Exhibit 3, #34

Control of Erosion and Sedimentation by Treatment of Arid Rangelands

by

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ABSTRACT

Control of Erosion and Sedimentation by Treatment of Arid Rangelands

The number one pollutant of the waters in the United States, by volume, is sediment. Annual sediment deposition is estimated at $10,489 \times 10^5$ m^3. Rangeland treatments such as vegetation manipulation by mechanical and chemical treatments are ways of controlling and regulating surface runoff, reducing sediments and increasing water quality. The presence of vegetation can affect infiltration by reducing the direct impact of raindrops on the soil surface which reduces erosion and sediment loads.

Studies have shown that several factors can affect water yield and sediment production such as storm intensity, watershed size, and soil surface microrelief. Other important factors are soil depth and water storage capacity, rainfall amount and distribution, infiltration rates, and the type of vegetation, before and after site conversion.

Measurements of soil surface characteristics indicate a significant reduction in surface runoff with increased amounts of erosion pavements. Mechanical treatment is important in converting rangeland infested with shrubs to grass and is a prime consideration in controlling runoff and erosion and, reducing sediments. Ripping and seeding an area to grass and browse species reduced runoff by 97 and 83 percent the first and third years following treatment. Also erosion was reduced 86 percent and 30 percent, the first and third years, after the ripping treatment. Contour furrowing retains water at onsite locations and significantly reduces surface runoff. Pitting significantly reduced runoff when compared to a control treatment. No significant differences were noted between pitting and rootplowing treatments. Additional detention storage is provided by pitting and rootplowing treatments although smoothing of the soil surface with time was very apparent for both treatments. Infiltration increased and subsequently runoff and erosion decreased after approximately four years following rootplow and seeding treatments.

Runoff from rangelands is of interest for several reasons. First, runoff is required to provide beneficial off-site or downstream industrial, agricultural, and domestic water supplies. Secondly, runoff from rangelands erodes soil and transports sediments and dissolved solids to streams and reservoirs. Sediment is the number one pollutant of the waters in the United States (Becker and Mulhern, 1975).

Prior to the late 1940's and early 1950's sedimentation research in the arid and semiarid areas of the Southwest was practically nonexistent. Sedimentation problems are especially acute in arid and semiarid areas because of the sparse vegetation cover of rangelands, severely intense thunderstorms, and flash floods. The need for erosion and sedimentation data is increasing rapidly with the population explosion, urban development, building of extensive highway systems, and the long range outlook for vastly increased development of water supplies throughout the Southwest in the last decade (Renard and Hickok, 1967). The Sedimentation Subcommittee (1964) reported that little sedimentation data were available on upstream watersheds. The majority of the available information was related to research on sediment transport on large streams and sediment studies on larger reservoirs.

Surface erosion processes under sparse vegetation and a desert erosion pavement is a subject that has had limited attention and is worthy of considerable investigation. Rangeland treatments such as vegetation manipulation by mechanical and chemical treatments are ways of controlling and regulating surface runoff, reducing sediments and increasing water quality. The presence of vegetation can affect infiltration by reducing the direct impact of raindrops on the soil surface which indirectly reduces erosion and sediment loads.

RUNOFF

Water erosion has two important consequences. The more obvious of these is the removal of soil material, including plant nutrients, by runoff water. This results in gullies, tunnels and sheet-eroded surfaces, and silted dams, creeks, and outwash fans where the eroded material is deposited. The second consequence precedes the first and is the beginning of a sequence of interrelated events. This is water lost by runoff which would otherwise be stored in the soil mantle, and some that would subsequently be available for plant growth.

The reductions in stored soil water due to increased runoff in arid rangelands, where water limits plant growth, obviously has serious repercussions. An examination of the equation expressing what happens to rain once it has fallen allows a ready appreciation of the source of water available for erosion in relation to other possible pathways of water use (modified from Satterlund, 1972).

Thus:

$$P = S + \Delta D + \Delta M + \Delta U + E\Delta t$$

where:

P = rainfall

S= net surface runoff

ΔD = change in surface water storage (detention storage + storage provided by dead and living plant materials).
ΔM = change in soil water storage in plant rooting zone
ΔU = change in storage below the plant rooting zone
$E\Delta t$ = total evaporation over the period (Δt) under consideration.

The net surface runoff (S) is that water which has not entered the area of ground under consideration and which, therefore, is available move soil away from the area. It can also be expressed in terms of the rate of infiltration of water into the soil (I) thus:

$$S = P - (\int Idt + \Delta D).$$

Surface runoff then depends on the rate at which rainfall can enter the soil, and the amount of water retained in soil surface detention storage (D).

