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FOREWORD

The workshop objective was to review briefly the state of the art regarding knowledge of the infiltration mechanism and to begin development of a SEA research plan to expand that knowledge. Participants were asked to prepare short state-of-the-art papers relating to various aspects of infiltration. Part I presents these papers. Part II will present results of the planning task, which is still in progress at this time.

The papers present views of the individual authors and not necessarily those of the U.S. Department of Agriculture. Each paper is brief, but they provide a comprehensive overview of infiltration knowledge today and contain lists of references for readers interested in expanding their knowledge further. Copies are available from

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INFILTRATION EFFECTS OF SOIL SURFACE CONDITIONS

R. M. Dixon

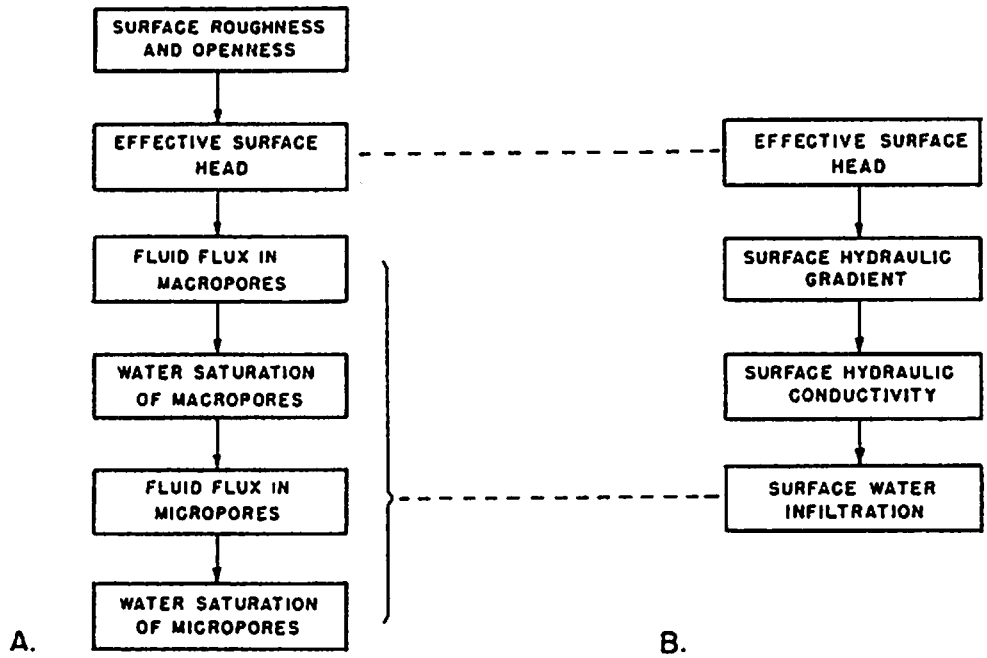
Infiltration literature contains contrasting views on the physical mechanisms controlling water infiltration into soils (Swartzendruber and Hillel, 1973). Field experimentalists such as Duley and Kelly (1939), Horton (1940), Holtan (1961), and Dixon (1966) have argued that infiltration is controlled at the soil surface, whereas theorists (Philip, 1969; Bear, 1972) have maintained that infiltration is controlled by measurable hydraulic characteristics of the soil profile. Dixon (1977) has noted that these contrasting views are not contradictory but rather are complementary. Furthermore, the surface control concepts represent valuable extensions of classical Darcy-based infiltration theory. Physical properties of the soil surface can control the transmission characteristics of the soil profile, and soil profile conditions often manifest themselves at the soil surface. The view held by Childs (1969) that infiltration is a function of hydraulic conductivity and hydraulic gradient at the immediate soil surface also seems to reconcile the contrasting views about infiltration control.

The historical development of these contrasting views is understandable, since theorists have largely neglected the infiltration role of surface conditions through their simplifying assumptions. Laboratory soils used in testing this theory commonly possess unrealistic pore space geometries, unrealistic initial conditions, and unrealistic upper and lower boundary conditions. Although such experiments have, at times, verified theory, they have contributed less than might be expected to the understanding of natural infiltration processes because the laboratory soil column models field soils very poorly. Unfortunately, the physical significance of Darcy-based infiltration theory is limited to highly idealized laboratory soils wherein the "soil surface" is usually a stable, horizontal, biologically inert, microporous plane. Such a surface, if found in the field, would indicate serious mismanagement of the land. Such mismanagement often causes rapid deterioration (often irreversible) of soil and water resources.

