing crop production. Research utility of rainfall and rainwater simulation techniques is briefly discussed.

The research results reported herein represent minor extensions of the experimental works of Free et al. (1948), Duley and Kelly (1939), Kostiakov (1932), Gardner (1962), and Bertrand and Parr (1960), and minor additions to Darcy-based flow theory as developed and described by Klute (1973), Philip (1969), and Childs (1969).

Locations Studied

Infiltration research was initiated in Wisconsin in the early sixties and later conducted in Montana, Nevada, and Arizona. Plant-sized infiltration systems were studied, since the prime objective of the research was to gain control of infiltration to, in turn, improve the crop plant's microhydrologic and microclimatic environment.

Principles Developed

First, an attempt was made to understand the *natural infiltration system* of the crop plant through an extensive literature review. This involved compilation and organization of a large number of infiltration facts, many of which seemed to be contradictory. After collecting some infiltration data myself, these facts were synthesized into a general principle called the *two-flow system* concept of infiltration (Dixon, 1966). This concept postulates that infiltration involves the flow of air and water in two interacting flow systems (namely, the *channel* system and *capillary* system), and that soil surface conditions control the infiltration contribution of the channel system. After collecting some more data in Montana, the two-flow system concept was refined slightly and renamed the *channel system* concept (Dixon, 1971; Dixon and Peterson, 1971). This concept holds that the typical soil contains a large-pore system, and that microroughness and macroporosity of the soil surface regulate flow of air and water in this system during an infiltration event.

The channel system concept was further refined in Nevada, and then referred to as the *air-earth interface* (AEI) concept (Dixon, 1972). This concept

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states that the *microroughness and macroporosity of the air-earth interface control infiltration by regulating flow of water and displaced soil air in underlying macropore and micropore systems*. Thus, the *AEI* infiltration concept describes the influence of two physical conditions on the flow of two fluids in two subsystems of interconnected soil pores.

The preceding three concepts for controlling water infiltration differ primarily in their emphasis or in the frame of reference from which infiltration mechanisms are described. These concepts represent an evolution, progressing from a basic understanding of plant-sized infiltration systems to practical control of infiltration through soil surface management (Dixon, 1975a).

Development and refinement of infiltration control theory required use of rainfall and rainwater simulators to provide some of the conditions experienced by a natural system during the course of an infiltration event (Bertrand and Parr, 1960; Dixon and Peterson, 1964 and 1968). Sometimes these simulators were used in combination to isolate various components of the AEI infiltration system (Dixon, 1966).

In Wisconsin, the infiltration contribution of the macropore system was isolated by using sprinkling and flooding infiltrometers in side-by-side runs. This contribution was also isolated by sprinkling water onto soil surfaces with and without either organic or simulated mulches (window screen) to absorb water drop impact (Dixon, 1966).

In Nevada, the soil air pressure effect was isolated by using a *border-irrigation infiltrometer* in runs made before and during actual border irrigation (Dixon and Linden, 1972). This device is capable of measuring infiltration during overland or channel flows of irrigation waters and rainwaters which produce up to 30 cm of head.

The border-irrigation infiltrometer led to the development of the *effective surface head* (ESH) concept which states that ESH is the hydraulic manifestation (or hydraulic equivalent) of surface microroughness and macroporosity with ESH defined as the surface water pressure head minus the soil air pressure head (Dixon, 1974).

The ESH concept in turn led to the invention of the *closed-top infiltrometer* which is designed to produce a realistic range of effective surface heads surrounding zero or the ambient atmospheric pressure. This infiltrometer is useful in isolating the infiltration effect of soil air pressure and the infiltration contribution of the macropore system (Dixon, 1975b). Not only the rate, but also the route of infiltrating water was determined (as a function of ESH) by adding a readily adsorbed dye to the water within a modified closed-top infiltrometer (Linden and Dixon, 1976).

The principle of the closed-top infiltrometer is presently being utilized in the development of a sprinkling infiltrometer that can simulate realistic soil air pressures such as would be produced by intense summer rains on sloping land. A *natural rainfall* infiltrometer is also being developed which utilizes some of the components of the modified Purdue sprinkling infiltrometer. This new infiltrometer should help evaluate data from the rainfall, rainwater, and soil air pressure simulating devices which were discussed previously.

Kostiakov's equation (Kostiakov, 1932), $I_v = AT^B$, has been re-interpreted in light of the AEI concept (Dixon, 1976, 1977a, 1978b; Dixon, et al. 1978; Dixon and Simanton, 1979). Kostiakov's equation is shown to be a general infiltration formulation with the equations of Darcy (1856), Ostashev (1936), and Philip (1957) representing special cases. Parameters A and B are shown to be functions of the microroughness-macroporosity parameter or its hydraulic equivalent, effective surface head. Coefficient A may be viewed as an infiltration capacity parameter, whereas exponent B is a parameter reflecting the rate of infiltration abatement.

To expedite fitting of 2-parameter infiltration equations to sprinkling infiltrometer data, an overland flow tube is used to introduce massive slugs of water for rapid runoff induction at the beginning of the infiltration run.

Practice Developed

Recently in Tucson, a new land treatment method and a new machine (called *land imprinting* and the *land imprinter,* respectively) have been developed for practical application of the AEI-ESH concept (Dixon, 1977b and 1978a; and Dixon and Simanton, 1977). This machine, through its mechanical action and the ensuing biotic activities, converts a microsmooth microporous AEI with a negative ESH to a microrough macroporous surface with a positive ESH.

Utility Suggested

Since the microrough and macroporous surface can infiltrate most of the rainwater from a 100-year storm (Dixon et al. 1978), imprinting can be effective in holding soil and water resources in place to increase and stabilize crop production to, in turn, meet present-day needs for food, feed, fodder, fiber, fuel, and fertilizer; while at the same time be effective in improving land resources for even greater productive capacity in the future.

Also, since microsmooth and microporous surfaces shed most of the rainwater from a 100-year storm (Dixon et al. 1978), thereby directly contributing to increased aridity of the crop plant's environment (and indirectly through erosional loss of soil resources), land imprinting has the potential for arresting and reversing world-wide desertification or man-induced degradation of land resources. Desertification is estimated to annually cost the world 16 billion dollars in lost agricultural production, and is expected to reduce the arable land area by one-third by the year 2000, at which time world food needs will have doubled (Biswas, 1978).

Research Planned

Future research directions will be steered by the progress cited above. Some general and specific research objectives to be pursued are:

(1) To evaluate ESH under natural rainfall on sloping and flat land areas.
(2) To relate plant litter to ESH and the microroughness-macroporosity parameter.
(3) To determine the microclimatic, microhydrologic, and biotic impacts of land imprinting.
(4) To improve imprint geometries for successful crop stand establishment under adverse edaphic and climatic conditions.
(5) To evaluate land imprint seeding as a method for arresting and reversing desertification.

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