Infiltration rate is related to many environmental parameters and it is the variation of one or more of these which usually determines the amount of runoff. There is a correlation of soil texture with infiltration rate, with light, sandy soils having higher rates than heavy clay soils. However, this correlation is confounded by surface conditions. Infiltration rate also depends on the condition of the soil water storage M and U in the water balance equation. The rate is generally highest when the soil is dry; the wetter the soil prior to infiltration, the lower the rate of infiltration. Also, for a given soil type, the shallower the soil, the smaller the capacity of soil water storage, M and U.

The presence of vegetation can affect infiltration of water into the soil in several ways, including the reduction of direct impact of raindrops on the soil surface and the improvement in soil texture with an increase in pore space due to old root channels and the addition of organic matter to the soil. Surface sealing of soil under raindrop impact may be reduced by the presence of vegetation.

EROSION

Erosion is the inevitable consequence of the rangeland environment largely because that environment is unable to support a permanently adequate cover of vegetation. Soil erosion is therefore a natural feature of rangeland. Any use of the rangeland which further reduces the cover of vegetation tends to lead to accelerated soil erosion, that is, erosion consequence of the environment. It is this accelerated erosion which is discussed here with a view to indicating how it can be minimized and, thereby, how the renewable biological resources of rangeland may be restored and conserved.

Both natural and accelerated erosion are taking place on rangeland. The rate of accelerated erosion can exceed that of natural erosion many times, probably by as much as 10 to 100 times in places. Thus, while natural erosion has persisted in balance with soil-forming processes and vegetation development to present a harmonious landscape, accelerated erosion often does not. Severe accelerated erosion frequently gives rise to marked soil truncation and semi-permanent changes in vegetation, including complete denudation.

Erosion varies with the square of the velocity of the runoff water and with the natural erodibility of the soil. Velocity varies approximately as the square root of the slope; thus increasing the slope by 4 times will double the velocity. Doubling the velocity will increase by 4 times the eroding power, by 32 times the quantity of material that can be carried and by 64 times the size of the particle that can be moved (Ayres, 1936).

A peak in erosion occurs in arid lands somewhere between the 25.4- and 50.8-cm rainfall limits (Fig. 1). This peak occurs because of the natural decrease in protective vegetation cover due to the lower rainfall which itself is still high enough, with storms of high intensity, to erode the poorly protected soil. In a still lower rainfall region, where the rainfall is still generally inadequate for vegetation protection, the rainfall is so infrequent that water action contributes progressively less as an erosion agent.

In New Mexico, erosion and sediment problems exist over most of the state (USDA, SCS, 1975). Critical erosion and sediment problems exist in the Rio Puerco drainage, along the Pecos, and in the San Juan drainage. About 3.1×10^6 ha have high annual sediment yields. Sedimentation surveys on small watersheds indicate annual sediment yields may exceed $38 m^3$/ha. A summary of soil loss resulting from sheet, rill and gully erosion by vegetative types for New Mexico are shown in Table 1.

TREATMENT EFFECTS

Watershed management on rangelands is based on the concept that land, consisting of the plant cover and the soil and rock mantle, is a reservoir that receives, stores and discharges water, and that the hydrologic behavior of this reservoir is subject to change and regulation by treatment or land use.

Treatment opportunities to reduce sediment loading of water supplies are limited by climatic factors and often require intensive use of structures, vegetative treatment, and good management.

Attempts are often made to convert vegetation not suited for grazing, to more desirable plant species that will provide increased forage as well as protection of the soil surface from erosion (Tromble, 1976). These practices include cutting contour furrows, pitting, rootplowing, water spreading, and water harvesting. They are based on the principle that one way to manage runoff is to manipulate the depression storage capacity of rangelands. Pitting increases forage production by breaking soil crusting, encouraging water infiltration, and decreasing water runoff. A water spreading system is for spreading and controlling flood water to irrigate rangeland, reducing and storing sediments, or obtaining deep storage of groundwater (Heady, 1975).

A 12,915 ha area treated by ripping and seeding to grass and browse species on the Rio Puerco drainage reduced surface runoff 95% and 83% the first and third years following treatment. Also, erosion was reduced by 86% and 30%, for the first and third years after the ripping treatment (Dortignac and Hickey, 1963). Contour furrowing has been used to retain surface water at on-site locations. Plotting accumulated runoff versus accumulated rainfall (Fig. 2) reveals that the contour furrowing treatment did reduce runoff. Runoff increased steadily during the pretreatment years, 1955 to 1964. During the post-treatment years, 1965 to 1969, surface runoff was significantly reduced (Tromble, 1977). Contour furrowing at 0.9- and 1.6- m intervals and broadbase furrowing consisting of low dikes 0.45 m in height have been found effective in controlling runoff (Branson, et al. 1966). Longevity of contour furrows has been determined to be about 14 years for southern Arizona, and grass production 2.5 times greater than the untreated land, 10 years following treatment (Brown and Everson, 1952).

