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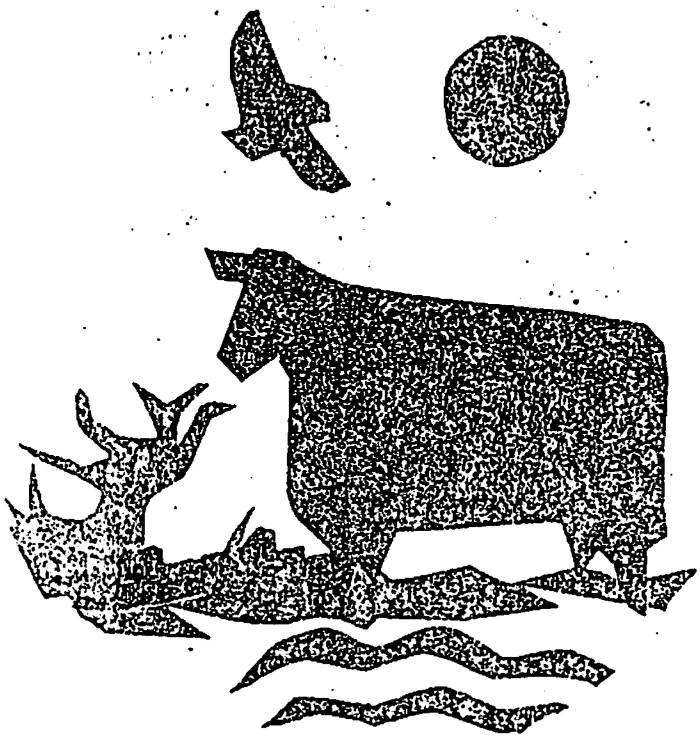
ABSTRACTS
First International Rangeland Congress



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SOCIETY FOR RANGE MANAGEMENT

western United States. Moisture-retention capabilities of soils can be determined from measurements of moisture contents and related moisture-retention forces. The moisture-retention characteristics of soils can be described in terms of surface available to adsorb water, number of molecular layers of water adsorbed or depleted, and related retention forces. With this information the force exerted by vegetation per unit of water depleted from storage can be determined. Measurement of differences in volume weight of soils with increasing depth facilitates computations of water depths that are stored in and taken from the solum. Void capacities, computed from volume weights, indicate maximum quantities of water stored. The actual size of drainable voids determines the rate of flow. The energy requirements, quantities of water available, and seasonal precipitation patterns have considerable influence on what species of vegetation occur in various range habitats.

Water Infiltration Control on Rangelands: Principles and Practices.

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The rate and route of water infiltration into rangeland soils depends on the two interacting and interrelated soil surface properties: microroughness and macroporosity. These two surface conditions contol infiltration by regulating the flow of air and water in soil micropore and macropore systems. Where the surface is rough and macroporous, rainwater penetrates the soil rapidly via the relatively short, straight, broad paths of the macropore system; but where the surface is smooth and microporous, water penetrates the soil slowly via the relatively long, narrow, tortuous paths of the micropore system. The rough macroporous surface can usually absorb water about 10 times faster than the smooth microporous surface. Consequently, a rough-open surface will absorb most of the rainwater from a 50-year maximum intensity thunderstorm; whereas a smooth-closed surface will shed most of this water. If rough-open and smooth-closed surfaces are imposed and maintained for several years, the infiltration may approach two orders of magnitude. The rough-open and smooth-closed surface conditions occur naturally and often side by side in rangelands. Grass or litter covered areas exhibit the rough open condition; but the interspersed bare land areas possess the smooth microporous surface. Rangeland management practices should be directed to controlling surface microroughness and macroporosity for better protection and use of soil and water resources in forage production.

Effect of Contour Furrows on the Soil Moisture Regime of a Hard Eroded Ridge at Cobar New South Wales, Australia.

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The ridges of the Cobar Pediplain have been severely eroded and produce only small quantities of pasture, much of which is ephemeral or inedible.