Field experimentalists have observed water infiltrating into natural surfaces and have been impressed with the complexity of this unique and dynamic interface. The zone immediately surrounding the air-earth interface is the most active life zone, by far, in the biosphere, being unsurpassed both in kinds and numbers of plants and animals (Dixon, 1971). These organisms profoundly influence surface microroughness, surface macroporosity, soil surface aggregation, and the water stability of soil aggregates. Although clean tillage practices may leave a surface that approaches the laboratory "ideal," modern tillage practices leave surfaces that are rough, macroporous and often covered with plant residues which feed a wide diversity of soil organisms. The smooth microporous surface produced by clean tillage in croplands often infiltrates water only 1/10 as fast as the rough macroporous surface produced by modern minimum and no-tillage practices. Overgrazing and low or no grazing in pasture lands have effects on surface conditions and water infiltration analogous to that of cropland tillage. The same can be said for forest lands with no litter and abundant tree litter at the air-earth interface. The

rough open (or litter covered) interface will infiltrate most of a 1-hour, 50-year, maximum intensity storm; whereas the smooth closed (or bare) surface sheds most of the same storm (Dixon, 1977; Hershfield, 1961). This means that land management can have a profound effect on watershed hydrology.

The air-earth interface (AEI) concept (Dixon, 1977) describes the mechanisms through which soil surface conditions control the hydraulic characteristics of the soil profile (see block diagram below).



A: Mechanisms by which surface roughness and openness control surface water transmission into a soil and subsequent storage of this water within soil pores. B: Mechanism by which effective surface head controls infiltration.

The two interrelated and interacting soil properties--surface microroughness and macroporosity--are singled out as being principally responsible for infiltration control. According to the AEI concept, these two surface conditions control infiltration by regulating the flow of air and water in underlying macropore and micropore systems. They also control the effective surface head which is defined as the ponded water depth minus the soil air pressure head (Dixon, 1975).

Satisfactory methods for directly characterizing surface microroughness and surface macroporosity for the purpose of infiltration control are not yet available. Some progress has been made in characterizing the microroughnesses associated with various tillage practices (Burwell et al., 1963). The author has tried various visual approaches to characterizing surface macroporosity. Surface macroporosity can probably be measured indirectly as the air permeability of a soil surface wherein the micropore space is water-saturated. The interacting effects of surface microroughness and macroporosity

can probably be measured as effective surface head and as mass or percent cover of plant litter. Litter would also provide a measure of the stability, equilibrium level, and generation rates of these two surface conditions.

CRITICAL RESEARCH NEEDS

Methods need to be developed or refined, or both, for characterizing surface microroughness, surface macroporosity, plant litter, and effective surface head. Since these infiltration parameters are profoundly influenced by tillage and cropping practices, they should be spatiotemporally quantified for each major land management system. Such quantification will expedite the refinement of land management systems for better protection and more efficient use of soil and water resources in crop production. Natural relationships that need to be researched include:

1. Rainwater infiltration versus effective surface head, surface microroughness and macroporosity, and plant litter.
2. Plant litter versus effective surface head and surface microroughness and macroporosity.
3. Plant litter versus populations of small soil animals, fungi, actinomycetes, and bacteria.
4. Plant litter versus macropore geometry near the soil surface.
5. Plant litter versus soil structure water stability at the soil surface.
6. Stability of microroughness versus tillage implement and surface plant residue.
7. Development of populations of soil organisms, surface macroporosity, surface microroughness versus time elapsed after mulching a bare smooth microporous surface.
8. Hydrologic behavior of microwatersheds versus tillage implement used in creating the microwatershed and elapsed time. Aspects of hydrologic behavior should include infiltration, runoff, erosion and sedimentation; and wind velocity, relative humidity, soil temperature, and soil surface evaporation. The effects of vegetative growth in seedbeds on these hydrologic parameters should be studied as a function of elapsed time.
9. Hydrologic behavior of microwatersheds formed by land imprinting rollers versus those formed by other tillage implements (Dixon and Simanton, 1977).
10. Magnitude of parameters in Kostiakov's equation (Kostiakov, 1932) versus effective surface head, plant litter, surface microroughnesses, surface macroporosity, and elapsed time after imposing surface treatment.

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