Rootplowing and pitting are two rangeland treatments that have had limited success in the southwestern United States. In an Arizona study rootplowing was done at a depth just below the root crown of shrubs while pits were constructed about 60 cm long and 10- to 15 cm deep. A mixture of Eragrostis lehmanniana and Eragrostis chloromelas was seeded on the rootplowed area. Runoff from the three treatments--rootplow, pit, and control--were measured for three years (Fig. 3). Comparison of treatment versus runoff for all study years indicated that pitting significantly reduced runoff as compared with the control treatment. No significant difference was noted between pitting and rootplowing or between the control and the rootplow treatment (Tromble, 1976).

To evaluate the effectiveness of the treatments in altering the volume of runoff with time, differences among treatment means for each year were tested for significance with Duncan's multiple range test. This test suggested that runoff volume was related to the length of time after treatment (Tromble, 1976).

Using a modified linear regression analysis technique (Diskin, 1970), Simanton et al. (1978) reported results for a rootplowed and seeded pre- and post-treatment period. They indicated that the rainfall threshold for runoff initiation was approximately 20 percent greater for the time period immediately following treatment when compared to the pre- and post-treatment periods. Although this mechanical treatment changed the soil surface storage and drainage network and increased water storage during small rainfall events it did not compensate for the loss in vegetation cover with a consequent increase in runoff from large events. Associated with the reduction in runoff, which occurred 4 years after the treatment, was a 60 percent reduction in sediment per millimeter of runoff.

Water spreading has been used effectively in Australia to increase forage production (Quilty, 1972; Newman, 1966; Jones, 1967). In New Mexico, five types of structures to control runoff water from semiarid rangelands were tested: 1) contour channels, 2) brush "dams", 3) widely spaced terraces, 4) small diversion dams with brush "hedges" placed to conduct the diverted water over depleted rangeland, and 5) smaller, closely spaced contour earthern structures. None of the structures used was found to be effective in the improvement of vegetation cover. Soil factors were thought to be partly responsible for this failure (Valentine, 1947).

The surface cover of the soil can serve an important function in breaking up raindrops which reduces the raindrop impact energy on the soil surface. Reduction in raindrop impact energy can reduce sealing of the soil surface and thus maintain greater infiltration rates and reduce soil erosion.

The effect of soil surface characteristics on runoff are given in Table 2. In order for the surface characteristics to be significant (0.05) in its effect on runoff, the r value must be greater than 0.60. Thus, crown cover (Fig. 4) with an r value of 0.80 was significant in runoff reduction. Also, gravel (-0.64) and rock (-0.69) were significant in the reduction of runoff. Combining rock and gravel (Fig. 5) into the single parameter erosion pavement, gives an r value of -0.93 indicating a significant decrease in runoff. This may be a result of increased roughness of the surface and also an increase in the tortuosity of the runoff path (Tromble, 1976).

Tromble (1974) determined the best time for seeding treated areas was accomplished by examining the available climatic records and determining when the greatest possibility existed for having adequate soil water. This information is shown (Fig. 6) by the dashed line and indicates the best time for seeding. This assumes that seeding would be done just prior to the time that the greatest probability for soil water occurs. In spite of the comparatively poor natural vegetal protection of arid land during dry seasons and times of drought, there is evidence to suggest that water erosion can be increased by livestock. Compaction of the soil by trampling and destruction of the vegetation cover by grazing may, together, result in an increase in the rate of water erosion by as much as three to four times.

CONCLUSIONS

Preventive control can be exercised in several ways; however, the guiding rule is that the land user should carefully consider the principles of water action in relation to each management decision, whether it concerns livestock numbers, fencing and subdivision of land, installation of watering facilities, or of corrals. Where placement of the fore-mentioned facilities may cause an increase in volume and velocity of runoff, preventive measures such as contour furrowing, damming or other means of water conservation should be carried out in anticipation of the consequences rather than in retrospect. The potential consequences of the actions of the land manager should be countered by means which reduce their erosion effects, thereby leading to a balanced, planned development-which will have the efects of maintaining and improving a resource rather than degrading it.

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Table 1. Soil loss resulting from sheet, rill, and gully erosion by vegetation type in New Mexico (Soil Conservation Service, 1975).

Vegetative Type	Area Hectares	Soil Loss Tons/Yr	Soil Loss Percent of Total
Rangeland	27,834,730	98,892,015	89
Grassland	17,384,080	60,192,378	54
Brushland	6,177,150	20,622,504	19
Pinon-Juniper	4,273,500	18,077,133	16
Forest	2,900,800	8,696,007	8
Cropland and other	616,420	2,893,829	3
STATE TOTAL	31,351,950	110,481,851	100

Table 2. Correlations of runoff vesus plot surface charcteristics (Tromble, 1976).

Characteristic	r*	Equation
crown cover	-0.80	y = -0.064x + 2.96
litter	-0.29	y = -0.027x + 1.76
soil	0.92	y = 0.014x - 0.62
gravel	-0.64	y = -0.086x + 3.75
rock	-0.69	y = -0.071x + 2.25
rock + gravel	-0.93	y = -0.070x + 4.52

* r must be .60 for significance at .05 level.