Recent studies have shown that the main reasons these rangelands have not responded to 11 years of exclosure from domestic animals is lack of moisture penetration, and hence an unfavourable soil moisture regime. Untreated areas had moisture tensions less than 15 bars for 20 days and 11 days of a 250-day monitoring period at 5 cm and 10 cm soil depths, respectively; whereas at various positions in and adjacent to contour mouldboard plough furrows, moisture content was above this level for 109 to 179 days at 5 cm depth and 150 to 250 days at 10 cm depth.

Rainfall of 39 mm was required to reduce moisture tension at both depths of the untreated (inter-furrow) soil below 15 bars. The reasons for lack of moisture penetration are low infiltration rates due to high surface bulk density and formation of an algae-covered surface seal. After contour furrowing, prolific natural reseeding gradually occurs in and adjacent to furrow lines. Vegetation has become established up to 2.4 m uphill and 2.8 m downhill from furrow lines, whilst the remainder of the inter-furrow areas is still bare but for a few plants of grey copper burr (Bassia diacantha) after 11 years.

Sediment Yields of Rangeland Watersheds.

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The rangelands of the Southwestern United States have deteriorated in this century primarily because of climatic pressure and misuse by man. Rangelands have become more exposed and gullied, with brush replacing grass in many areas. The region also experiences intense convective rains with thunderstorms producing over 1/2 of the annual rainfall in many areas. Sparce cover and intense rain combine to produce relatively high sediment yield rates. Five years of sediment yield data from small (less than 260 hectares) watersheds within the 15,000-hectare USDA Walnut Gulch Experimental Rangeland Watershed in Southwestern Arizona are related to watershed size, vegetation and ground cover, channel type, land uses, and rainfall and runoff characteristics associated with the climatic regine. Sediment yields per unit area decrease with increasing drainage area and with increasing grass and gravel cover (erosion pavement). Sediment yields per unit area are as much as 3 times greater for gullied as ungullied watersheds. Both suspended sediment load and bed load are well correlated with peak discharge and runoff volume. Sediment yields are also well correlated with rainfall amount and the USLE rainfall factor (R).

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Water Infiltration Control on Rangelands: Principles and Practices

ROBERT M. DIXON

Highlight

An air-earth interface concept for controlling water infiltration was developed which provides basic principles for existing rangeland practices and can lead to the design of new and improved practices for better use and protection of soil and water resources in forage production. The concept, which has been rigorously tested at several cropland and rangeland sites, indicates that soil surface microroughness and macroporosity control infiltration rates and routes. Application of the concept can help solve many diverse soil and water management problems on rangelands, where uncontrolled infiltration is a contributing factor. This includes revegetation of barren land areas to slow worldwide desertification and the consequent irreversible deterioration in soil, water, and vegetal resources. To economically apply this concept, a land imprinting roller has been developed for revegetating barren lands. The land imprinter forms efficient rainwater-irrigated seedbeds designed to increase the probability of grass stand establishment.

Better use and protection of limited soil and water resources are vital to the welfare, if not survival, of civilization as global population continues to expand. Development of these soil and water resources on rangeland watersheds of the world has been largely neglected, even though these watersheds occupy 40% of the earth's land surface — 80% of which lies within arid and semiarid regions. In these drier regions, overgrazing and short-term droughts drive a vicious circle of decreasing soil surface microroughness and macroporosity, decreasing water infiltration, increasing surface runoff and evaporation, and increasing land barrenness (Dixon and Simanton 1977). This vicious circle leads to desertification and irreversible deterioration of vital soil and water resources. Although the total rainwater resource of such land is immense, it is often too sparsely and unevenly distributed for efficient use in revegetation and forage production. Rainwater could be used more efficiently if it were concentrated onto just part of the total land area. Rainwater can be concentrated by applying an infiltration concept, called the *air-earth interface* concept, which establishes the principles underlying infiltration control (Dixon 1975a and 1977a). This concept not only can provide a sound scientific basis for existing range conservation practices, it also can lead to the development of new and improved practices for more efficient and enduring use of rangeland soil and water resources. The concept is an outgrowth of infiltration experiments conducted on both crop and rangelands during the past 10 years. This paper briefly describes the air-earth interface concept, and discusses some approaches used in testing, quantifying, and applying it.

Air-Earth Interface Concept

The air-earth interface concept establishes the general principle that *soil surface roughness and openness control infiltration of free surface water by governing the flow of air and water in subsurface macropore and micropore systems. Roughness* refers to the microrelief that produces depression storage and *openness* refers to the macroporosity that is visible at the soil surface. If the surface is rough and open, soil air and free surface water exchange places freely and water infiltrates rapidly via the relatively short, broad paths of the macropore system. In contrast, if the surface is smooth and closed, surface exchange of air and water is greatly impeded and water infiltrates slowly via the relatively long, narrow, tortuous paths of the micropore system.

The air-earth interface concept embodies 6 physical interface conditions which represent 2 degrees of surface roughness and 3 degrees of surface openness (Fig. 1). The macropore system is depicted as a single U-shaped tube to graphically reflect its infiltration role as a water intake-air exhaust circuit. These conditions can guide practical applica-

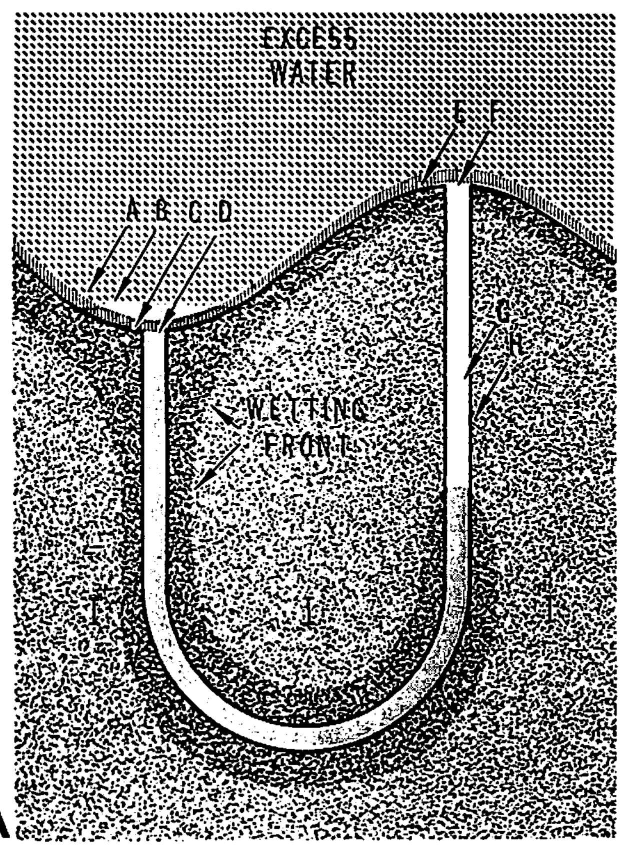

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Fig. 1A. Diagramatic soil containing a micropore system and a macropore system. The macropore system includes the space immediately above the air-earth interface and that within macropores, whereas the micropore system includes the space within and between individual soil aggregates. Symbol definitions are: A = plant residue cover on air-earth interface; B = free water surface; C = microdepression in air-earth interface; D = water intake port of macropore; E = microelevation in air-earth interface; F = soil air exhaust port of macropore space; H = macropore wall; and I = micropore space.