Figure Legend

Fig. 1 Annual sediment yield as related to effective precipitation for major vegetation types.

Fig. 2 Accumulated runof versus accumulated rainfall for the contour furrow treatment.

Fig. 3 Accumulated rainfall versus accumulated runoff for storms of greater than 12.7 mm of precipitation for 1970, 1971, and 1972.

Fig. 4 Runoff as related to vegetation crown cover on arid rangeland.

Fig. 5 Runoff as related to erosion pavement on arid rangeland.

Fig. 6 The probability of having available soil water for seedling establishment superimposed over the distribution of precipitation that exceeded 2.54 mm during July, August and September of 1971 and 1972.

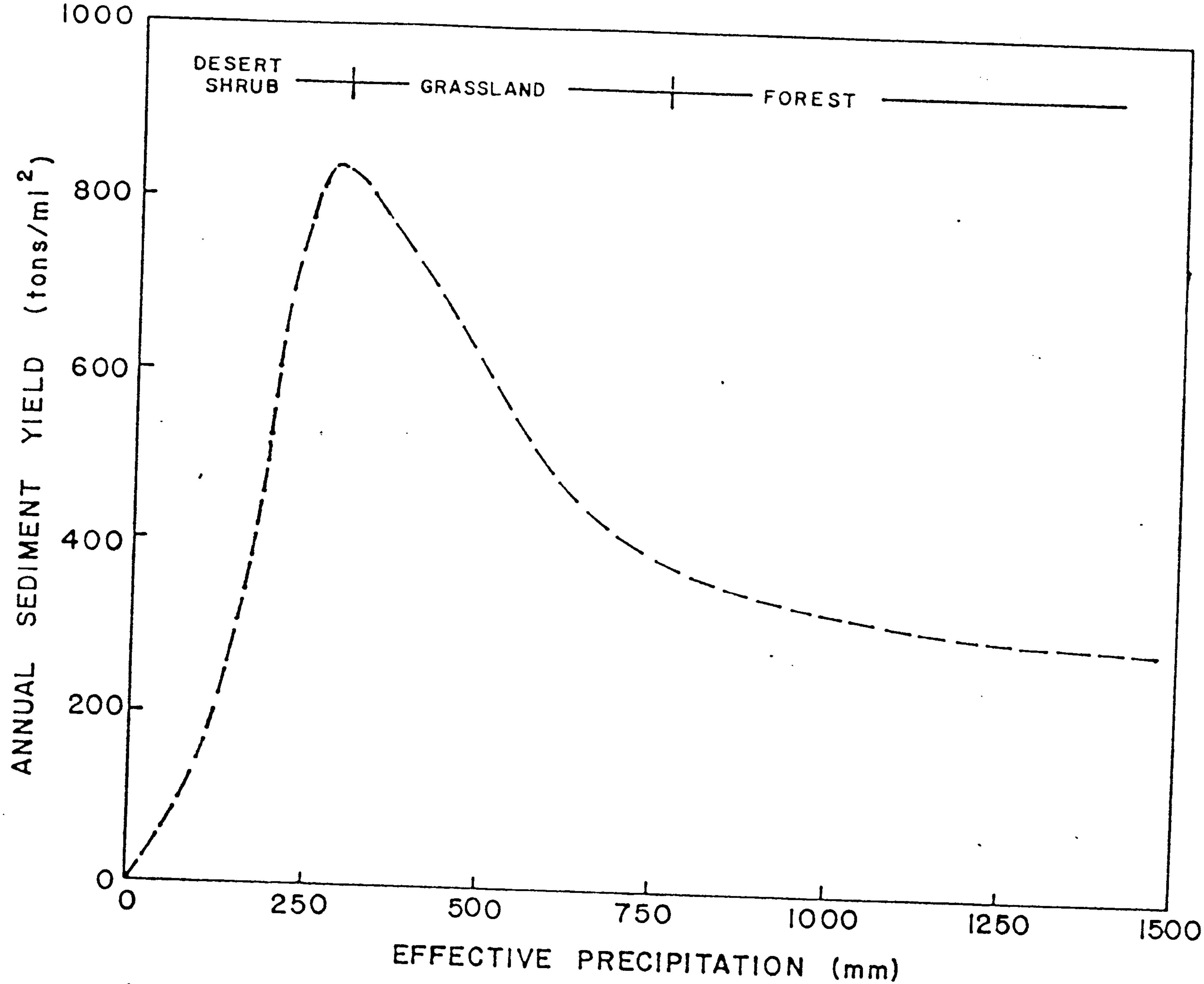

Fig. 1. Annual sediment yield as related to effective precipitation for major vegetation types (after Langbein and Schumm, 1958).

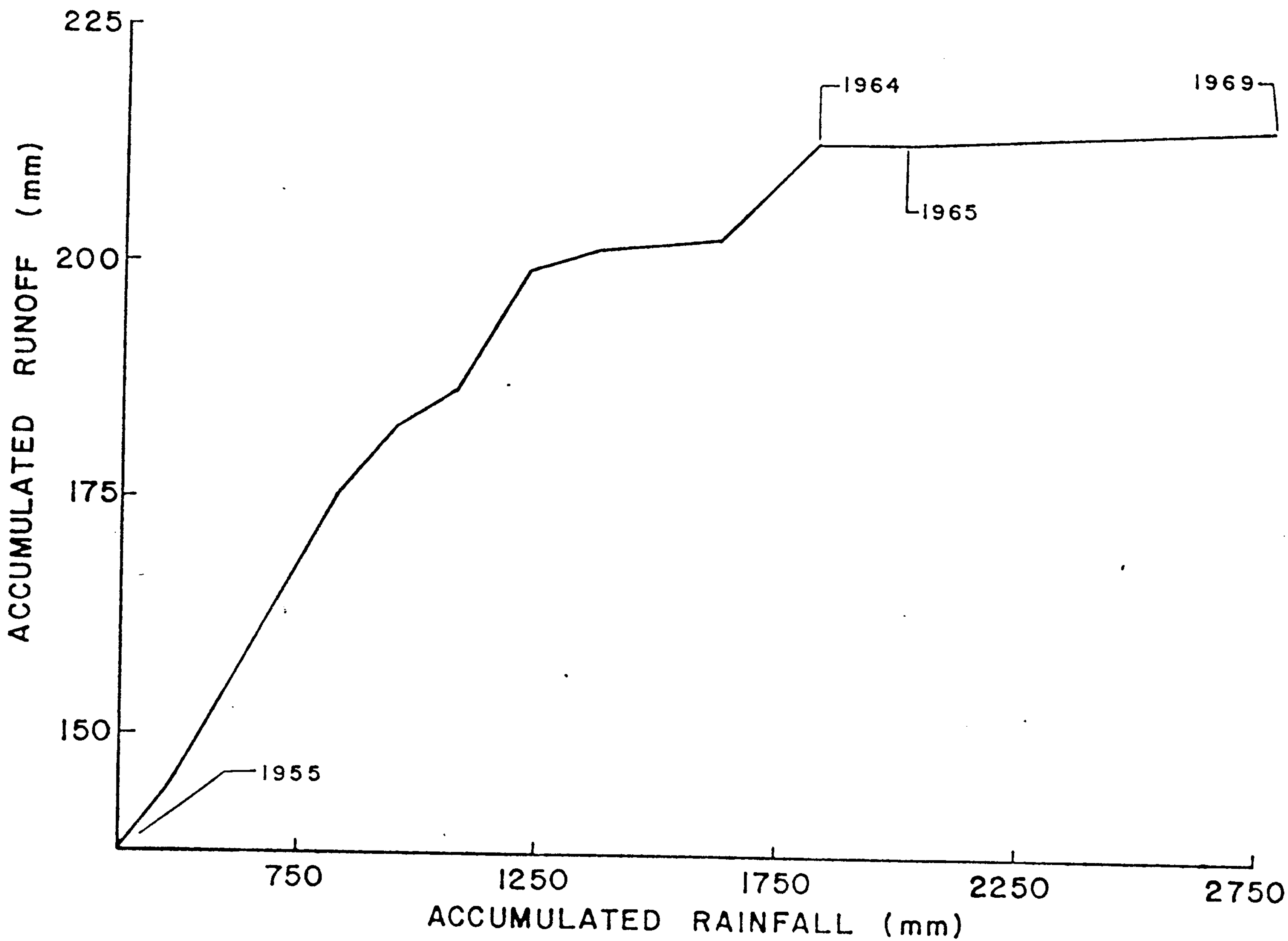

Fig. 2. Accumulated runoff versus accumulated rainfall for the contour furrow treatment (modified from Tromble, 1977).