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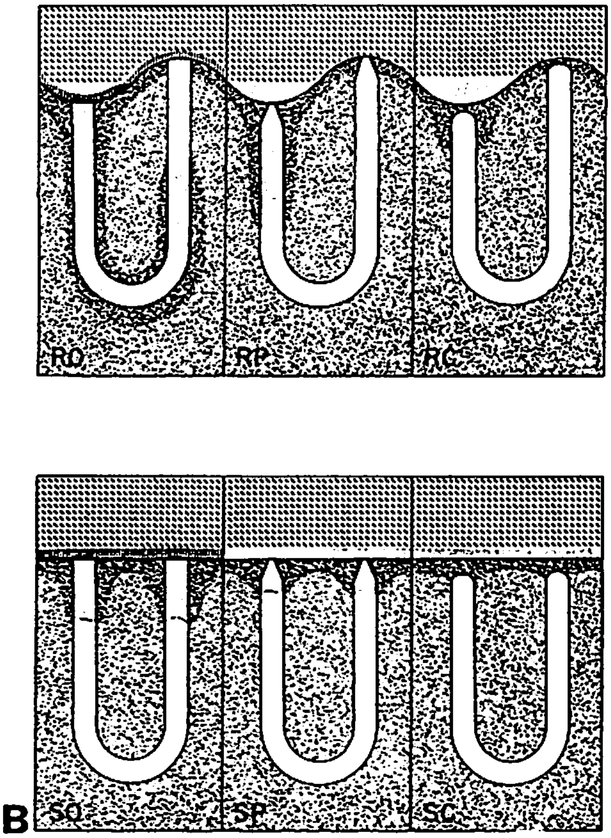

Fig. 1B. Diagramatic air-earth interface conditions and associated U-shaped macropore for water infiltration into soils. Conditions *RO*, *RP*, and *RC* represent rough interfaces containing open, partly open (unstable) and closed macropores, respectively; whereas conditions *SO*, *SP*, and *SC* represent smooth interfaces containing open, partly open (unstable) and closed macropores.

tion of the concept by serving as a reference framework within which needed modifications in existing surface conditions may be considered.

Concept Testing

This air-earth interface concept has been directly tested at cropland sites in Wisconsin and Nevada, and rangeland sites in Montana, Nevada, and Arizona. These tests, in which a standard rough open surface treatment and a standard smooth closed treatment were compared with the natural surface, showed that infiltration could be controlled by a factor of 10 immediately upon imposition of surficial treatments (Fig. 2). Results indicated that this factor increases in magnitude with the length of time during which such imposed treatments are maintained (Table 1).

Concept Application

In its present formulation, the air-earth interface concept seems adequate for expediting relative infiltration control. To increase infiltration above existing levels, the range manager would simply select practices that would increase surface roughness and openness, and conversely to decrease infiltration.

Practices, like contour furrowing, root plowing and pitting, roughen and open the soil surface; however, this increased roughness and openness is only temporary if the soil surface is left exposed to raindrop impact and sunlight. Practices, which include the return of plant residue to the freshly tilled surface, help to maintain (and sometimes increase) the roughness and openness through physical and biological means (Dixon 1971). Also, such practices can help establish grass stands (Herbel 1973), which in turn can stabilize surface roughness and openness. Runoff-irrigation practices, in the form of alternating smooth closed and rough open contour strips of land, may have