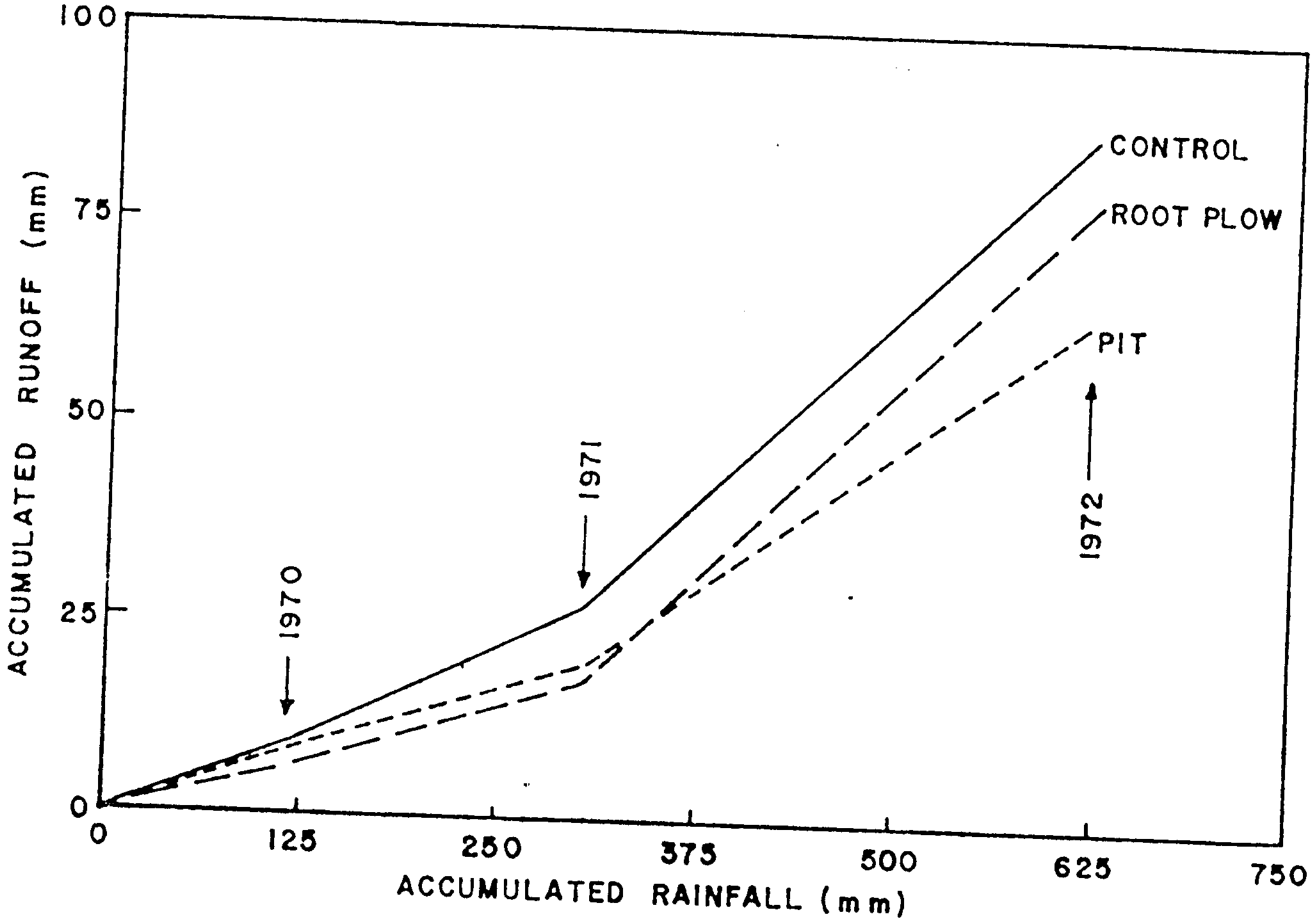

Fig. 3. Accumulated rainfall versus accumulated runoff for storms of greater than 12.7 mm of precipitation for 1970, 1971, and 1972 (from Tromble, 1976).

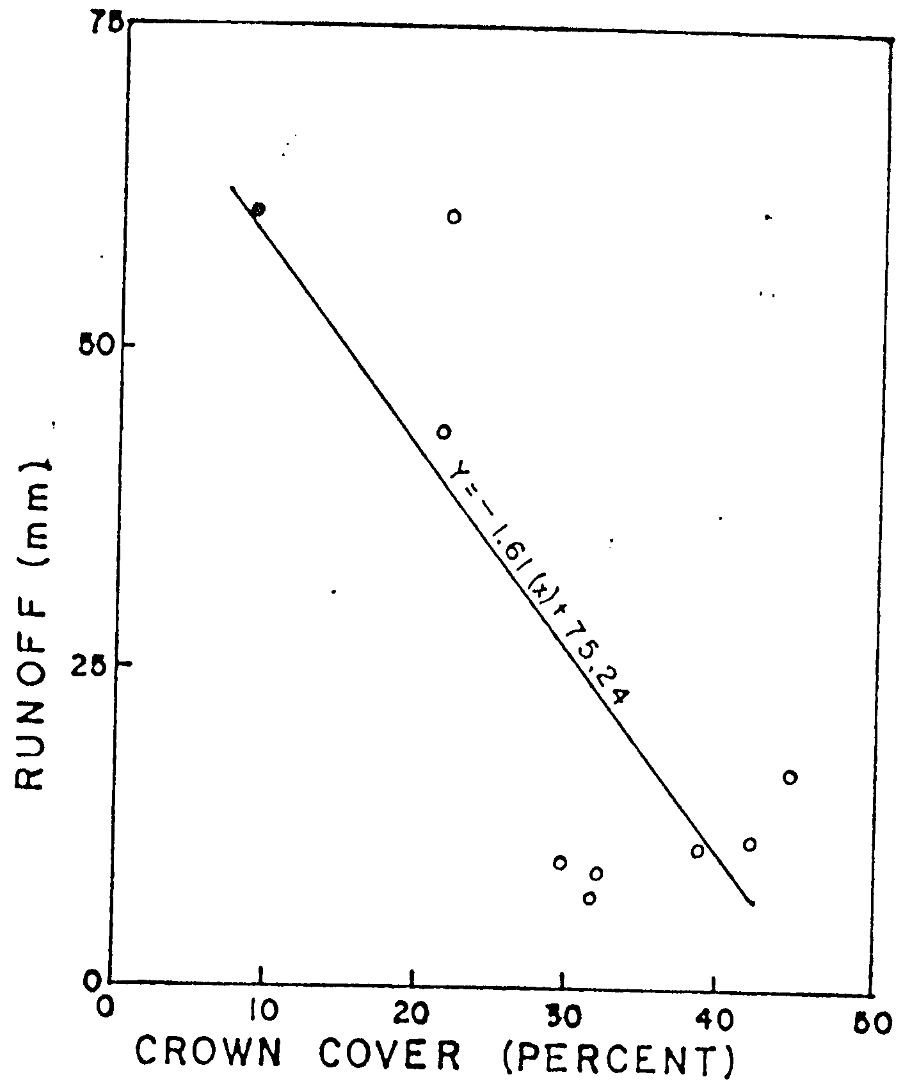

Fig. 4. Runoff as related to vegetation crown cover on arid rangeland (modified from Tromble, 1976).