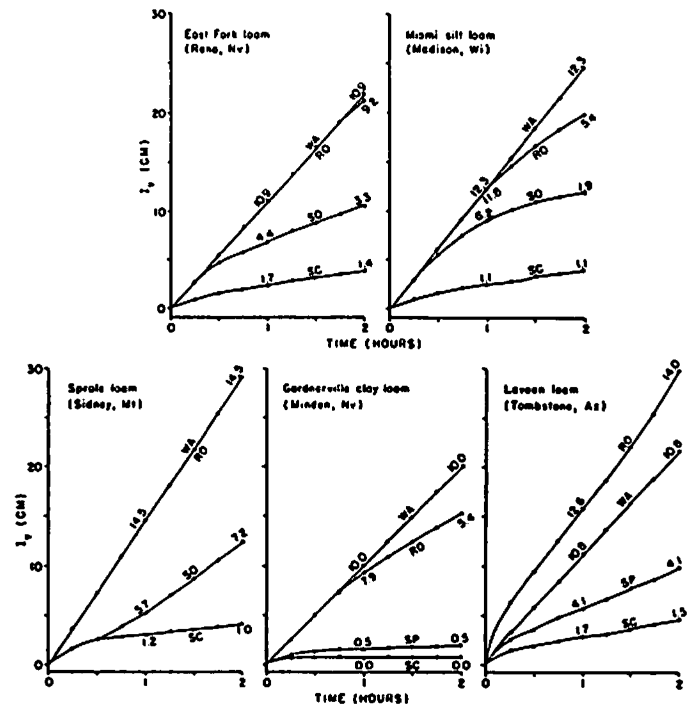

Fig. 2. Sprinkled-water infiltration under imposed air-earth interfaces *RO* and *SC*, and naturally occurring interface either *SO* or *SP*. The curve labeled *WA* gives the total water applied by the infiltrometer spray nozzle. Numbers near curves at 1- and 2-hour times denote infiltration rates in cm/hr for these times.

potential in improving forage stands and then in increasing and stabilizing the forage yield of semiarid and arid lands. The overall objective would be to concentrate sparsely distributed soil, water, and vegetal resources onto the fraction of the total land area where growth of the forage plants is to be encouraged. Theoretically, such concentration should not only stabilize forage production, but also increase forage yield per unit of total area.

Experimental rangeland tillage implements of two different designs are under development which were designed to make efficient use of soil, water, and vegetal resources of revegetating semi-desert shrublands (Abernathy and Herbel 1973, Dixon 1977b, and Dixon and Simanton 1977). When these implements are used to prepare seedbeds, smooth closed surfaces are converted to the rough open condition through both physical and biological means. This conversion increases

Table 1. Two-hour infiltration volumes and rates for an East Fork loam soil under the air-earth interfaces *RO* and *SC*, and the natural interface *SO* where interfaces *RO* and *SC* were imposed in 1969 and then maintained until 1972.

		Infiltration volume		Infiltration rate	
Air-earth interface*	Observation year	Absolute (cm)	Relative** (1)	Absolute (cm/hr)	Relative** (1)
RO	1969	13.0	1.6	3.6	1.5
RO	1970	39.2	5.0	10.0	4.2
RO	1971	74.6	8.6	20.4	8.9
RO	1972	115.6	11.6	36.6	13.1
SO	1969	8.0	1	2.4	1
SO	1970	7.9	1	2.4	1
SO	1971	8.7	1	2.3	1
SO	1972	10.0	1	2.8	1
SC	1969	6.1	0.8	1.6	0.6
SC	1970	5.3	0.7	1.5	0.6
SC	1971	3.7	0.4	0.6	0.3
SC	1972	5.3	0.5	1.4	0.5

*RO = rough open, SO = smooth open, and SC = smooth closed.
**Relative values are expressed as a fraction of the infiltration occurring under the natural interface *SO* for the specific year.

infiltration, reduces runoff and evaporation and, thereby, routes more of the rainwater resource to germinating seeds and seedlings. Consequently, the probability of establishing an adequate forage stand is enhanced. The implement, referred to as the *land imprinter* (Dixon 1977b), was also designed to improve forage stands without seeding. Operated for this purpose, the land imprinter conserves water for forage plants by increasing infiltration and reducing transpiration from shrubby species.

Concept Quantification

For predicting the magnitude of infiltration response to a change in management practice, Kostiakov's two-parameter infiltration equation (Kostiakov 1932) is being adapted to the air-earth interface concept, which entails characterizing surface roughness and openness in terms of the equation parameters. To be successful, this characterization must adequately reflect the hydraulic effects of surface roughness and openness on the infiltration process. Such characterization presents a formidable task, not only because of the complexity of the hydraulic effects, but also because of the dynamic spatiotemporal variability of surface roughness and openness, which is produced by many rapid physical and biotic processes operating at the immediate soil surface. However, any predictive method not accounting for the overriding influence of these two surface conditions would fail to even roughly approximate infiltration values, except under extremely rare and fortuitous circumstances. Preliminary results suggested that surface roughness and openness may be characterized hydraulically by a single parameter called *effective surface head*, h_s, (Dixon 1975b) which is defined as the difference between surface water hydrostatic pressure, h_w, and the soil air back pressure, h_a, (or $h_s = h_w - h_a$), and is conveniently expressed as centimeters of water head. Infiltration is highly responsive to effective surface head in a narrow range of only a few centimeters surrounding zero (Fig. 3), and this head in turn is highly responsive to common cultural practices that affect surface roughness and openness.