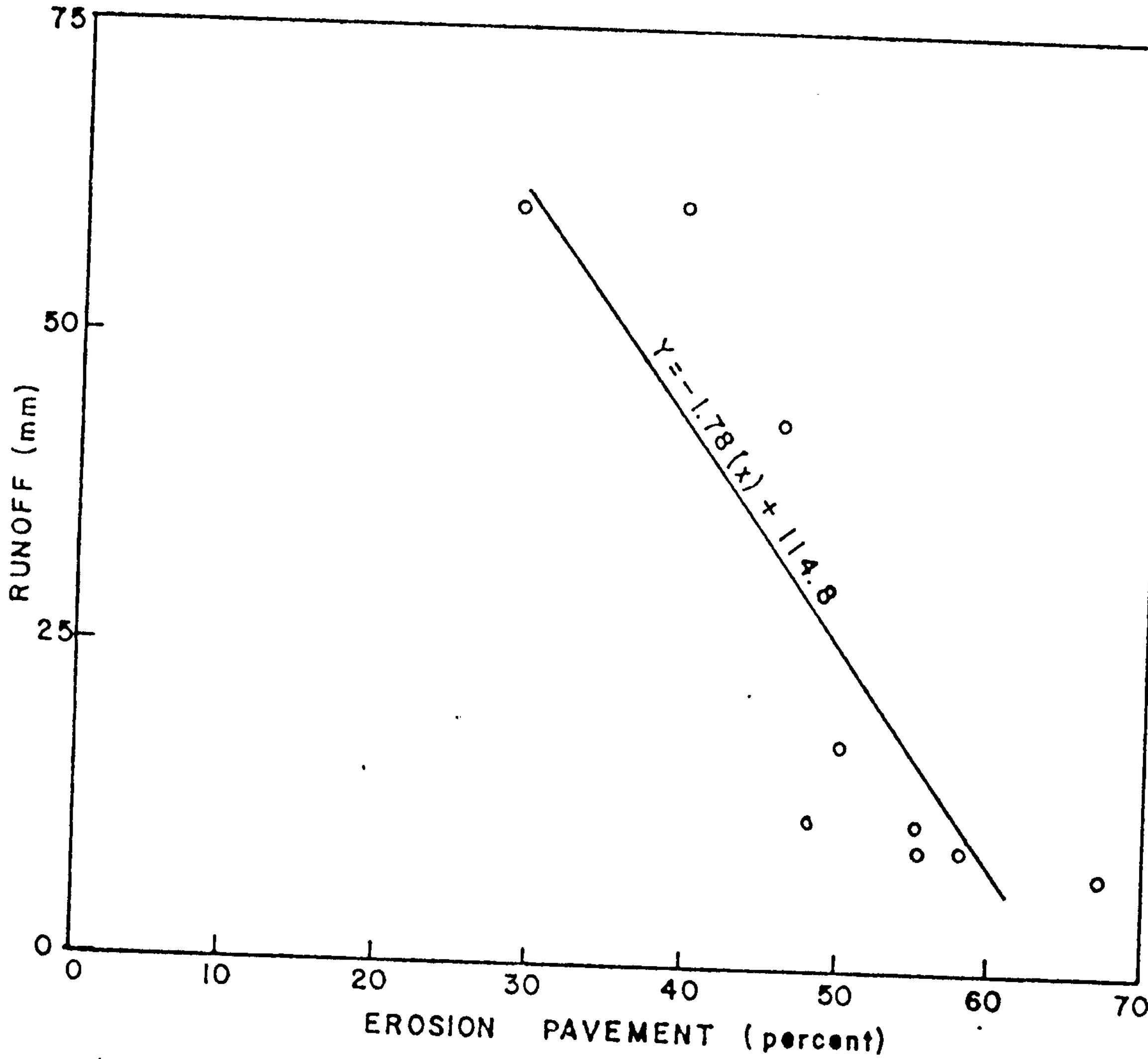

Fig. 5. Runoff as related to erosion pavement on arid rangeland (modified from Tromble, 1976).

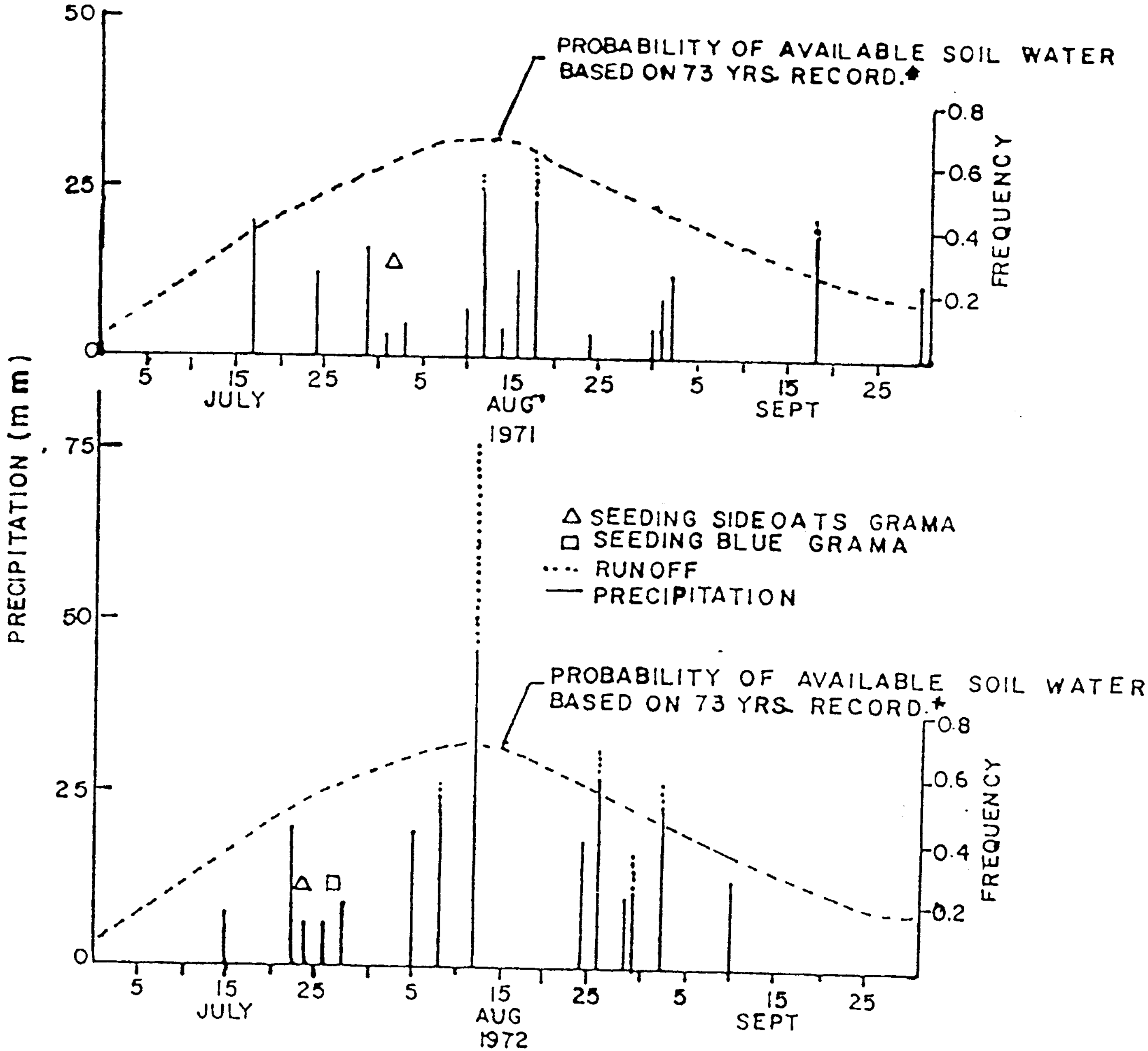

Fig. 6. The probability of having available soil water for seedling establisment superimposed over the distribution of precipitation that exceeded 2.54 mm during July, August and September of 1971 and 1972 (modified from Tromble, 1974).