Since effective surface heads occurring under natural rainfall are often negative, and since conventional infiltrometers produce only positive heads, *closed-top infiltrometers* (Dixon 1975b) are required to evaluate infiltration responses to natural effective surface heads. The values of the two parameters in Kostiakov's equation are determined by fitting the equation to the resulting cumulative infiltration curves as shown in Fig. 3. The parameter value is then plotted graphically as a function of effective surface head (Fig. 4). This graph plus Kostiakov's equation can then be used to predict the infiltration curve associated with a known value of effective surface head or the corresponding values of surface roughness and openness.

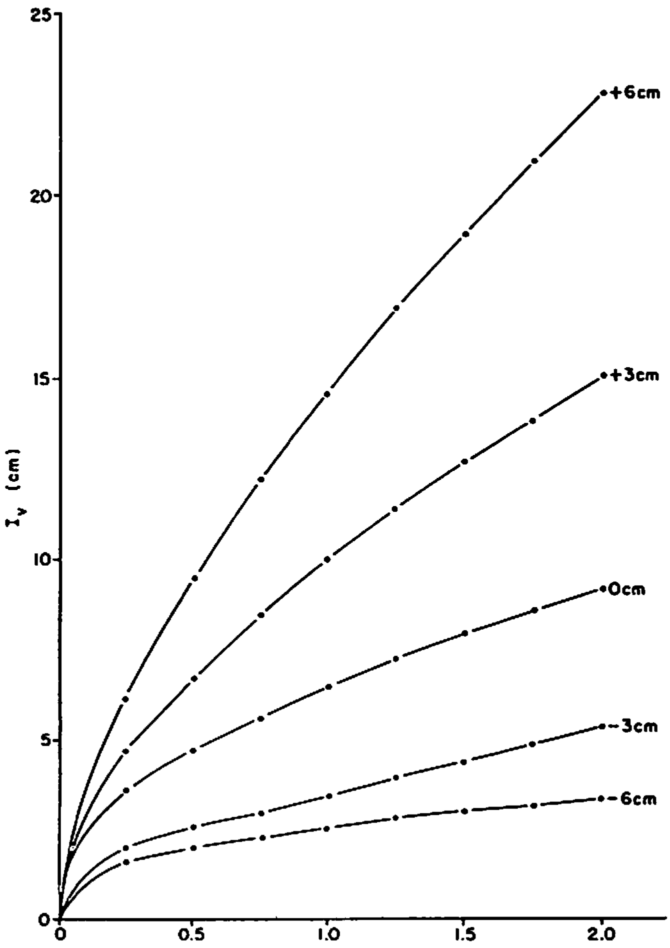

Fig. 3. Ponded-water infiltration I_v as a function of time and effective surface heads ranging from a − 6 to a + 6 cm of water, as produced by a closed-top infiltrometer.

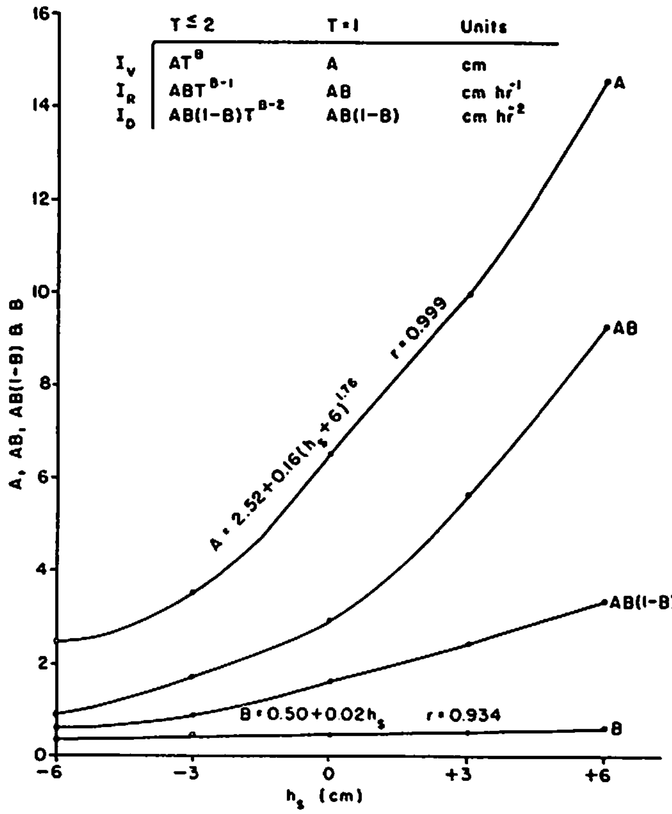

Fig. 4. Parameters for Kostiakov's equation, $I_v = AT^B$, and its first derivative, I_R, and second derivative, I_D, as functions of effective surface head, h_s, where I_v, I_R, and I_D denote infiltration volume, infiltration rate and deceleration in infiltration rate, respectively, *T* is elapsed time after ponding, and *A* and *B* are constants.

Summary and Conclusions

The flow diagrams in Fig. 5 summarize the mechanisms by which cultural practices and the resulting effective surface heads control infiltration. The theory that infiltration is controlled by the effective surface head agrees with that of E. C. Childs (1969), since the effective surface head is the only component of the surface hydraulic gradient that is easily controlled by cultural practices. The four lower blocks in Fig. 5a reflect the fact that the infiltration process involves both transmission and storage — first the transmission and storage of water in the macropore system and then the transmission and storage of water in the micropore system.

Application of the air-earth interface concept to rangelands can help solve many diverse soil and water management problems, where uncontrolled infiltration is a contributing factor. Such problems include excessive runoff and erosion; flash flooding of upland watersheds; sedimentation of waterways and reservoirs; pollution of surface and

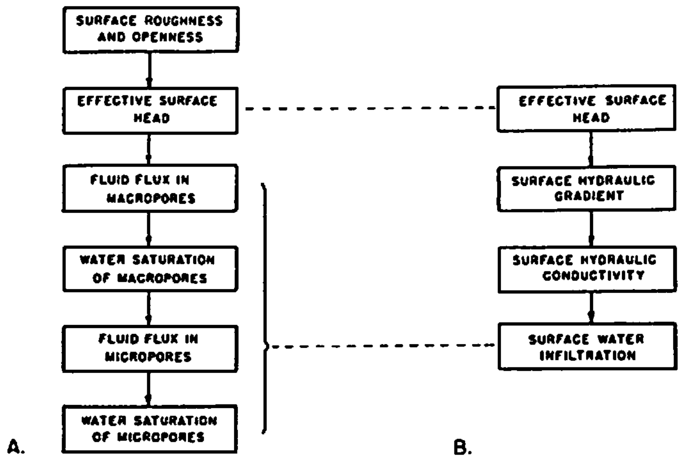

Fig. 5. A: Mechanisms by which surface roughness and openness control surface water transmission into a soil and subsequent storage of this water within soil pores. B: Mechanism by which effective surface head controls infiltration.

ground waters; excessive evaporation from soil surfaces; inefficient on-site use of rainwater for forage production; and inefficient water harvesting for off-site rainwater uses.

Further research is needed to evaluate natural effective surface heads under diverse soil surface and water source conditions, to develop better methods for characterizing surface roughness and openness, to relate effective surface head to surface roughness and openness, and, finally, to develop new and improved cultural practices, based on the air-earth interface concept.

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